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**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

**Direct Conversion of Surplus Fissile
Materials, Spent Nuclear Fuel,
and Other Materials to High-
Level-Waste Glass**

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**MANAGED BY
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DEPARTMENT OF ENERGY**

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Predecisional Draft

Fissile Material Disposition Program PEIS Engineering Data Input

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Other Materials to High-Level-Waste Glass**

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Direct Conversion of Surplus Fissile Materials, Spent Nuclear Fuel, and Other Materials to High-Level-Waste Glass

EXECUTIVE SUMMARY

With the end of the cold war the United States, Russia, and other countries have excess plutonium and other materials from the reductions in inventories of nuclear weapons. The United States Academy of Sciences (NAS) has recommended that these surplus fissile materials (SFMs) be processed so they are no more accessible than plutonium in spent nuclear fuel (SNF). This spent fuel standard, if adopted worldwide, would prevent rapid recovery of SFMs for the manufacture of nuclear weapons. The NAS recommended investigation of three sets of options for disposition of SFMs while meeting the spent fuel standard: (1) incorporate SFMs with highly radioactive materials and dispose of as waste, (2) partly burn the SFMs in reactors with conversion of the SFMs to SNF for disposal, and (3) dispose of the SFMs in deep boreholes. The U.S. government is investigating these options for SFM disposition.

A new method for the disposition of SFMs is described herein: the simultaneous conversion of SFMs, SNF, and other highly radioactive materials into high-level-waste (HLW) glass. The SFMs include plutonium, neptunium, americium, and ^{233}U . The primary SFM is plutonium. The preferred SNF is degraded SNF, which may require processing before it can be accepted by a geological repository for disposal. The primary form of this SNF is Hanford-N SNF with preirradiation uranium enrichments between 0.95 and 1.08%. The final product is a plutonium, low-enriched-uranium, HLW, borosilicate glass for disposition in a geological repository.

There are two major benefits with this option. The first benefit is disposition of SFMs. The second benefit is conversion of SFMs and degraded SNF into a form acceptable for disposal in a geological repository.

There are two major requirements for this disposition option. The first requirement is that the plutonium, low-enriched-uranium HLW glass product meet the defined spent fuel standard for disposition of SFMs. The second requirement is that the plutonium, low-enriched-uranium HLW glass be acceptable for repository disposal within the currently proposed repository design and licensing envelope.

The combined processing of SFMs and SNF into HLW glass provides several benefits for the disposition of SFMs. The SNF provides an available radiation source to meet the spent fuel standard. There are no limits on the availability of SNF. The SNF provides a source of low-enriched-uranium for the final product. This has two benefits. First, the uranium in the plutonium, low-enriched-uranium, borosilicate glass

makes separation of the plutonium from the glass more difficult and thus helps to ensure that the spent fuel standard is met. Second, the low-enriched-uranium in the HLW glass ensures the avoidance of nuclear criticality in the repository over geological time periods by isotopic dilution of the ^{235}U decay product of plutonium with ^{238}U from the SNF. This is the same approach to geological repository criticality control as that which will be used for commercial SNF containing plutonium. Using this approach ensures an HLW glass product that can be accepted by the repository within the currently proposed design and licensing basis for the repository.

The proposed conversion process is the Glass Material Oxidation and Dissolution System (GMODS), which is a new process. Significant development work would be required to develop the process. As a result, there are significant uncertainties.

The initial analysis of the GMODS process indicates that a GMODS facility for this application would be similar in size and environmental impact to the Defense Waste Processing Facility (DWPF) at the U.S. Department of Energy (DOE) Savannah River Site (SRS). The DWPF is currently being commissioned. When operational, it will vitrify HLW tank wastes at the SRS and produce a HLW borosilicate glass. GMODS is designed to vitrify SFMs and SNF. The similarities between the two facilities include the following:

- The number of canisters with HLW borosilicate glass produced per year will be about the same (350 to 400). HLW canister welding, inspection, storage, and other activities will be essentially identical.
- The total quantities of radioactivity to be handled per year are similar. Basic facility design, licensing requirements, and operating philosophy will, by necessity, be similar.
- The processing complexity is roughly similar. Both are vitrification plants. The DWPF includes added process steps to pretreat the tank wastes to feeds acceptable to the vitrifier. The GMODS includes added process steps to make solid feeds acceptable to the vitrifier.

Because of these similarities, there does not appear to be a significant difference in facility size, external environmental impact, construction times, or other similar parameters between building a GMODS facility and building a new DWPF. Because of this, the detailed information available on DWPF was used as the basis for much of the GMODS input into the SFMs programmatic environmental impact statement (PEIS). This approach has several benefits. The DWPF is a real facility that is actually being commissioned. It meets current requirements. Its construction provides realistic numbers and characteristics that would not be available for a GMODS or any other proposed facility until most of the detailed engineering is complete.

Direct Conversion of Surplus Fissile Materials, Spent Nuclear Fuel, and Other Materials to High Level Waste Glass

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this document is to provide a stand-alone referenceable report that describes one option for the disposition of surplus fissile materials (SFMs), which include plutonium, neptunium, americium, and ^{233}U . The option described herein is the direct conversion of SFMs, spent nuclear fuel (SNF), and other highly radioactive materials into a plutonium, low-enriched-uranium, borosilicate, HLW glass acceptable for direct disposal in a geological repository.

This description is to be used in the preparation of a programmatic environmental impact statement (PEIS) for the Fissile Material Disposition Program. The description herein is oriented toward that goal. The PEIS will evaluate many disposition options.

The report contains seven sections and one appendix. Section 2 describes the design basis and assumptions for the technology, processes, and facilities. Section 3 describes the process while Section 4 provides facility descriptions. Section 5 includes engineering and technical assessments and Sect. 6 gives environmental data. Section 7 provides preliminary schedule information. Section 8 is a list of references. Appendix A describes alternative GMODS facility options.

1.2 PROGRAM OVERVIEW

The U.S. Department of Energy (DOE) has been directed to complete a comprehensive review of long-term options for SFM control and disposition, taking into account technical, nonproliferation, environmental, budgetary, and economic considerations. DOE's objectives in the furtherance of this policy include:

To strengthen national and international arms control efforts by providing an exemplary model for storage of all weapons-useable fissile materials and disposition of surplus weapons-useable fissile materials:

To ensure that storage and disposition of weapons-useable fissile materials is carried out in compliance with environmental, safety, and health (ES&H) standards;

To minimize the prospect that surplus U.S. weapons-useable fissile materials could be reintroduced into the arsenals from which they came, therefore increasing the prospect of reciprocal measures by Russia and other nuclear powers:

To minimize the risk that surplus U.S. weapons-useable fissile materials could be obtained by unauthorized parties;

To accomplish these objectives in a timely and cost-effective manner.

1.3 SUMMARY DESCRIPTION OF THE GLASS MATERIAL OXIDATION AND DISSOLUTION SYSTEM (GMODS) FOR DISPOSITION OF SFMs

1.3.1 Description

It is proposed to dispose of SFMs by chemically converting and combining SFMs, SNF, and other materials into a plutonium, low-enriched-uranium HLW glass. The HLW glass would meet the defined spent fuel standard for the disposition of SFMs. The HLW glass would be acceptable for geological repository disposal within the currently proposed design and licensing envelope (DOE 1991, DOE 1993) for repository geological disposal of HLW and SNF.

The SFM is primarily plutonium. The SNF (DOE 1994) would be degraded SNF in the United States that may require processing before it can be disposed. Hanford-N SNF and Three Mile Island-2 core debris are examples of such materials. This SNF is primarily owned by DOE. The other materials are highly radioactive materials, such as ^{137}Cs that may require conversion from their current forms before they can be disposed of in a geological repository.

The conversion process is GMODS, which is a new process (Forsberg 1994) that has the unique capability of directly converting metals, ceramics, amorphous solids, and organics to glass. It is an enabling technology that makes it technically possible to accomplish the above tasks.

1.3.2 Rationale for Option

There are five incentives for this SFM-SNF disposition option.

1.3.2.1 Meets National Academy of Sciences (NAS) Spent Fuel Standard

The final HLW glass meets the NAS spent fuel standard (NAS 1994) for disposition of SFMs. The plutonium and other materials are (a) within a matrix of highly radioactive materials, (b) mixed with large quantities of low-enriched uranium as in commercial SNF (low concentration of plutonium), and (3) in a chemically resistant waste form.

1.3.2.2 Provides Unlimited Supply of Radioactivity for Disposition

Three sources of radioactivity (DOE 1994b) can be used to spike SFMs in glass as a barrier to their extraction for use in nuclear weapons. The sources are (a) SNF, (b) cesium capsules, and (c) HLW in tanks. The SNF is the only material in effectively unlimited supply. Furthermore, the radioactivity of any batch of glass can be boosted to very high levels by addition of appropriate quantities of high-burnup SNF.

1.3.2.3 Addresses Other Nonproliferation Concerns

Three classes of SNF are potential proliferation concerns: (a) unirradiated or low-burnup plutonium containing SNF, (b) high-enriched uranium, low-burnup SNF, and (c) degraded SNF. Conversion of any of these SNFs by themselves or in combination with other SNFs, as appropriate to HLW glass, would eliminate the concerns associated with these SNFs.

Significant quantities of SNF were designed to be reprocessed for the recovery of plutonium. Examples include the British Magnox SNF (and the North Korean copies), the production reactor SNF at Hanford, and similar fuels in other nuclear weapons states. Many of these SNFs may not be acceptable for repository disposal in their current forms. These SNFs were designed to be quickly reprocessed after reactor discharge and not designed for long-term storage or disposal. At the current time, reprocessing with waste solidification is the only process for conversion of this SNF to an acceptable waste form for geological waste disposal. Unless alternative processes are developed to treat these SNFs, reprocessing with plutonium recovery will be required. This creates added inventories of SFMs to be disposed of. (It is noted that conventional power reactor fuel is of a different design and thus can be disposed of directly in a geological repository.)

Significant quantities of high-enriched-uranium, low burnup SNF exists. Weapons-useable high-enriched uranium could be recovered with limited effort from these SNFs. The concerns about high-enriched uranium SNF can be avoided by converting the SNF and depleted uranium simultaneously to a low-enriched-uranium HLW glass. The source of depleted uranium can be degraded SNF with low-enriched uranium or clean depleted uranium.

1.3.2.4 Assures Repository Acceptance

Conversion of SFMs and SNF to HLW glass allows acceptance of the plutonium-loaded, low-enriched-uranium HLW glass within the currently proposed envelope for repository licensing and design. No new repository design and licensing basis are required. Repositories are designed and licensed (DOE 1993) to accept HLW glass and low-enriched-uranium SNF. A plutonium-loaded, low-enriched-uranium HLW glass fits within this repository design and licensing envelope.

There are four types of repository waste acceptance criteria (DOE 1993, DOE 1991): mechanical (container size etc.), chemical (waste form performance etc.), thermal (maximum decay heat load), and nuclear (criticality). An HLW glass meets the repository mechanical, chemical, and thermal criteria. An HLW glass made from SFMs and low-enriched uranium SNF meets the long-term repository nuclear

criticality waste acceptance criteria (WAC) in the same way that commercial SNF meets the criteria. In a repository, plutonium decays to ^{235}U . A plutonium only waste form in time becomes a highly-enriched uranium waste form. The chemistry of uranium (over geological time) may allow the uranium to migrate short distances within the repository and concentrate in specific locations. This creates the potential for nuclear criticality if the uranium is highly enriched in the fissile isotopes ^{235}U or ^{233}U . This can be avoided (Patrick 1992) if the waste form contains large quantities of depleted uranium (^{238}U). In such cases, the ^{235}U decay product of plutonium is isotopically diluted with ^{238}U to low enriched uranium. This avoids the potential of nuclear criticality in a geological repository. Other approaches to repository nuclear criticality control may exist, but they require a different repository design and licensing basis (Rechard 1993).

1.3.2.5 Improves Waste Management

The DOE has about 2800 metric tons (MT) (U.S. DOE 1994) of miscellaneous SNF. Some of this SNF is badly degraded and is considered an unresolved safety issue. Much of the SNF must be processed to an acceptable form for disposal. Conversion of this material to an HLW glass would address major safety and environmental issues associated with SNF management during the disposal of SFMs.

2. DESIGN BASIS AND ASSUMPTIONS

2.1 SURPLUS FISSILE MATERIAL FEED INPUTS

The immobilization/pretreatment facilities shall receive plutonium in the following forms and quantities

— Clean oxide and metal	28 MT
— Scrap	10 MT
— Unirradiated reactor fuel	5 MT
— Irradiated spent fuel	8 MT

The immobilization/pretreatment facilities shall also receive 2 MT of surplus ^{233}U , 0.5 MT of surplus neptunium, and 0.3 MT of surplus americium. The americium will be associated primarily with the plutonium.

2.2 SNF AND RADIATION SOURCE FEED INPUTS

The immobilization facility shall receive SNF and other highly radioactive materials requiring treatment before geological repository disposal. This includes, but is not limited to, Hanford-N SNF and debris (2100 MT) and Three Mile Island (TMI)-2 spent nuclear fuel and debris.

The immobilization facility shall receive high-enriched SNF where there is a concern about recovery of the high-enriched uranium.

The immobilization facility shall receive radiation sources requiring treatment before geological repository disposal and added radiation sources (^{137}Cs capsules) as required to meet the spent fuel standard (see below).

2.3 PRODUCT REQUIREMENTS

The product will be a plutonium, low-enriched-uranium, borosilicate HLW glass that meets the proposed design and licensing envelope for waste acceptance at Yucca Mountain Repository (DOE 1993). The licensing and design envelope is defined by the two wastes expected for the repository: HLW glass and light-water-reactor (LWR), low-enriched-uranium spent nuclear fuel. There are four criteria:

- Chemical requirements (waste form leachability etc.): The product glass chemical performance shall match or exceed repository acceptance criteria for HLW glass.
- Nuclear requirements (criticality): The product glass shall meet long-term repository criticality control by use of low enriched uranium mixed with the plutonium in the HLW glass. The primary source of depleted uranium will be low-enriched SNF. This is the same basis for criticality control as exists for acceptance of LWR spent nuclear fuel into the repository. This requirement translates into about 1 part plutonium to about 50+ parts uranium.
- Thermal requirements: The product glass heat generation rate will not exceed waste package limits.
- Mechanical requirements (container size): The product container will have identical external dimensions as those of the Savannah River Site (SRS) HLW glass containers.

The product will meet the spent fuel standard as defined by the SFMs disposition program. The standard will be met by appropriate mixing of different feed materials including SNF and ^{137}Cs from capsules.

2.4 FACILITIES

The GMODS facility throughput shall process these materials in ~10 years. In terms of canisters of HLW glass produced per year or in terms of radioactivity handled, the GMODS throughput is essentially identical to the Defense Waste Processing Facility (DWPF) at the DOE SRS near Aiken, South Carolina. Much of the equipment will be identical (canister weld, decontamination, storage, etc.). The DWPF will convert HLW liquids and solids to HLW glass. The DWPF is in the startup phase of operation. The GMODS facility will convert highly radioactive solid materials such as degraded SNF and SFM to HLW glass.

For input to the PEIS, it is assumed (except where noted) that these facilities are identical in terms of construction materials required, general releases to the environment, and safety except where there is a clear basis for alternative features. The general site layouts are identical.

3. PROCESS DESCRIPTION

3.1 GMODS IMMOBILIZATION PROCESS

3.1.1 System Description

The system is shown in Fig 3.1. It consists of two types of facilities. At existing sites, plutonium and neptunium with low radiation levels are converted in glovebox-type facilities to an intermediate glass product, which is shipped to a single central GMODS facility, where the intermediate glass product is combined with SNF and other materials with high radiation levels to produce the final HLW product. In the central facility, this conversion process is a two-step process. The first step creates HLW glass marbles. The second step consolidates mixtures of marbles into glass HLW logs for disposal.

3.1.1.1 Production Site GMODS Glovebox Melters and Intermediate Glass Product

An intermediate plutonium borosilicate glass is produced at multiple production sites to meet transport, process safety, and economic requirements. The intermediate glass product is designed to be chemically inert, have a low chemical leach rate in water, be nondispersable in air, contain sufficient neutron poisons such that nuclear criticality can not occur, and be an acceptable feed to the central GMODS facility. There are several reasons for production of an intermediate glass:

Transport Requirements. Some of the existing plutonium and neptunium are in chemical and physical forms that are unacceptable for transport. Conversion to glass creates a transportable form that is a compatible feed to the central GMODS facility.

Process Safety. Plutonium and neptunium metals are chemically reactive. In addition, inadvertent nuclear criticality may occur if plutonium and neptunium concentrations and quantities exceed set limits. Conversion to glass as the first process step in the system reduces these safety concerns in subsequent process steps.

Nuclear Materials Accountability. Significant quantities of plutonium are in the forms of scrap and residue. Nuclear accountability is difficult on these complex mixtures. Conversion of heterogeneous materials into a homogeneous glass simplifies nuclear materials accountability during transport and at the central facility.

Fig. 3.1. Direct conversion of plutonium-containing materials (PCMs), SNF, and other materials to HLW glass.

Economics. Initial conversion of plutonium and neptunium to stable glass provides two economic benefits. First, conversion to a glass with neutron poisons as the first process step allows the use of larger equipment in subsequent steps with significant economic savings. Nuclear criticality control changes from avoidance of criticality by geometry control to avoidance of criticality by composition control. Second, a single chemical form for plutonium and neptunium feed to the central facility simplifies central facility operations.

This conversion step would be done at all sites (1) where there are major inventories of plutonium and/or neptunium and (2) where the chemical and physical forms are such that they could not be easily shipped to central sites for further processing. Depending upon the chemical forms of the materials, several different types of glass melters may be used. Small GMODS melters would be used for many types of scrap and residue. Other types of glass melters could be used for easier-to-process plutonium or neptunium for which the full capabilities of a GMODS processing system are not required.

3.1.1.2 Main GMODS Melter

At the central GMODS facility, the main GMODS glass melter simultaneously processes plutonium and/or neptunium glass, SNF, and other materials. This process is carried out in highly shielded, remotely operated hot cells. The SNF implies very high radiation levels in these hot cells. This process operation accomplishes two tasks:

- *Direct conversion of SFMs, SNF, and other materials to HLW glass.* GMODS is capable of direct conversion of metals, ceramics, organics, and amorphous solids into an HLW glass; hence, pretreatment of feed materials (except for size reduction) is usually not required.
- *Direct conversion of heterogeneous, complex mixtures of materials to homogeneous glass solutions.* This allows small glass samples to be taken and analyzed to accurately determine the glass chemical and radiological composition. HLW glass must meet strict performance goals and be well characterized. Many SFMs and SNFs are poorly characterized in terms of their chemical composition and thus are not acceptable for disposal. It is very difficult to characterize with high-assurance nonhomogeneous mixtures of materials, but it is easier to characterize homogeneous materials.

3.1.1.3 HLW Glass Marble Production, Storage, and Consolidation into HLW Glass Logs

The GMODS melter produces marbles. The marbles from particular production campaigns are inspected and stored in bins. Marbles not meeting intermediate HLW glass-product requirements are recycled to the main melter. The final HLW glass logs are produced by mixing different marbles from different campaigns to produce a homogeneous, high-quality HLW glass.

There are strong incentives to produce a single homogeneous HLW glass from a multitude of different SFMs and SNFs using marbles as an HLW glass intermediate product.

- Each HLW glass must be qualified for disposal in the repository. Fewer waste glass types reduce repository waste qualification costs. Costs to qualify a single glass may be tens of millions of dollars.
- Mixing different wastes minimizes HLW glass volume by maximizing waste loadings in the glass. The cost of disposal of HLW glass is high (>\$100,000/canister). Also, there are limits on the concentrations of specific elements that can be in a glass if a high-quality HLW glass is to be produced. If a waste with high concentrations of a particular element *E* results in low waste loadings in glass, that waste can be mixed with other wastes with low concentrations of element *E* to avoid this limitation on glass-waste loading.
- Mixing different wastes ensures nuclear criticality control by mixing depleted uranium from SNF with SFMs or high-enriched-uranium from SNF.
- It minimizes the need to fully characterize SFMs and SNFs before processing. Many SFMs and SNFs (such as TMI core debris) are poorly characterized in terms of chemical composition. It would be difficult and expensive to characterize these materials. The option exists to convert them to homogeneous glasses, analyze the homogeneous glasses, and mix with other glasses to produce an acceptable waste form.

3.1.2 Process Block Flow Diagram

The major process blocks are shown in Fig. 3.2 for a GMODS facility containing both the intermediate glass production step and the centralized facility. This option would exist if the central facility were collocated with a site that currently has an existing plutonium inventory. The plutonium facilities to produce the intermediate plutonium/americiu glass (top line of Fig 3.2) would be glove-box-type processing facilities, whereas the SNF facilities are large, remote-maintenance, canyon-type facilities. Figure 3.3 shows a more schematic perspective of the major process activities including chemical reagent flows.

The SFM operations are separated from other operations because of the special security requirements associated with these materials. The main link is a small transport corridor to transport plutonium and/or neptunium glass from the SFM area to the main GMODS melter.

The SFMs, SNF, and other materials that are received for processing would first be inspected. This inspection is done for several reasons. There are safeguards requirements for the SFMs. Equally important, the materials must be inspected to ensure that they can safely be processed and to determine the optimum processing conditions. The central facility is designed to receive a wide variety of feed materials. Process operations will be adjusted for different feed materials. Initial inspection provides the information needed to define optimum processing parameters.

Fig. 3.2. Block flow diagram: GMODS direct conversion of PCMs and SNF to HLW glass.

Fig. 3.3. GMODS immobilization flow diagram (major plutonium storage and production sites).

After their inspection, SFMs will be stored in interim storage vaults before processing. The interim storage facilities decouple the SFM transport system operation from day-to-day facility operations and allow fuller use of process facilities. Short-term transport disruptions (weather etc) will not impact process operations.

The SNF interim storage facilities will contain both SNF storage pools and dry storage facilities to handle the full range of feed materials. All of these materials are shipped in heavy, shielded SNF shipping casks; thus, both road and rail access is required. Significant inventories of SNF will be in interim storage. Laboratory testing of feed materials will be necessary for some feeds; thus, some feeds will remain in interim storage for some time while laboratory tests are completed. Interim storage requirements reflect the highly heterogeneous feed materials to GMODS.

The main GMODS melter block includes extensive feed preparation facilities plus the GMODS melter. The actual GMODS glass conversion process is a batch process. Feed preparation includes activities such as cutting open packages, size reduction, and separation of SNF material from packaging material. This facility will receive degraded SNF and other highly radioactive materials packaged over many decades under very different sets of conditions—including accident-recovery conditions. This implies many customized prefeed operations for specific wastes.

The glass inspection, qualification, and packaging system includes glass-marble inspection, storage, consolidation of glass marbles into glass logs, and HLW canister welding. The marble consolidation melter will be a small induction-heated melter. The remelting of marbles to glass logs is a relatively simple, small operation requiring small equipment. It is simpler because, unlike the GMODS melter, there is (1) minimal off-gas, (2) no large-scale nonhomogeneous mixtures, and (3) no chemical reactions that must go to completion.

The off-gas treatment system is coupled to the melter operations in two directions. The off-gas system receives off-gas from the melters. The roughing filters and dried sludge from the off-gas system would be recycled back to the melters. Specifically, glass filter composition is chosen to be a supplementary glass frit addition to the main melter replacing cold-frit-feed addition. This is the same off-gas design philosophy as is in the British Harvest process for HLW conversion to glass.

The HLW glass interim storage facility would be a dry, air-cooled vault that is essentially identical in design to current HLW vaults at the SRS.

3.1.3 GMODS Process

The GMODS process steps are shown in Fig. 3.4. GMODS, for this application, is a batch glass process during which sequential process steps convert feed to HLW glass (Forsberg 1995). This process would be used to both create the intermediate SFM glass and the HLW glass. Batches may vary from kilograms to metric tons. Production of intermediate glass would be produced in small GMODS melters, whereas the GMODS melter to make HLW glass would be a large-scale facility. Cold-wall (scull), induction-heated glass melters are required for this application.

The initial condition for the process is a melter filled with an oxidation-dissolution (lead borate) glass and lead metal. The lead borate glass has a composition of 2 or more mol PbO per mole of boron oxide (B_2O_3). The PbO is a component of the glass and a sacrificial oxide.

3.1.3.1 Waste Oxidation and Dissolution

In the first step, feeds are added to the molten dissolution glass. The ceramic and amorphous solid components in the feeds dissolve into the glass. Metals and organics do not dissolve into conventional molten glasses; however, this dissolution glass has special properties. The inclusion of a sacrificial oxide in the molten glass provides a method to oxidize in situ (a) metals to metal oxides and (b) organics to carbon dioxide gas and steam. If plutonium metal is fed to the melter, it is converted to plutonium oxide. If SNF is fed to the melter, the metallic clad materials are converted to metal oxides. The resultant metal oxides, such as plutonium oxide, dissolve in the glass; carbon oxides (in gaseous form) and steam exit the melter.

The sacrificial oxide is PbO. Lead oxide, which is a component in many glasses, reacts with metals in glass to yield metal oxides and metallic lead (Pb):

The reaction product, molten lead, separates from the glass and sinks to the bottom of the melter. The lead at the bottom of the melter forms a liquid with a high density such that various feeds float at the lead-glass interface while reacting with the PbO and dissolving into the glass. This floatation process protects the bottom liner of the melter from both physical abrasion and chemical attack by unprocessed materials.

Fig. 3.4. GMODS batch processing of wastes.

The properties of lead-borate glass allow rapid oxidation and dissolution of metal, ceramic, organic, and amorphous solids into glass. The PbO in this system is a powerful oxidant. Some metals will, however, form protective oxide coatings that slow chemical reactions. Boron oxide is a dissolution agent for metal oxides and rapidly solubilizes these metal oxides. It is the combination of both the PbO and boron oxide that makes GMODS feasible.

Dense, reactive metals, such as plutonium, when added to the glass, may sink through the glass into the molten lead. Some of the dense metal will react and dissolve in the glass during the decent. Plutonium has a low melting point (638°C); thus, it will melt at GMODS's operating temperatures ($700\text{--}1000^{\circ}\text{C}$). When the plutonium metal enters the molten lead, it dissolves into the lead. Dissolved plutonium in the lead is then oxidized at the lead-glass interface and extracted back into the glass (Fig. 3.5). This oxidation-extraction process is a common phenomenon in many two-phase systems.

3.1.3.2 Glass Refining

After oxidation-dissolution of the feeds, various glass additives [silicon oxide (SiO_2) etc.] are added to improve the glass quality. Optimum glasses for rapid oxidation-dissolution of materials are different in composition from glasses for long-term durability; thus, glass additives that create a more durable glass are introduced after feed oxidation-dissolution takes place.

Excess PbO is removed from the final glass by adding carbon. The carbon reduces the PbO to lead metal while producing gaseous carbon dioxide [Eq. (3)]. Excess lead oxide is removed from the dissolution glass for multiple reasons: (1) better final glass, (2) reduction of the volume of the glass, and (3) avoidance of the costs to provide added sacrificial PbO. The final glass is chemically nonhazardous (Equity 1992).

3.1.3.3 Glass Pour

The final waste glass mixture is sent to "marble" production machines where it is solidified.

3.1.3.4 Makeup Glass Formulation

The product glass contains both B_2O_3 and PbO. Replacement B_2O_3 and PbO are added to the melter for processing the next batch of materials.

3.1.3.5 Lead Recycle

The lead at the bottom of the melter is reoxidized back to PbO by the addition of oxygen. Lead is an oxygen carrier that does not leave the system. The oxidation reaction is

1. DENSE METAL

Fig. 3.5. High-density-metal oxidation-dissolution cycle in GMODS.

This lead-oxidation process is a common industrial process used in the manufacturing of car batteries and in other industrial activities. This oxidation creates the new dissolution glass for the next batch of feed to be processed.

The optimum quantities of PbO in the oxidation-dissolution glass will usually exceed the quantities of PbO needed to oxidize various feeds. This excess lead oxide assists the dissolution process. It is later removed from the glass by addition of carbon before the final product glass is poured. After the product glass is poured, the new oxidation-dissolution glass is made with its high PbO content. This processing implies that much of the lead in the system is both oxidized and reduced during the processing of a single batch of material.

Noble metals (gold, silver, etc.) will build up in the lead because they can not be oxidized by PbO; thus, they can not enter the glass. The glass does not dissolve metals into its structure. For small-scale operations, vacuum distillation may be used on an infrequent basis to remove excess noble metals from the lead.

3.1.3.6 Off-Gas System

GMODS produces limited off-gas because solid PbO is the oxidizer. The primary off-gases are water and carbon dioxide, by-products of (a) oxidation of organic wastes (if organics are in the feed) or (b) reduction of PbO with carbon in producing the product glass. The GMODS melters include an off-gas system similar to the British Harvest process for vitrification of HLW. This type of off-gas system uses special glass filters to remove the aerosols from the off-gas. When the filters are blocked, they are used as glass frit in the main process. This minimizes secondary waste generation.

3.2 KEY INTERFACES

The GMODS facility is a stand-alone facility. In size and operations (HLW glass logs etc.), it matches the DWPF at the SRS and requires essentially identical transport, utility, and other support services. These include major truck and rail access. The feeds include SNF that is usually shipped in SNF shipping casks with gross weights up to 120 MT. Major inputs and outputs are shown in Fig. 3.3.

3.3 PROCESS SUPPORT SYSTEMS

In size and operation (number of HLW glass logs etc.) this facility essentially matches the DWPF at the SRS and requires essentially identical process support systems (except those only for pretreatment of the HLW slurry).

3.4 WASTE MANAGEMENT PROCESSES

The secondary waste management processes for GMODS for utility wastewater, process wastewater, and sanitary wastewater are essentially identical to equivalent HLW management facilities such as the DWPF at the SRS. There are unique systems for treatment of chemical wastes, low-level wastes (LLWs), transuranic wastes and Greater Than Class C LLWs. These wastes include both process wastes and failed equipment wastes.

Many secondary waste treatment operations within the GMODS facility are different than most other vitrification facilities because of three characteristics of GMODS. These differences both reduce secondary waste generation and change the characteristics of the wastes:

GMODS requires as a process feedstock carbon to convert wastes to glass. This carbon feedstock can be pure carbon or secondary wastes containing carbon. Gas streams are often purified by use of activated carbon beds. Wastewater streams are often cleaned by use of activated carbon or ion exchange resins. Many ion exchange resins are primarily carbon. For a GMODS facility the use of activated carbon and ion exchange resins in secondary waste cleanup systems will be preferred because the used activated carbon and ion exchange resin wastes can be dried and be used as internal feed stock while eliminating particular waste streams.

GMODS requires, as a process feedstock, glass frit to make borosilicate glass. Glass frit can be provided in the forms of ground glass, glass marbles, or fiberglass. Air and water filters are often made of fiberglass. Fiberglass filters, bags, and structures will be preferred because when contaminated they become feedstock.

GMODS is a waste management treatment facility designed to convert metals, ceramics, organics, and amorphous solids to glass. This implies that many secondary wastes, such as failed melters and other failed equipment, can be processed into glass waste forms. This capability also implies that if any waste does not meet waste acceptance criteria, it can be recycled. This includes HLW glass logs.

The above capabilities may allow GMODS to treat secondary wastes from other facilities. If internally generated rates of carbon and glass containing wastes are insufficient to meet process feedstock requirements, the option may exist to process such wastes from other facilities and avoid feedstock purchases of fresh materials.

Waste quantities are also minimized by appropriate selection of other feed materials and materials of construction. Some materials can be easily processed by GMODS. Other materials are difficult to process or create significant added glass waste volumes if processed through GMODS. This type of standard waste minimization is common to many types of waste processing systems.

The facility will generate significant quantities of transuranic and Greater Than Class C LLW. This is a direct consequence of processing SNF and plutonium-containing wastes. Wastes in these categories include SNF hardware, secondary wastes from processing SNF, and many one-of-a-kind highly radioactive components. These wastes will be converted into two final waste forms:

Metal. Bulk metal wastes (SNF hardware etc.) are packaged for disposal as metal transuranic or metal Greater Than Class C wastes. This may include some containers that have been used for long-term storage of degraded SNF or other highly radioactive wastes.

Transuranic borosilicate glass. Other secondary transuranic wastes are converted to transuranic waste glass using a secondary waste treatment GMODS melter. Feed pretreatment operations may generate large quantities of transuranic wastes with the quantities dependent upon the SNF or other materials being processed. These pretreatment operations include steps such as cutting and grinding operations to open welded packages, failed equipment such as melters, and various other waste streams.

4. FACILITY DESCRIPTION

4.1 GENERIC SITE PLAN

A generic site plan for the central GMODS facility is shown in Fig. 4.1. This site plan is essentially identical to the DWPF at the SRS because the GMODS facility would be about the same size and produce similar quantities of HLW glass.

The major site facilities include the main vitrification building including an attached warehouse and service building, the operations building, HLW glass storage building, cooling towers, and off-gas system. The off-gas system includes a sand filter, fan house, and stack. The site requires major rail and road access. SNF is transported in SNF shipping casks with gross weights up to 120 MT.

4.1.1 Vitrification Building

The vitrification building contains process equipment, auxiliary equipment, and personnel facilities for converting SFMs, SNF, and other highly radioactive materials to a leach-resistant HLW glass. Additional facilities are provided for decontamination of equipment, treatment of secondary wastes, and treatment of off-gas streams. Space is provided to house equipment for process chemical additions, sampling, personnel and effluent monitoring, and electrical distribution switchgear. Off-line analyses of routine control samples will be performed in associated analytical cells and analytical laboratories within the building.

Fig. 4.1. Generic GMODS site plan.

4.1.2 Glass Waste Storage Building (GWSB)

The GWSB serves as a temporary storage location for sealed stainless steel canisters filled with glass awaiting shipment to a geological repository. Facilities for receiving and loading shielded casks for shipment of the canisters will be provided when required. The GWSB contains an electrical equipment room, an office, and change rooms.

4.1.3 Operations Building

The operations building, which is of standard construction, provides office space for the supervision of various administrative departments.

4.1.4 Warehouse and Service Building

This facility, which is of standard construction, provides space for offices, a lunchroom, and change rooms for operational personnel assigned to the receiving-storage warehouse, cold-feed area, or canyon area, and for technical assistant personnel associated with container inspection, interim storage, and cold-feed area. The facility houses the central control room and auxiliary control areas. Space is dedicated to housecleaning shops, fabrication areas, tool cribs, welding booths, office space, electronic and instrumentation shops, and an electrical equipment room. The utility equipment area is used to receive, inspect, store, and dispense new canisters for the waste glass product and to receive, sample, store, and disperse bags and drums of dry and liquid cold-feed chemicals.

4.1.5 Sand Filter

The sand filter removes radioactive particulates from the vitrification building process cell exhaust air and provides a final stage of filtering for the process vessels and melter off-gases.

4.1.6 Fan House

The fan house for Zone 1 (process areas with the highest potential for airborne contamination) contains fans and motors for exhausting the ventilation air from Zone 1 through the sand filter and sand filter exhaust stack.

4.1.7 Exhaust Stack

The exhaust stack receives the filtered Zone 1 exhaust air from the vitrification building and disperses it into the atmosphere.

4.1.8 Cooling Tower Building

The cooling tower building provides cooling water for process, air compressors, heating, ventilation, and air-conditioning (HVAC) chillers, and nonprocess equipment through heat exchanges in the closed-loop cooling waste systems. The cooling tower system is an induced draft, crossflow cooling tower, and associated systems.

4.1.9 Bulk Frit Handling Building

The Bulk Frit Handling Building receives, stores, and prepares clean glass frit and glass frit slurry for use in glass making and canister decontamination. The building is connected to the vitrification building by conveyors to allow for efficient transfer of frit to the process cells. Contaminated glass frit will be processed in other areas of the process building, such as the feed preparation cell.

4.1.10 Water Supply

The water supply on-site will probably come from a combination of supply water wells, surface water impoundments, and domestic water supply lines. The choice will depend on the site on which the facility is constructed. Water will be needed for melter cooling and other process cooling, heat exchangers, air chillers, fire protection, and various other uses. Some areas will be able to utilize untreated well or surface water, while others will require purified water.

4.1.11 Electrical Substation

Electrical power will be purchased from off-site utilities and distributed from a dedicated on-site substation. Backup electrical power will be provided by diesel generators and batteries for systems related to safety and shutdown of the process cells.

4.2 OVERALL GMODS FACILITY LAYOUT AND DESIGN DESCRIPTION

4.2.1 Process Building Layout

The general layout and arrangement of the GMODS building are shown in Figure 4.2. The main vitrification structure containing the GMODS process cells is a maximum-resistance reinforced concrete structure. Standard structural steel frames are used for supporting operations including the manipulator repair shop, controlled machine shop, railroad airlock, decontamination and maintenance equipment areas, and some filter ventilation equipment rooms. The vitrification building is a Category I structure.

ABBREVIATIONS

A/L	AIRLOCK
CDC	CANISTER DECONTAMINATION CELL
CDMC	CONTACT DECONTAMINATION AND MAINTENANCE CELL
CM	CONSOLIDATION MELTER
FP	FEED PREPARATION
GMODS	MAIN GMODS MELTER
MS	MARBLE STORAGE
REDC	REMOTE EQUIPMENT DECONTAMINATION CELL
SFMF	SURPLUS FISSILE MATERIALS FACILITY
SFS	SPENT FUEL AND HIGHLY RADIOACTIVE WASTE FEED STORAGE AREA
SWT	SECONDARY WASTE TREATMENT
WTC	WELD TEST CELL

Fig. 4.2. GMODS facility layout.

4.2.2 Major Building Areas

4.2.2.1 SFM Storage and Processing

This separate area includes (1) the receiving facilities for SFMs with low radiation levels, (2) any processing facilities required to convert SFMs into an intermediate glass, and (3) storage vaults. Plutonium or neptunium glass from these vaults is directly transferred to the main GMODS melter as needed. The facility is part of the main vitrification building and uses many of its support services. The operations of this area are separate from the main building because of the special security requirements associated with weapons capable materials.

4.2.2.2 Spent Fuel Storage

This area includes (1) the receiving facilities for spent fuel shipping casks, (2) pool storage for SNF and other highly radioactive materials, and (3) dry storage vaults for SNF and other highly radioactive materials. Wet and dry storage are included to handle different forms of highly radioactive materials that may be received. This area receives SFMs with high radiation levels such as ^{233}U . The receiving facilities have both rail and truck access.

4.2.2.3 Feed Preparation

This area prepares feed materials for the main GMODS melter. For some types of SNF, no feed preparation is required. For other types of SNF, assembly hardware may be separated from fuel material to be separately processed as a secondary waste stream. Very large items may require size reduction. Badly degraded highly radioactive materials may be received in welded containers requiring disassembly of the waste package. Some wastes may require limited processing such as vacuum-drying to provide dry feed to the melter. Because of the variability of the feeds, this area includes full remote manipulator capabilities to conduct custom operations on specific materials.

4.2.2.4 GMODS Melt Cell

The GMODS melt cell contains the main GMODS melter and its support equipment. It converts mixtures of SFMs, SNF, and other highly radioactive materials to an HLW glass. The cell also contains a marble production machine to convert the molten glass to marbles. The main melter is a large, cold-wall, induction-heated melter operated in a batch mode.

4.2.2.5 Marble Storage

The marble storage area contains marble inspection equipment, multiple bins for marble storage, and marble transport systems to feed marbles in any desired ratios from different bins to the glass consolidation melter.

4.2.2.6 Consolidation Melter

The consolidation melter melts glass marbles, mixes the molten glass, and pours the molten glass to the HLW canister. It is a small induction-heated glass melter.

4.2.2.7 Canister Decontamination and Weld Test Cells

These cells include the canister decontamination cell and weld test cell. In the canister decontamination cell, glass frit will be used to remove potentially contaminated coatings from the waste canisters that formed when the canisters were filled. High-pressure slurry blasting, similar to sandblasting, is used to remove this oxide coating. The used frit will be recycled as feed to the glass melter. The decontaminated canister will have a final plug welded at the weld test cell. Canister weld quality will be checked, the radiation and temperature levels monitored, and the canisters surveyed for radioactive contamination before they are transferred to the GWSB.

4.2.2.8 Secondary Waste Treatment

The secondary waste treatment area processes wastes generated by feed preparation, the main GMODS melter, and equipment maintenance. As described in Sect. 3.4, the GMODS process offers the option of returning many waste types back to the main melter for inclusion in the final HLW glass form. This may include radioactive wastes (low-level, high-level, transuranic), hazardous wastes, and mixed wastes produced at the facility. Both solid and liquid waste forms may be treated on-site and used as feed materials for the GMODS melter. The secondary waste treatment area will include a GMODS melter to process some waste types into glass marbles. These marbles could be incorporated into the final HLW glass logs by using them as feed to the consolidation melter, or they could be sent for separate disposal. This cell will also include equipment for packaging highly contaminated or irradiated metals. There is direct access between this cell and the feed preparation cell so that material can be transferred easily between these areas.

4.2.3 Facility Building Service Systems

4.2.3.1 Fire Protection

Fire protection services will include both active and passive components. Active fire protection includes fire detection, suppression, and control systems. Passive components include systems for fire prevention, confinement, and damage limitation as well as life safety features. These systems will be incorporated as appropriate in the design of the facility.

4.2.3.2 Radiation Monitoring

Radiation monitoring equipment will be used, where appropriate, to promptly detect the spread of radioactive contamination, monitor plant personnel and visitors, monitor plant effluents, and guard against criticality incidents. This equipment will include area radiation monitors, personnel monitors, stack gas monitors, building air monitors, and liquid radioactivity effluent monitors. Alarms from permanently installed monitors will be connected to the health physics office. Radiation detection and measurement equipment will be available for the analysis of contaminant smears, environmental samples, bioassay samples, and process line grab samples.

4.2.3.3 Drain Collection Systems

Drains in areas of the process building where there is known or suspected radioactive contamination will collect into a holding tank. This tank will be sampled for radioactivity prior to discharge. If the radioactivity levels exceed those allowed by permit for discharge, the water in the tank will be treated using ion exchange resins or precipitation methods. The residue from these treatment methods may be used as feed material for the main GMODS melter to prevent the generation of secondary waste streams.

4.2.3.4 Ventilation

In addition to normal heating, ventilation, and air conditioning needs, process building ventilation is designed to prevent the spread of radioactive contamination. Negative air pressure will be maintained in areas of highest contamination so that air will tend to travel from areas of low or no contamination towards the contaminated sections of the building. Filters will be used to remove airborne contamination within the process building and before the air is exhausted to the atmosphere. These filters may then be used as feed material to the main GMODS melter.

4.2.3.5 Electrical Power

Electrical systems will be designed to provide reliable power for normal operations and for shutdown during emergency conditions. A dedicated substation will be constructed and connected to a reliable power grid. This substation will be located away from the main process building for safety purposes. Diesel generators and batteries will provide backup power in the event of grid failure. Uninterruptible power supplies will be installed where needed, such as in the GMODS melter control room.

4.3 PROCESS AREA LAYOUTS AND DESIGN DESCRIPTION

The conceptual layout of the process area is similar to that of the DWPF. The GMODS facility process is housed in a series of remotely operated, heavily shielded cells that are connected so that material can be moved easily from one cell to another. All equipment in the process area must be designed to be operated and maintained remotely to minimize worker radiation exposure. Radiation shielding, ventilation, and decontamination systems will be used to protect workers and the public from radiation exposure.

4.3.1 Radiation Shielding

Concrete shield walls will be designed to limit the radiation exposure level to 0.5 mrem/hr or less in areas where facility personnel are located. Cell windows will be designed to provide the same level of shielding while allowing adequate viewing of the process operations by facility personnel. Access control systems will be used to prevent unnecessary or inadvertent exposure. In areas of lower radiation, glove boxes may be used to contain radioactive contamination. Area radiation monitors will be installed to provide immediate notification to personnel if radiation levels exceed those allowed.

4.3.2 Maintenance Philosophy

The method used for maintenance of facility equipment will depend on the radiation levels present. Remote maintenance will be required in areas of extremely high radiation or radioactive contamination, such as in the GMODS cell or the feed preparation cell. Contact maintenance will be used in areas of lower radiation or contamination or for non-radiological areas. The procedures used for contact maintenance in radiological areas will need to be reviewed by health physics personnel, who will determine the length of time that crew members will be allowed to remain in the area.

4.4 PROCESS SUPPORT SYSTEM FACILITIES DESCRIPTION

Because of the nature of the GMODS process, minimal cold feed preparation facilities are required. Waste will arrive at the facility by truck or by rail, and must be unloaded and inspected prior to placing it in the feed preparation cell. All processing will take place in the main GMODS building. In addition, the GMODS process makes waste management at the facility different than at other vitrification plants. Solid, liquid, and gaseous wastes can be treated on-site, and many secondary wastes may be used as feed materials back into the GMODS melters. Treated liquid and gaseous waste will be discharged at permitted locations and will be monitored to assure compliance with all applicable regulations.

4.4.1 Glass Waste Storage Building

The GWSB will store glass waste canisters until a federal repository is available or until the canisters are moved to another facility. It will be designed to meet DOE Order requirements for safeguards and criticality controls. Underground vaults will be used for canister storage to provide radiation shielding, protection of the canisters from external damage, and cooling to remove radioactive decay heat. The vaults will be earthquake and tornado resistant structures. The design capacity will be ~3,000 canisters.

4.4.2 Waste Management Facilities

Facilities will be provided for the management of waste streams generated by the GMODS process. These waste streams will include radioactive, hazardous, mixed, and sanitary/industrial wastes in a solid, liquid, or gaseous form. Many of these wastes may be treated on-site, and many secondary wastes may be used as feed materials back into the GMODS melters. This will require careful selection of treatment processes and materials, but could result in a significant reduction in secondary waste generation over conventional vitrification processes. Other waste minimization and pollution prevention methods will be incorporated wherever possible to reduce the generation of all types of waste.

Waste management facilities on-site may include a chemical waste treatment facility, a radioactive liquid waste treatment facility, wastewater treatment facilities, and off-gas treatment systems.

4.5 BALANCE OF PLANT FACILITIES DESCRIPTION

Other buildings on the GMODS site are described in Sect. 4.1 as follows.

Operations Building	Sect. 4.1.3
Warehouse and Service Building	Sect. 4.1.4
Sand Filter	Sect. 4.1.5
Fan House	Sect. 4.1.6
Exhaust Stack	Sect. 4.1.7
Cooling Tower Building	Sect. 4.1.8
Bulk Frit Handling Building	Sect. 4.1.9
Water Supply	Sect. 4.1.10
Electrical Substation	Sect. 4.1.11

4.6 ENGINEERED SAFETY SYSTEMS

The facility contains the standard engineered safety systems, but the first line of safety is the process safety philosophy. There are two components that define safety philosophy.

- The first process step is conversion of SFMs to an intermediate glass form that (1) is chemically inert, (2) has low water leachability, (3) ensures a low potential for aerosol production under normal and accident conditions, and (4) ensures criticality control by chemical composition rather than geometry. First-step conversion of chemically reactive materials with potential criticality concerns to inert glasses minimizes safety risks for all the following processing steps.
- The process is designed to minimize the presence of liquids or finely divided solids within the facility. Release risks are primarily determined by the potential to have finely dispersed particulates or liquids. The facility is a solids processing facility with minimum liquids handling (except molten glass) to minimize the potential for radionuclide release.

Engineered safety features are used throughout the facility to provide defense against accidents and to mitigate the effects of accidents on plant personnel, equipment, and the environment. Confinement barriers and systems restrict releases of radioactive or hazardous materials to the environment or to areas occupied by plant personnel. Filters and other treatment systems are part of this confinement process to reduce contamination in facility effluent streams. The confinement system must be designed to withstand pressure differentials associated with normal plant operations and with design basis accidents. Penetrations through confinement structures for pipelines, ventilation, and process off-gas systems must be considered in the

design of the facility to ensure that they do not provide a path for contaminants to reach the environment or occupied plant areas. Fire protection and other systems are also designed into the facility to help ensure safe operations. All buildings on-site will be designed in accordance with DOE Order 6430.1A, *General Design Criteria*, and other applicable regulations.

4.6.1 Natural Phenomena (Seismic, Wind, Flood)

Each building on the GMODS site will be evaluated in terms of its importance in protecting the safety of employees and public and in avoiding an unacceptable loss. Some structures, such as the vitrification building, must be designed and constructed to withstand the effects of a design basis earthquake or tornado. Other buildings may only need to meet standard construction codes. The site for the GMODS facility should be selected to avoid the need to consider design basis floods, buoyancy, and static water force effects.

4.6.2 Systems Related to Safety

DOE Order 6430.1A, Section 1300-3.2 specifies the criteria for determining which systems, components, and structures are safety class items. The criteria include those systems whose failure would produce unacceptable exposure consequences to the public, systems required to maintain safe operating parameters during normal operations and anticipated operational occurrences, systems required for criticality safety, systems required to monitor releases of radioactive material associated with a design basis accident, systems required to achieve and maintain a safe shutdown condition, and systems that control those described above. Each system within the GMODS facility must be evaluated against these criteria to determine if it must be classified as a safety class item. Those expected to be classified in this way include the confinement/containment structure for the GMODS melter, shielding around the process cells, ventilation systems, off-gas monitoring systems, electrical supply to the process cells, and the melter control room.

4.6.3 Fire Protection

Fire protection services will include both active and passive components. Active fire protection include fire detection, suppression, and control systems. Passive components include systems for fire prevention, confinement, and damage limitation as well as life safety features. Applicable requirements for fire safety include DOE Orders and National Fire Protection Association standards.

Active fire protection components must be designed to be compatible with the areas in which they are used. In some cases, water sprinkler systems are appropriate, and in other areas carbon dioxide or Halon may be required for fire suppression. Water supply systems for fire protection must be reliable and have the necessary capacity and pumping pressure. Wet standpipes and hose stations will be installed as needed. Fire extinguishers and fire detection/alarm systems will also be provided throughout the facility in accordance with applicable standards.

Passive fire protection will be designed into the facilities to reduce the probability of fires and to confine or mitigate fires that do occur. Components of passive fire protection include plant arrangement, building and structural design (including fire barriers), construction material, penetration seals, drainage, ventilation systems, emergency lighting, and provision of egress.

4.6.4 Safety Class Instrument and Control (I&C), Electrical, and Monitoring Systems

As discussed in Sect. 4.6.2, systems within the facility will need to be evaluated against criteria contained in DOE Order 6430.1A, Section 1300-3.2, to determine if they must be designed as safety class items. Many of the I&C, electrical, and monitoring systems will meet these criteria. These include the backup diesel generators, control room equipment, criticality monitoring equipment, effluent monitoring systems, and area radiation monitors.

4.6.5 Nuclear Criticality

Nuclear criticality avoidance is ensured by three mechanisms: process design, process instrumentation, and nuclear criticality safety systems.

The locations of buildup of fissile material in the process systems depend upon the process chemistry; thus, the first level of nuclear criticality safety is a detailed understanding of fissile material process chemistry to determine potential locations for fissile material buildup. This will, in turn, determine the nuclear criticality safety systems.

Avoidance of nuclear criticality is also achieved by on-line process control systems that measure the concentrations and quantities of fissile materials in many parts of the plant. This capability is required for process control purposes independent of nuclear criticality considerations, but the process control system also has the unique capability to avoid nuclear criticality. Product requirements necessitate a uniform glass-product composition starting with highly heterogeneous feeds. This requires multiple measurement and control systems to ensure production of a homogeneous glass product. One of the methods to measure uniformity in the glass is to measure the concentration of fissile materials in various glasses throughout the plant and determine if the fissile contents are uniform. Some of the key systems for this include the following:

- The main GMODS melter instrumentation includes pulse-neutron sources and detectors mounted on a rail system to measure the location and concentration of fissile materials in the molten glass on a real-time basis. This is an extension of the use of pulse-neutron sources and detectors for determination of the fissile content of waste packages before processing and disposal. In this application, the instrumentation is one of several systems to determine when the feed materials have been dissolved and when a homogeneous glass exists.

- Marble inspection systems include nondestructive nuclear measurements of glass homogeneity, fissile content, and chemical composition.
- The consolidation melter-monitoring systems are similar to the main GMODS melter and monitor fissile concentrations as a mechanism to ensure glass homogeneity.

4.6.6 Confinement and Containment (Safety Class)

Confinement and containment systems in this facility will be designed as safety class items. These systems serve to limit spread of contamination during normal operations and accident conditions. They consist of shield walls, ventilation and process off-gas systems, coolant systems, air locks, filters, and other components. The main confinement structures are the process cells in the vitrification building. These cells must be constructed to contain pressures associated with the major design basis accident, loss of coolant to the GMODS melter. The process cells also serve to protect facility personnel from radiation exposure associated with routine operation.

4.7 Safeguards and Security Systems Description

Safeguards and security systems include both material control and accountability and physical security activities. Special nuclear materials, source materials, and other nuclear material identified in DOE Order 5633.3A, *Control and Accountability of Nuclear Materials*, are considered accountable nuclear materials. SFM, SNF, and other accountable nuclear materials must be carefully monitored at the GMODS facility to properly deter, prevent, detect, and respond to theft or diversion. Intrusion detection and lighting systems must be designed for areas where accountable nuclear materials will be stored or processed. Access control, physical barriers, and entry/exit inspections will also be used to provide security and prevent theft. United States nonproliferation policy requires that SFM be made available for inspection and verification by the International Atomic Energy Agency.

Transportation of nuclear materials to the GMODS site must be performed in accordance with applicable regulations. Once on-site, the materials must be kept in secure Material Access Areas and carefully controlled and inventoried. Following vitrification, the glass will still be classified as accountable nuclear material and must be protected accordingly. Therefore, both the vitrification building and the glass waste storage building must be considered part of the Material Access Area.

4.8 Facility Operations Description

Operational requirements for the GMODS facility are expected to be similar to that of the DWPF. The facility will operate at ~75% of capacity, and will produce 350 glass waste canisters per year. Roughly 800 people are expected to be employed by the GMODS facility.

4.9 DECONTAMINATION AND DECOMMISSIONING (D&D)

The D&D philosophy of this facility is different than that of other facilities because of its unique capabilities. This facility is functionally designed to convert metals, ceramics, organics, and amorphous solids to waste glasses acceptable for disposal. Most of the facility would be decontaminated and decommissioned by processing the radioactive components of the facility through the secondary waste GMODS melter. Only this cell will require decontamination after this processing is complete.

5. ENGINEERING AND TECHNICAL ASSESSMENTS

5.1 ACCIDENT ANALYSIS AND RISK ASSESSMENTS

The GMODS facilities are expected to be similar in terms of accident risks to the DWPF except that accident scenarios associated with benzene and formic acid will not occur. These specific components are not present in the feeds to a GMODS facility.

5.2 PRODUCT HLW GLASS DEVELOPMENT NEEDS AND UNCERTAINTIES

The product HLW glass must be acceptable for geological disposal in a repository. There are two approaches to ensure repository acceptability.

- Produce a waste form that meets currently accepted repository waste acceptance criteria. Repositories are designed to accept (1) HLW glass with no significant fissile material and (2) LWR SNF. The design and licensing envelope is defined by these two waste types.
- Modify the design and license of a repository to accept the specific waste form that is produced.

The GMODS option is to produce a waste form that is acceptable within the current repository design and licensing window; therefore, glass-development needs are defined by what is required to ensure that the glass is acceptable for repository disposal. No changes in basic repository design or licensing are proposed. The development needs herein are modest because of the choice of waste form: a plutonium, low-enriched-uranium, HLW, borosilicate glass. The product glass was explicitly chosen to ensure repository acceptance. There are four classes of acceptance criteria: mechanical, thermal, chemical, and nuclear.

5.2.1 Mechanical Criteria

The mechanical acceptance criteria include such specifications as canister size, ensurance of gas tight welds, and related factors. The proposed HLW canister has identical external dimensions to the SRS canister and is similar in most other respects. The proposed HLW canister may or may not have minor design differences because of the different glass properties that imply different thermal cycling of the canister during glass loading operations. No significant development is required to meet these criteria.

5.2.2 Thermal Criteria

The thermal criteria include maximum allowable heat load per canister and distribution of heat within a canister. The characteristics of the GMODS process with creation of a homogeneous glass indicate that there will be no difficulty in meeting thermal criteria.

5.2.3 Chemical Criteria

The HLW glass must meet multiple chemical criteria. These criteria are designed to prevent leachability of radionuclides by groundwater from the glass over geological time periods in the repository. The traditional HLW glass is borosilicate glass. The proposed glass herein is borosilicate glass, but the chemical composition is different with the addition of fissile and fertile materials. To develop and qualify a new borosilicate glass for the repository will require a moderate development effort. The development of the current borosilicate glasses for HLW disposal provides the fundamental scientific and technical basis to qualify a new borosilicate glass composition.

5.2.4 Nuclear Criteria

Repository criteria require that nuclear criticality be avoided over geological time frames. The proposed product is a plutonium, low-enriched-uranium, HLW glass that is designed to meet this criteria. Specifically the glass contains a fissile:fertile material ratio similar to LWR SNF and thus meets the long-term repository nuclear criticality requirements by the same mechanisms as does LWR SNF. This implies no changes in the repository licensing or design basis. The fissile:fertile ratio is about equal to $([^{235}\text{U} + ^{239}\text{Pu} + ^{241}\text{Pu}] / ^{238}\text{U})$.

One of the major licensing issues for a repository is avoidance of nuclear criticality. The fundamental problem is that uranium is expected to migrate in a geological repository, over time, and may concentrate in specific locations. If the uranium is significantly enriched in ^{233}U or ^{235}U , nuclear criticality will occur. Geological studies of old uranium deposits show that nuclear criticality has occurred in some naturally occurring uranium deposits when uranium enrichment levels were above several percent. The heat generated from nuclear criticality and the added fission products are potential threats to repository integrity.

Plutonium decays to ^{235}U . If only plutonium is in the waste form, the waste becomes, over time, high enriched uranium. This would be a major nuclear criticality design and licensing issue for a repository. Plutonium in wastes is acceptable if the wastes contain large quantities of depleted ^{238}U . In this case, the plutonium decays to ^{235}U , but the ^{235}U is born into an environment of ^{238}U . The ^{238}U isotopically dilutes the ^{235}U and prevents the possibility of nuclear criticality (Patrick 1992). LWR SNF (primarily ^{238}U) and the proposed plutonium, low-enriched-uranium, HLW glass herein are acceptable for repository disposal because of their content of ^{238}U . Waste forms containing plutonium but no ^{238}U require alternative repository nuclear criticality design and licensing philosophies (Rechard 1993).

Limited work with the repository organization will be required to define the maximum allowable ratio of fissile material to fertile material in the HLW glass. This ratio impacts scheduling of specific feeds to a GMODS facility. Lower allowable ratios of fissile material to fertile material imply more blending of SFMs and different SNF feeds to maintain allowed fissile:fertile ratios within the glass.

5.3 PROCESS DEVELOPMENT NEEDS AND UNCERTAINTIES

GMODS is a new process, and thus there are major uncertainties that must be addressed. Initial thermodynamic analysis of the process has been completed. Initial proof-of-principle experiments have been successfully conducted, but major work is required before the process can be considered ready for industrial application. This will include operation of a cold pilot plant. A multiyear research and development (R&D) plan is being prepared.

5.4 EQUIPMENT DEVELOPMENT NEEDS AND UNCERTAINTIES

The main equipment for GMODS is the cold-wall, induction-heated melter. This technology is used industrially for casting of superalloys and titanium. It is being developed in France (Monconyoux 1992) and Russia (Sobolev 1994) for radioactive waste processing. Significant engineering development will be required to ensure reliable operations within a hot-cell environment.

The GMODS facility requires development of many other types of specialized equipment. In each case, the base technology is available, but in many cases equipment has not been designed and qualified for hot, remote operations. Significant development efforts will be required to design and qualify this equipment.

6. ENVIRONMENTAL DATA

Due to the preliminary nature of the process design for GMODS, it is difficult at this time to estimate the environmental impact of the construction, operation, decontamination, and decommissioning of this facility. However, because the facility is conceptually similar in many ways to the DWPF being constructed at the SRS, some approximate values can be given. Much of this information is taken from *Defense Waste Processing Facility, Savannah River Plant, Aiken, S. C. Final Environmental Impact Statement*, DOE/EIS-0082-Final, February 1982.

6.1 EMISSIONS, EFFLUENTS, WASTE, AND RADIOLOGICAL IMPACT

6.1.1 Impacts During Construction

This section gives information that can be used to estimate the environmental impacts resulting from construction of the GMODS facility. These impacts will come from direct physical disturbance and from waste materials emitted to the atmosphere, discharged into surface water, or disposed of in solid form.

6.1.1.1 Emissions

Air emissions during construction of the GMODS facility should be no different from those of any large construction project. Dust will be produced during clearing of the land, and exhaust from construction equipment will also be emitted to the atmosphere. No regulated radioactive or hazardous air emissions are expected. Construction impacts to air quality are expected to be minimal. All applicable standards related to ambient air quality will be observed.

6.1.1.2 Effluents

As with air emissions, liquid effluents during construction of the GMODS facility should be no different from those of any large construction project. Aqueous waste generated during construction will be treated as necessary to meet all applicable regulations before discharge into sewer systems or surface waters. Provisions will be made to collect storm water where appropriate to minimize silt and suspended solids before the storm water reaches surface streams or ponds. No regulated radioactive liquid effluents are expected. Hazardous liquid wastes will be collected for treatment and disposal as stipulated by hazardous waste regulations.

6.1.1.3 Waste Generation

Construction of the GMODS facility will generate many different waste streams, including hazardous wastes, sanitary wastes, and construction/industrial wastes. The types of waste will be similar to those generated by other large construction projects. Non-regulated sanitary and construction wastes will be treated as necessary and disposed of using conventional waste management systems and landfills. Reusable construction materials will be stored for later on-site use, and recyclable materials will be separated from the waste stream and sent to appropriate recycling facilities. Hazardous wastes will be collected for treatment and disposal as stipulated by hazardous waste regulations. No radioactive waste (low-level, high-level, transuranic, or mixed) is expected from the construction phase of GMODS.

6.1.1.4 Radiological Impact

Assuming the site chosen for construction of GMODS is not radiologically contaminated from previous land uses, there will be no radiological impact to employees or the public from construction of the GMODS facility. If GMODS is constructed on a site with the potential for radiation above background levels, such as within a DOE reservation, the radiological impact will need to be evaluated.

6.1.2 Impacts During Operation

This section gives information that can be used to estimate the environmental impacts resulting from operation of the GMODS facility. These impacts will come from waste materials emitted to the atmosphere, discharged into surface water, or disposed of in solid form.

6.1.2.1 Emissions

Atmospheric emissions during operation of the GMODS facility will include gases and particulates that may be either radioactive or nonradioactive. Pre-treatment processes, such as the unpackaging and size reduction of SNF, may produce off-gases. Noble gases and other volatile fission products will be released when fuel assemblies are opened. Off-gases from the GMODS melter will include carbon dioxide and steam from the oxidation of organic materials and any volatile elements present in the feed material. Volatile fission products present in SNF will escape during the melting process. This includes ^{85}Kr , which is a relatively long-lived fission product that tends to stay trapped in the fuel matrix. Due to the variable nature of the feed material to the melter, emission rates will not be constant over any given year. However, emissions will be kept as low as reasonably achievable (ALARA), and within all applicable regulatory limits. Filters, scrubbers, and holdup systems will be used where appropriate to minimize radioactive and hazardous emissions to the atmosphere.

Based on comparisons to the DWPF, the primary radionuclides expected in routine emissions from GMODS include ^3H , ^{85}Kr , ^{90}Sr , ^{129}I , ^{137}Cs , ^{144}Ce , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , and ^{241}Am . Radioactive emissions will be controlled and monitored to ensure that they meet the standard in 40 CFR 61, Subpart H. This standard states that the effective dose equivalent to any member of the public due to the releases in any year should not exceed 10 mrem.

6.1.2.2 Effluents

Liquid effluents from the GMODS facility during normal operation are expected to have minimal radioactive or hazardous contamination. Treatment systems for process wastes will be designed as part of the facility to treat liquid wastes prior to discharge. Where possible, secondary wastes from these treatment processes will be fed back into the GMODS melter for inclusion in the glass waste form. All effluents will be monitored for compliance with applicable permit conditions, including those for National Pollutant Discharge Elimination System outfalls. Sanitary wastewater will be treated on-site using standard techniques prior to discharge at permitted outfalls.

6.1.2.3 Waste Generation

Solid wastes generated during operation of the GMODS facility will include radioactive wastes (low-level, high-level, transuranic), hazardous wastes, mixed wastes, construction debris, and sanitary wastes. The high-level radioactive and transuranic wastes will be produced in the form of borosilicate glass which will be destined for a geologic repository. Other wastes will need to be managed as appropriate.

Low-level radioactive wastes will be produced during feed material pre-treatment, maintenance activities, treatment of liquid and gaseous waste streams, and other activities. Waste generation will be minimized to the extent practical, and volume reduction will also be used to minimize the amount of waste that must be sent to disposal.

Hazardous and mixed wastes must be treated to meet applicable regulations before being sent for disposal. The treatment method will depend on the form and composition of the waste. Waste minimization practices will be encouraged to reduce the amount of hazardous and mixed waste generated at the GMODS facility. Where practical, these wastes will be returned to the melter for consolidation into the borosilicate glass waste.

Approximate volumes for non-glass wastes are as follows:

	Low-Level Waste	Hazardous Waste	Mixed Waste	Construction Debris	Sanitary Waste
Cubic meters per year	1,500	2	30	200	3,000

6.1.2.4 Radiological Impact

Emissions that cause a radiological impact from operation of the GMODS facility will be primarily airborne releases from the exhaust stack. These emissions will affect both on-site employees and off-site populations. In addition, GMODS and surrounding facility personnel will receive some direct radioactive exposure during operation. All exposures are expected to be a fraction of that allowed by regulations, and will be maintained ALARA.

6.1.2.4.1 Radiological Impact to Employees

Radiological workers at the GMODS facility are expected to receive an average dose of ~200 mrem/year, while non-radiological workers may receive 0.003 mrem/year. Most of this dose will come from fission product activity in the SNF used as feed material to the main GMODS melter.

6.1.2.4.2 Radiological Impact to the Public

The radiological impact of GMODS operation to the public surrounding the facility depends heavily on the site chosen for construction and the distance from the facility to the site boundary. Since the primary pathway for radioactive exposure is from atmospheric emissions, the maximum dose to a member of the public also depends on the meteorology of the site. A preliminary estimate of the maximum annual dose to a member of the public is 3×10^{-2} mrem.

6.1.3 Impacts During D&D

Impacts from D&D of the GMODS facility will be similar to those from construction, with the addition of potential radiological releases and the production of radioactive wastes. The GMODS facility has the unique capability to convert metals, ceramics, amorphous solids, and organics to glass. Therefore, D&D of the facility will also be unique, in that process equipment and hot cell waste can be fed into the melter and vitrified. In effect, the process has the capability to D&D itself down to the point where only the GMODS melter and the necessary post-melter treatment systems remain.

6.1.3.1 Emissions

Air emissions during D&D will include those directly related to demolition (dust, vehicle exhaust, etc.) and radioactive emissions associated with cleanup of the facility. Since the GMODS melter can be used to process much of the hot cell and process equipment waste, air emissions during D&D will also be similar to the operational phase. Radioactive emissions will be similar in isotopic composition to operational emissions, but will be lower in overall quantity.

6.1.3.2 Effluents

Liquid effluents during D&D will also be similar to those during the operational phase. On-site systems will be used for treatment of liquid wastes prior to discharge. All effluents will be monitored for compliance with applicable permit conditions, including those for National Pollutant Discharge Elimination System outfalls. Sanitary wastewater will be treated on-site using standard techniques prior to discharge at permitted outfalls.

6.1.3.3 Waste Generation

The types of waste generated during D&D will be similar to those produced during the operational phase, but will differ in volume. Waste generation will be minimized to the extent practical, and volume reduction will also be used to minimize the amount of waste that must be sent to disposal.

Approximate volumes for non-glass wastes are as follows:

	Low-Level Waste	Hazardous Waste	Mixed Waste	Sanitary Waste
Cubic meters	4,000	700	1,000	12,000

6.1.3.4 Radiological Impact

The radiological impact from D&D to radiological workers, non-radiological workers, and members of the public is expected to be similar to the operational phase. Demolition activities may generate more airborne particulate contamination than during normal operations, but techniques to minimize this contamination will be used. All exposures are expected to be a fraction of that allowed by regulations, and will be maintained ALARA.

6.2 RESOURCE NEEDS

The construction, operation, and D&D of the GMODS facility will involve the consumption of many types of resources, including utilities, chemicals, and other materials. The use of these resources will have an impact on the environment and so must be described in the environmental impact statement. This section will give estimates of the type and quantities of resources needed for the GMODS facility.

6.2.1 Impacts During Construction

The GMODS facility will require ~150 acres of land with buildings, paved roads, parking lots, and graveled areas. Roughly 5000 workers are expected to be required on-site during the peak of the five year construction process. Significant resources that will be needed include concrete, water, electricity, and fuels.

6.2.1.1 Utilities

Utility needs during construction will be similar to those of any large construction project. Water, electricity, and liquid fuels are the primary utilities required. Estimated quantities are as follows.

Water	Electricity	Fuels
1000 m ³ /day	75 MW·h	500,000 liters

6.2.1.2 Chemicals

Chemicals that will be consumed during construction include cleaners, degreasing compounds, welding gases, lubricants, solder, glue, paint, caulking compounds, and antifreeze. Materials will be selected to minimize the amount of hazardous waste generated, and will be reused or recycled as appropriate.

6.2.1.3 Materials and Resources Consumed

Several types of materials will be irretrievably consumed during the construction process. These include concrete, structural steel, wood, and wiring. By comparison with the DWPF, $\sim 2.5 \times 10^5$ m³ of concrete and 36,000 tons of structural steel will be required.

6.2.2 Impacts During Operation

The GMODS facility is expected to operate for 40 years. During this time, significant resource needs will include electricity, chemical feed materials, water, and fuels.

6.2.2.1 Utilities

A significant amount of electricity is required to operate the GMODS melters. In addition, water and fuels will also be needed. Approximate average quantities of these resources to be used each year are as follows.

Water	Electricity	Fuels
30 million liters	25 Gwh	150,000 liters

6.2.2.2 Chemicals

Chemicals that will be consumed during operation include process feed materials, cleaners, degreasing compounds, lubricants, paint, caulking compounds, coolant compounds for air conditioning, and antifreeze. Materials will be selected to minimize the amount of hazardous waste generated, and will be reused or recycled as appropriate. Approximate amounts of feed materials to be used each year are as follows.

PbO	B ₂ O ₃	Glass Frit	O ₂	C
130.5 MT	86.5 MT	650 MT	150 MT	50 MT

6.2.2.3 Materials and Resources Consumed

Some construction materials will be required during the operational phase for maintenance and repair. Other materials that will be consumed include personal protective clothing (gloves, coveralls, boots, respirator cartridges, etc.), paper, plastic sheeting, and used cleaning equipment.

6.2.3 Impacts During D&D

The D&D of the GMODS facility will require similar resources as during the construction and operational phases, but in different quantities. As described in Sect. 6.1.3, the GMODS melter will remain operational during D&D of the facility to treat many of the wastes. Therefore, electricity, water, and process chemical needs will be similar to the operational phase of the facility.

6.2.3.1 Utilities

Utility requirements during D&D should be similar to those during operations. Fuel needs may increase somewhat due to the use of more large pieces of machinery, such as trucks and cranes.

6.2.3.2 Chemicals

Process chemical needs will remain at operational levels as long as the GMODS melter is functioning. In addition, cleaning, cutting, decontaminating, and site restoration (lime, fertilizer, etc.) chemicals will also be needed.

6.2.3.3 Materials and Resources Consumed

Many of the materials needed during construction of the facility will be required during D&D, but in different quantities. Other materials that will be consumed include personal protective clothing (gloves, coveralls, boots, respirator cartridges, etc.), paper, plastic sheeting, and used cleaning equipment. Materials will be selected to minimize the amount of waste generated, and will be reused or recycled as appropriate.

6.3 EMPLOYMENT NEEDS

6.3.1 Employment Needs During Construction

Approximately 5,000 workers are expected to be on-site during the peak of the construction of the GMODS facility. These workers will include skilled construction labor, engineers, foremen, and administrative personnel. The socioeconomic impact of the construction project will need to be evaluated following selection of a site.

6.3.1.1 Employees at Risk of Radiological Exposure

Assuming the site chosen for construction of GMODS is not radiologically contaminated from previous land uses, there will be no radiological impact to employees or the public from construction of the GMODS facility. If GMODS is constructed on a site with the potential for radiation above background levels, such as within a DOE reservation, the radiological impact will need to be evaluated.

6.3.1.2 Labor Category Descriptions

The types of labor required for construction of the GMODS facility are similar to other large construction projects. By comparison with the DWPF, the approximate number of workers in each category are as follows.

Labor Category	Approximate Employment
Administrative	300
Foremen	300
Engineers	200
Boilermakers	50
Carpenters	800
Insulators	50
Electricians	500
Concrete Finishers	300
Ironworkers	300
Painters	200
Millwrights	100
Heavy Equipment Operators	200
Teamsters	100
Pipe fitters/Plumbers	1000
Laborers	500
Sheet Metal Workers	100
Total	5000

6.3.2 Employment Needs During Operation

Operation of the GMODS facility will require process operations, maintenance, QA/QC, health physics, security, waste management, engineering, medical support, and administrative personnel. Total employment is estimated at 800. It is assumed that the facility will operate with three shifts/d and seven days/week.

6.3.2.1 Employees at Risk of Radiological Exposure

All employees at the GMODS facility will have the potential for at least very low radiological exposure. Those personnel working in process operations, maintenance, QA/QC, health physics, and waste management will likely be classified as radiological workers. This designation implies that these employees have the potential to receive 100 mrem or more per year. All radiation exposures will be carefully monitored and will be maintained ALARA.

6.3.2.2 Labor Category Descriptions

The labor categories, approximate employment, and radiological worker status for the GMODS facility are as follows.

Labor Category	Approximate Employment	Radiological Worker
Control Room Operations	50	Yes
Operations Staff	200	Yes
Equipment Operators	100	Yes
QA/QC	50	Yes
Health Physics	50	Yes
Security	50	No
Maintenance	150	Yes
Waste Management	50	Yes
Engineers	50	No
Administrative	50	No
Total	800	

6.3.3 Employment Needs During D&D

As described in Sect. 6.1.3, the GMODS melter will remain operational during D&D of the facility to treat many of the wastes. Therefore, employment needs will be similar to the operational phase of the facility. In addition, workers skilled in demolition activities will be required. Total employment during D&D is expected to be near the construction phase level of 5,000.

6.3.3.1 Employees at Risk of Radiological Exposure

Since D&D activities will involve the potential for radiological exposure for all personnel working in the process area, most D&D personnel could be classified as radiological workers. The actual exposure potential for each category of worker will need to be evaluated at the time that planning for D&D begins. At a minimum, personnel working in operations, maintenance, QA/QC, health physics, demolition, and waste management will likely be classified as radiological workers.

6.3.3.2 Labor Category Descriptions

Categories of labor required for D&D are similar to those for construction and operation. The total number of personnel on-site is expected to be near 800. The number of personnel in each labor category will need to be determined during the D&D planning phase. The unusual decommissioning strategy may reduce this number.

6.4 INTRASITE TRANSPORTATION OF RADIOLOGICAL AND HAZARDOUS MATERIALS

The DOE policy regarding intrasite transportation of hazardous materials recommends that Department of Transportation (DOT) requirements be fully followed, but notes that individual cases may arise where these requirements may not be practical. In these cases, temporary transportation provisions will be used to ensure the safety of employees and the general public.

Intrasite transportation of hazardous materials at the GMODS facility is not expected to be routine. Once the SFM and SNF is received, either by rail or by truck, it will remain inside the vitrification building until it has been processed. The glass waste canisters will be transported a short distance to the GWSB using shielded casks. DOT certified shipping casks will be used to transport the glass waste canisters to their final disposal site. Non-radioactive hazardous materials will be transported to the site according to all applicable regulations.

7. PRELIMINARY ESTIMATED SCHEDULES

7.1 R&D DURATION

The initial R&D schedule is shown in the following. Note that the schedule includes development of (1) GMODS melter for plutonium scrap/residue and (2) the main GMODS melter for the central facility. This staged development allows earlier conversion of the plutonium and neptunium to an intermediate glass product.

Process and thermodynamic tests completed	FY-1996
Plutonium demonstration	FY-1997
One-tenth scale cold-wall melter operation (melter scale to match size needed for conversion of scrap and residue at Rocky Flats and Hanford to glass intermediate form)	FY-1988
Three-eighths scale cold integrated test (melter scale to match special wastes in DOE system)	FY-2003
Tests completed	FY-2004

7.2 PERMITTING AND LICENSING SCHEDULE

The current program basis (Sandia 1994) for the immobilization options is facility startup in calendar year (CY) 2017 with completion of immobilization by CY-2027. If the facility is licensed by the U.S. Nuclear Regulatory Commission for the CY-2027 startup date, the following schedule is required (Sandia 1994):

Initiate conceptual design	CY-2004
Complete conceptual design	CY-2007
Submit license application	CY-2010
Preliminary safety	CY-2010
Approval for construction	CY-2012
Start construction	CY-2012
Final safety analysis report	CY-2015
Approval to operate	CY-2017

7.3 OPERATING SCHEDULE

The facility would start operations in CY-2017 (Sandia 1994). The expected duration of the SFMs immobilization campaign is 10 years from the start of operations. This assumes 3-shifts/d, 7 d/week operation. It is assumed that there are 200 operating days per year with the remaining time allocated for maintenance. SFM operations would end in CY-2027.

The GMODS facility would be designed to operate with appropriate refurbishment for 40 years. While the SFM disposition mission and the conversion of most of the current inventory of miscellaneous SNF to glass would be completed within 10 years of start of operations, there will be a long-term need for the facility. It is expected that SNF will be generated continuously for the foreseeable future from research and navy reactors. There are also other activities that may generate highly radioactive wastes requiring processing for repository acceptance. The continuing need for the facility (but at a lower throughput rates) would allow disposal of added surplus fissile materials if required.

The facility is subdivided into various process areas (feed preparation, main GMODS melter, consolidation melter, etc.) with lag storage between areas. It is expected that operations between process areas will not be tightly coupled; therefore, operations and maintenance in one process area may be on separate schedules from operations and maintenance in other process areas.

7.4 DECOMMISSIONING SCHEDULE

The unique characteristics of this facility imply a unique decommissioning approach. The facility is designed to process solid wastes into acceptable waste forms for disposal. That capability would be used for initial decontamination and decommissioning until most of the radioactivity had been removed from the facility. To take advantage of this capability, primary decontamination and decommissioning would be done immediately after completion of the main mission to allow use of the facility and its operation crew. It is estimated that this will take fewer than 3 years at which time the facility will be essentially decontaminated.

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**Appendix A: INTEGRATION OF GMODS WITH EXISTING OR FUTURE
TANK HLW VITRIFICATION FACILITIES**

Appendix A: INTEGRATION OF GMODS WITH EXISTING OR FUTURE TANK HLW VITRIFICATION FACILITIES

DOE will ultimately operate two very large vitrification facilities for HLW liquids and slurries. The SRS vitrification plant—the DWPF—is in a startup phase. The Hanford site vitrification plant is currently being designed.

A GMODS facility could be attached to either of these facilities as a special front-end processor for SFMs and SNF. In this case, the GMODS facility would produce glass marbles. The vitrifier for converting liquid and slurry HLWs to glass would also simultaneously accept glass marbles (or crushed marbles) and become the GMODS consolidation melter. Figure A.1 shows the overall flowsheet. This option offers both advantages and disadvantages.

There are three potential incentives for integration of such facilities:

- Combining facilities eliminates the GMODS (1) consolidation melter; (2) the downstream HLW can inspection, welding, and decontamination equipment; and (3) some on-site transport and storage facilities. Such combining of facilities would not be expected to cause a proportional derating of vitrifier liquid and slurry HLW throughput. There are several reasons for this. Liquid and slurry feed HLW vitrifiers have their throughput partly limited by off-gases generated by decomposition of nitrates in the melter. Nitrates are major components of the liquid feed. Second, much of the vitrifier energy input is used to evaporate water and decompose nitrates; thus, added glass feed does not proportionally reduce vitrifier output. Only a fraction of the vitrifier capabilities are needed to remelt glass. The downstream equipment is not fully utilized most of the time. Adding glass marbles (possibly crushed) to the melter boosts the equipment utilization.
- There is significant overhead in terms of staff and specialized equipment to support process operations involving highly radioactive materials. A fraction of this overhead cost is only partly a function of facility size. Costs do not rise as fast as capabilities.
- Combining tank HLW glass and GMODS glass may allow higher loading of wastes in the final glass by better avoidance of concentration limits for selected waste components in the glass.

There are three potential disadvantages to combined operations:

- The schedules of operations are tightly coupled. Programmatic goals in terms of schedule may not be met.
- The GMODS glass composition is different than that for typical HLW glass (high uranium and plutonium content). It is not assured that the GMODS glass will be compatible with vitrifier materials of construction for vitrifiers designed for HLW liquids and slurries.
- By definition, there are only two sites for such a combined facility. The facility must be located where the HLW tanks are located.

Fig. A.1. Combined tank HLW vitrification and GMODS system for all wastes requiring treatment before geological disposal.

The above considerations indicate potential benefits for combined operations but major uncertainties exist about GMODS and the detailed characteristics of plutonium-uranium glasses.

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