UCRL-AR-124080 Vol 2 Rev 2

DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

The Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride

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May 1997

Lawrence Livermore National Laboratory

Volume II

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

Section 6.9

Batch Reduction to Uranium Metal Facility

Section 6.9
Batch Reduction to Uranium Metal Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into uranium metal product and byproducts magnesium fluoride (MgF_2) and hydrofluoric acid (HF). Due to its high density, uranium metal product is a principal option for uranium use (e.g., as shielding material). UF_6 defluorination is achieved by reduction to UF_4 with hydrogen. Anhydrous HF is recovered as a saleable material to industry. Uranium metal product is produced by reduction of UF_4 with magnesium metal. MgF_2 is leached to reduce its uranium content so it can be sent to an ordinary landfill for disposal.

Process Summary

Depleted uranium hexafluoride (UF_6) is processed to produce uranium metal billets and byproduct anhydrous hydrogen fluoride (AHF). The conversion is based on the industrial batch metallothermic reduction process.

The UF_6 is converted to the metal in two steps. The UF_6 is vaporized using steam heated autoclaves and fed to a tower reactor where it is mixed with hydrogen gas. Solid uranium tetrafluoride (UF_4) is produced and byproduct AHF. The AHF is stored and then loaded into railcars for shipment to customers. The UF_4 is reduced to uranium metal in a batch operation. A blended mixture of UF_4 and magnesium metal is heated in small, graphite lined steel vessels. After initiation of the exothermic reaction, uranium metal in the molten state forms and settles to the bottom of the reactor. Magnesium fluoride (MgF_2) forms as a slag above the uranium billet. After cooling, the solidified billet and slag are removed from the reactor and physically separated.

The slag contains appreciable quantities of uranium in various forms. The slag is crushed, roasted, and then leached with nitric acid to reduce the uranium content to less than 90 ppm. After drying, the MgF_2 is packaged for disposal in an ordinary landfill. The uranium bearing leach liquor is evaporated, calcined, and grouted for disposal as low level waste.

1.0 DUF_6 Conversion Facility - Missions, Assumptions, and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Batch Reduction to Uranium Metal Conversion Facility converts depleted UF_6 into uranium metal for use (shielding).

1.2 ASSUMPTIONS AND DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or rail car. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three months supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure with an average isotopic composition as follows: 0.001% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinders, the short-lived daughter products of U-238, Th-234 and Pa-234m, are in equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- The leaching process reduces the uranium content in the slag to less than 90 ppm (<35 pCi/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is 7,000 hours based on a plant availability factor of 0.8.
- For the Batch Reduction to Uranium Metal process, two reactor trains are needed for the conversion from UF_6 to UF_4. Multiple filling stations, reaction furnaces, and unloading stations are needed for UF_4 reduction to metal. The MgF_2 leaching system and support systems can be accomplished with a single train.

- The anhydrous HF produced in the process is shipped off-site in rail tank cars or tanker trucks. Indoor storage of one month's production is provided on site.
- Uranium metal product is packaged in wooden boxes, and MgF_2, CaF_2, and grout are packaged in 55-gallon drums. Indoor storage space for one month's production is provided on site.
- On-site storage of one month's supply of magnesium metal, ammonia, nitric acid, and cement is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

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

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities", as defined in DOE Order 6430.1A, and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- HF Storage Building
- Uranium Product Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility, including the following:

- Mg Metal Storage Building
- MgF_2 Storage Building
- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF_6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20-year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

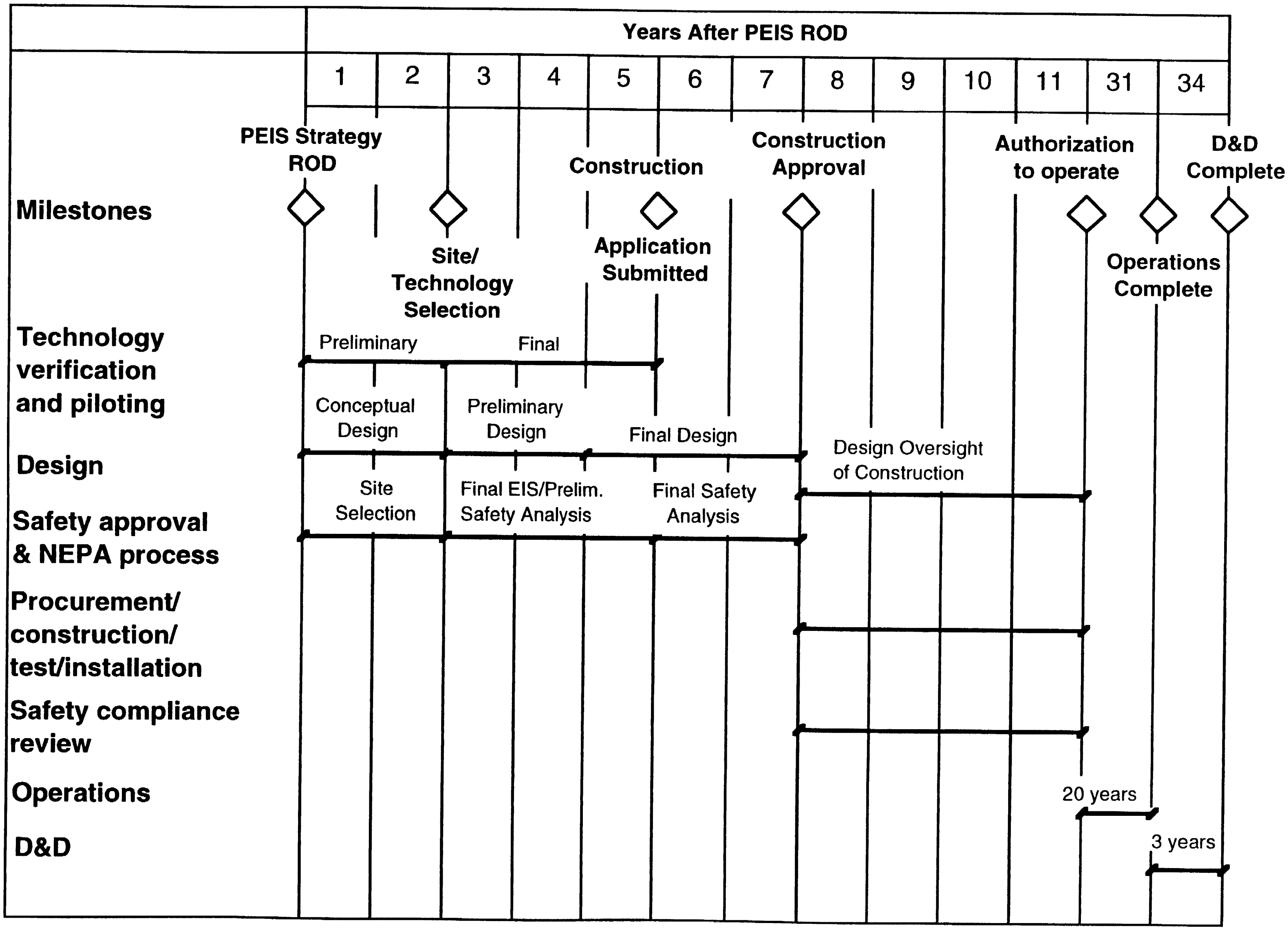

Figure 1-1 Preliminary Project Schedule

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

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

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, and guidelines, as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable Nuclear Regulatory Commission (NRC) regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*, DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, *National Environmental Policy Act*. Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection*. Also, NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, provides requirements applicable to the facilities handling and storing magnesium.

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements*; the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

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

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process include the following:

- The leaching of MgF_2 to enable it to be sent to an ordinary landfill for disposal has not been demonstrated at the throughput rate for this facility. Some equipment development work is required.
- It is assumed that decontamination of MgF_2 to a uranium concentration of 90 ppm or less (<35 pCi/g) will enable its disposal in an ordinary landfill site. It is assumed that an exemption for free release to a sanitary landfill could be obtained.
- Due to the pre-conceptual nature of the facility design, design details of process and support system equipment and components as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment, system, and facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF_6 Conversion Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium metal and magnesium fluoride (MgF_2) by reduction with hydrogen to UF_4 and subsequent reduction with magnesium to uranium metal. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the process building in a continuous reactor to produce UF_4, which is then reduced in small batches to uranium metal. The uranium product is packaged in crates. The uranium metal product is stored on-site until it is transported to another site for subsequent disposition (e.g., use). Anhydrous HF produced in the reaction is assumed to be shipped offsite for sale. MgF_2 byproduct is leached with nitric acid and assumed to be disposed of in ordinary landfill.

2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2-2, Plot Plan.

The plot plan shows the major structures on the site, as follows:

- Process Building
- HF Storage Building
- Mg Metal Storage Building
- Uranium Product Storage Building
- MgF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings, including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site.

Note: The size, number, and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.

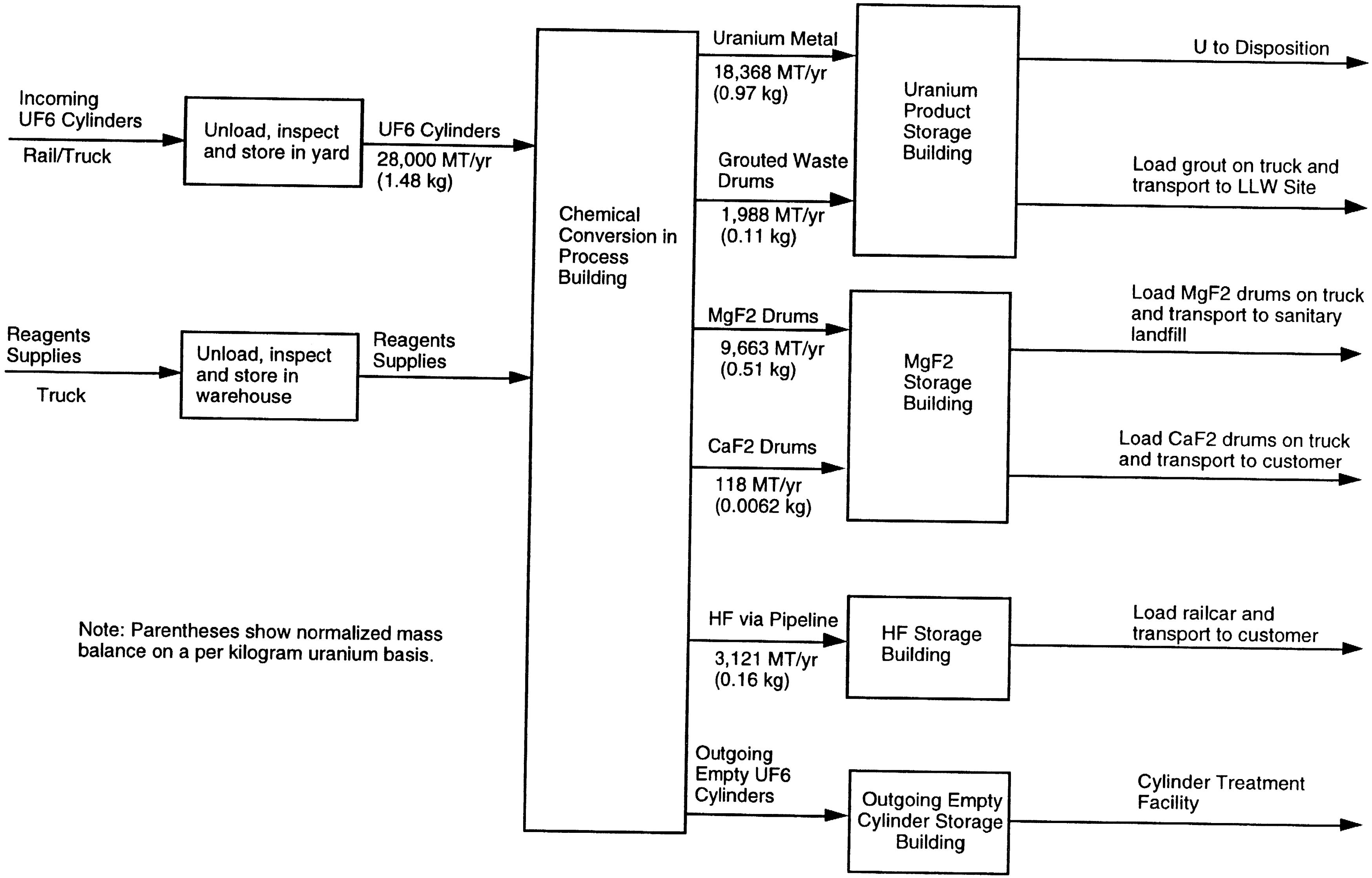

Figure 2-1 Batch Reduction to Uranium Metal Material Flow Diagram

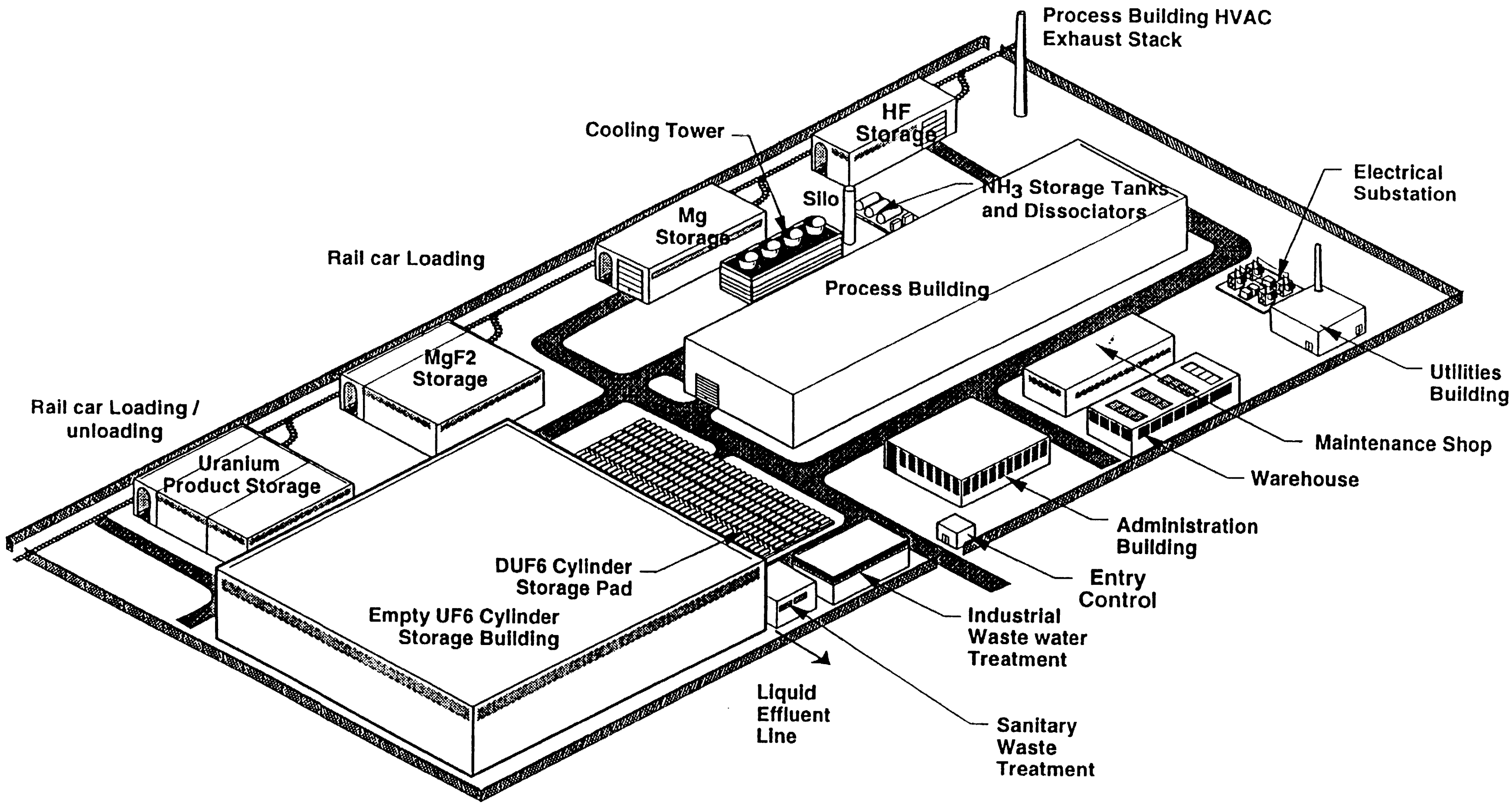

Figure 2-2 Plot Plan
Batch Reduction to Uranium Metal

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	69,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
HF Storage Building	5,400	1	No	Yes	NA / HH	Reinforced Concrete
Mg Metal Storage Building	7,500	1	No	No	General	Metal Frame
Uranium Product Storage Building	17,500	1	Yes	Yes	HC2 / MH	Metal Frame
MgF_2 Storage Building	15,500	1	No	No	General	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	10,000	1	No	Yes	General	Metal Frame
Administration Building	10,000	1	No	No	General	Metal Frame
Maintenance Shop	7,200	1	No	Yes	General	Metal Frame
Warehouse	8,400	1	No	Yes	General	Metal Frame
Industrial Waste Building	6,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	2,400	1	No	No	General	Metal Frame
Cooling Tower	7,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The layout, sections, and equipment arrangements for the Process Building are shown in Figures 2-3 through 2-5. The building is a two-story reinforced concrete structure classified radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where significant quantities of UF_6 and HF are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas, and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems, such as the heating, ventilating, and air conditioning (HVAC) systems and emergency electric power systems.

2.1.3.2 HF Storage Building

Due to the presence of a large inventory of HF, the HF Storage Building is classified as a nonradiological, chemically high hazard (HH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is a one-story reinforced concrete structure providing space for tanks that store one month's production of HF. The facility is provided with a rail car loading bay and space for the required storage tanks. An air refrigeration system is provided to maintain temperatures in the building in the range of 45 to 55°F to limit vaporization of HF in the event of a spill. Also, a water spray system and floors surrounded by dikes are provided to mitigate the effects of an HF spill.

2.1.3.3 Uranium Product Storage Building

The Uranium Product Storage Building is a one-story metal-frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility, as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse that provides space for one month's production of uranium metal product and associated grouted waste. A zone 2 HVAC system with filtered exhaust air is provided.

2.1.3.4 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three

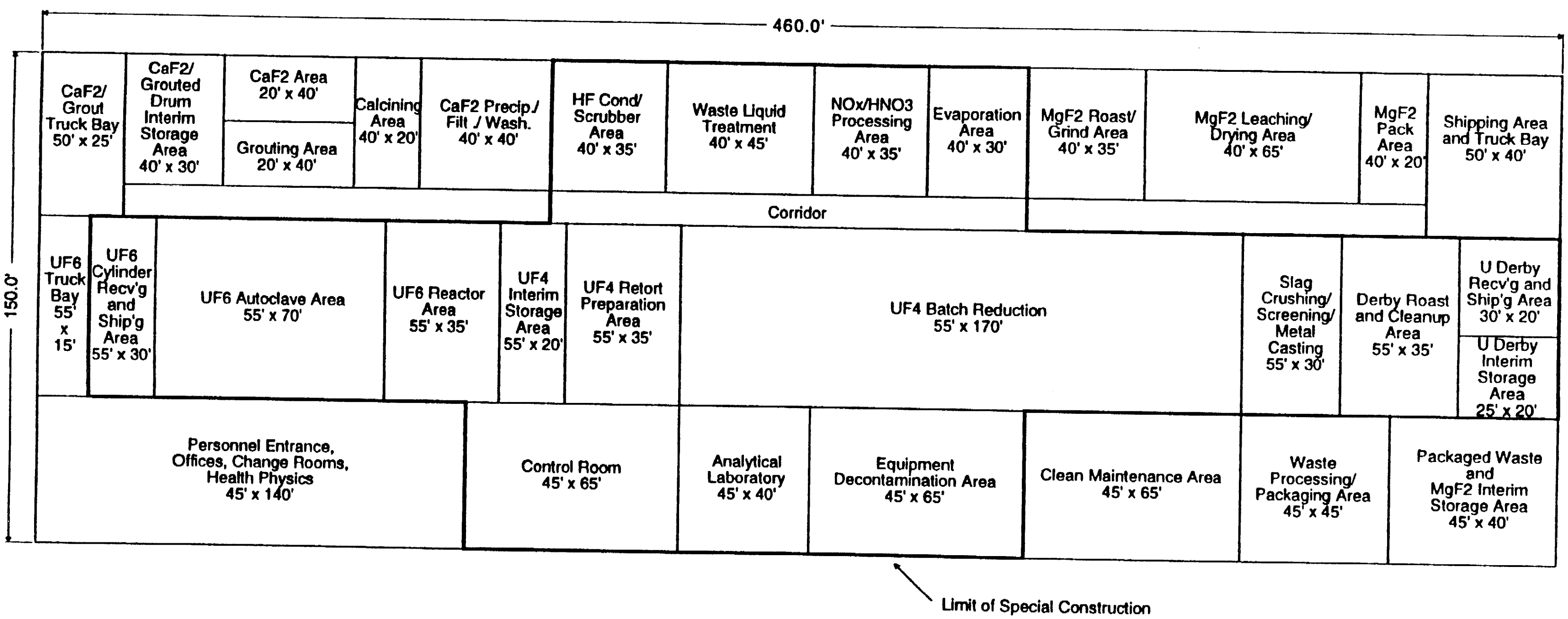

Figure 2-3 Process Building Layout
Batch Reduction to Uranium Metal

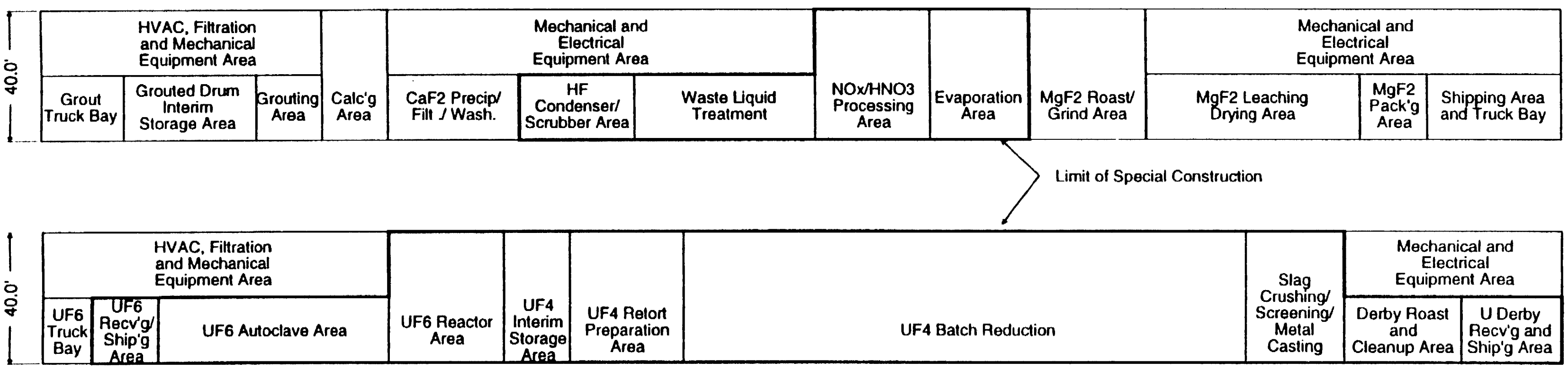

Figure 2-4 Process Building Sections Batch Reduction to Uranium Metal

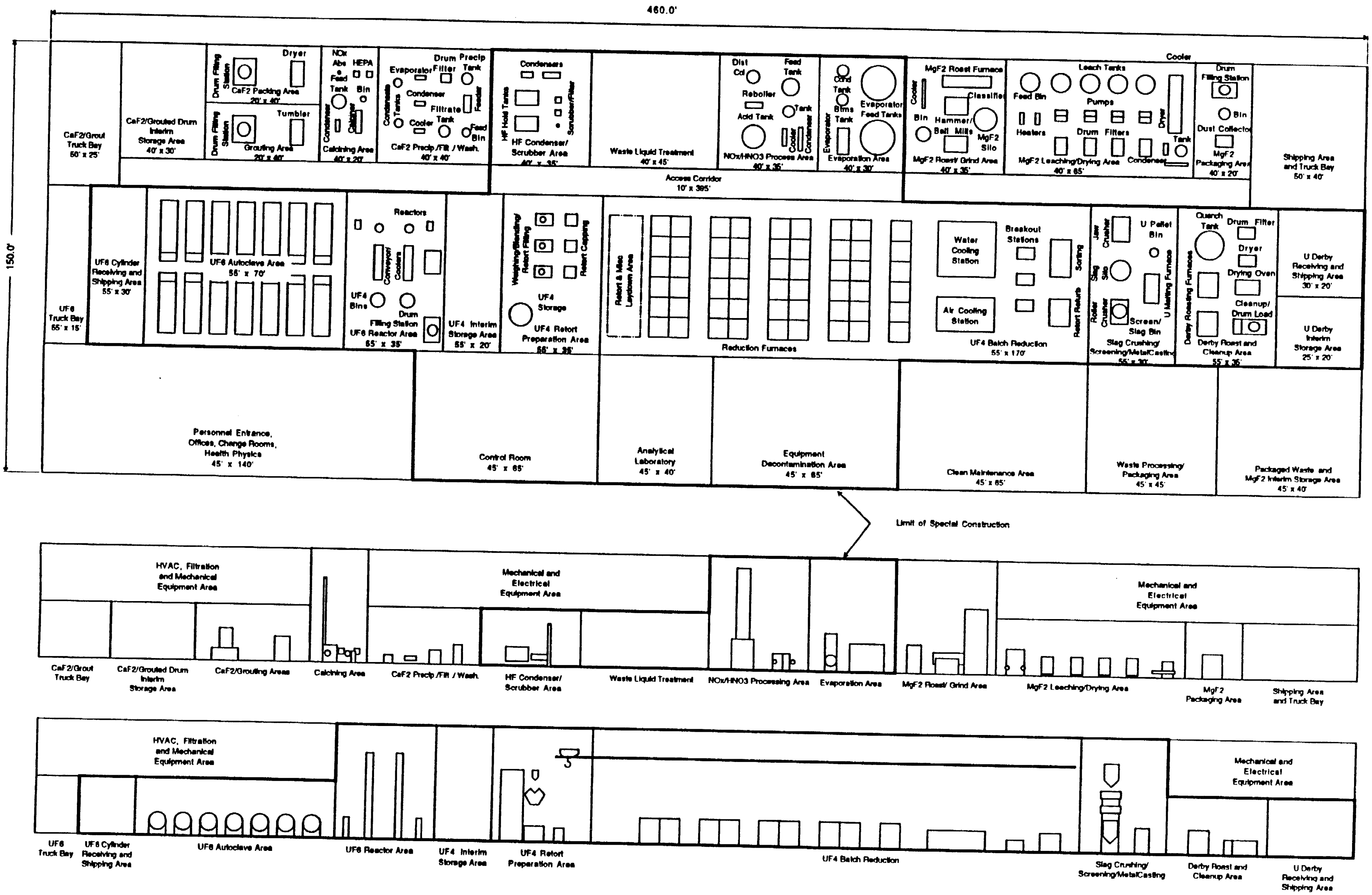

Figure 2-5 Process Equipment Arrangement

months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.5 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the DUF_6 Batch Reduction to Uranium Metal Conversion Facility includes the following facilities and systems (facilities are shown on Figure 3-1, Site Map):

A metal-frame Mg Metal Storage Building providing storage for one month's supply of magnesium. The facility includes the fire protection features required by NFPA 480.

A metal-frame MgF_2 Storage Building provides storage of one month's production of MgF_2 and CaF_2.

A metal-frame general-use Utilities Building houses raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling, and steam heating boiler systems.

A metal-frame or masonry Administration Building houses the facility support personnel.

A metal-frame general-use Maintenance Shops Building for housing clean maintenance and repair shops.

A 33 MM BTU/hr multiple cell, wood construction, induced-draft, crossflow-type cooling tower and a 3,300 gpm cooling tower water circulation system provides cooling for both the process and HVAC systems

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility accommodates the receipt, treatment, and disposal of noncontaminated chemical, liquid, and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown, and cold chemical area liquid effluents, will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility is provided with a capacity of approximately 6,300 gpd.

Compressed air systems, including plant air, instrument air, and breathing air include a single set of two redundant 300 cfm reciprocating air compressors for the plant and instrument air systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in desiccant-type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

An 850 ft^3 cement storage silo is provided in the yard.

A 5,000 cfh hydrogen/nitrogen supply system consisting of three 15,000 gal steel ammonia storage tanks and three ammonia dissociators to supply hydrogen and nitrogen to the UF_6 reduction reactors.

Building HVAC systems use a central chilled water system for building cooling. Three 50% capacity, 460 ton centrifugal water chillers, and three 750 gpm circulating pumps are provided. A steel stack serves the Process Building HVAC exhaust systems. The steam plant boiler vents through a dedicated steel stack (see Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant in the Support Utilities Building produces steam for process uses and for building heating by the HVAC systems. The plant produces 31,000 lb/hr of 50 psig steam, which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration, and chlorination. The demineralized water is used in the process and for steam boiler feedwater (see also Figure 5-1).

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The Electrical Substation has a design capacity of 3,300 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 500 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas that require special lighting for night-time operation include the UF_6 cylinder storage pad areas, the rail spur area, the utility area, and the site entry control area.

Site security fencing as shown on Figure 3-1, Site Map, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control, and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public, and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as the following:

- Barriers to contain uncontrolled hazardous material or energy release
- Preventive systems to protect those barriers

- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Condensation Areas
Uranium Product Storage Building	Zone 2 - Moderate Hazard Building	Single HEPA Filters	PC-3 for DBE & DBT	
HF Storage Building	Zone 1 - High Chemical Hazard	Conventional	PC-4 for High Hazard Areas	Automatic water spray and shutdown of HVAC system upon HF leak
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
NH_3 Storage Tanks	NA (Located Outdoors)	NA	Per ANSI Std. K61.1, Section 5.2	Vehicle Barriers, Diked Area, Emergency Equip., etc. per ANSI Std. K61.1
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1 Natural Phenomena

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

- Earthquake
- Tornado
- Flooding

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

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety-class structures, systems, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.2 Tornado

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Flood

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

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

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

- All buildings are subdivided by fire-rated barriers to limit the maximum possible fire loss and to protect life by providing fire-rated escape routes for operating personnel
- Fire detection and alarm systems are provided in all buildings
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.
- Automatic fire sprinkler systems are used throughout the facilities, except in areas where magnesium metal is stored and handled, per NFPA 480.
- The Mg Metal Storage Building includes suitable fire extinguishing agents, such as approved Class D agents per NFPA 480. Automatic sprinkler systems are prohibited in areas used to store magnesium metal per NFPA 480.

2.2.3 Materials Accountability and Plant Security

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3), and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Materials Handling

Uranium materials will be handled using automatic cranes and other material handling systems that allow operations to be controlled remotely or by operators that are located away from the uranium to reduce potential exposures to radiation and hazardous materials in the process.

2.2.5 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., UF_4 handling, slag crushing, container loading operations, and UF_6 sampling stations).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.6 Ventilation Systems

The HVAC systems will use a combination of dividing the buildings into zones according to level of hazard, space pressure control, and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate, or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will use local enclosures with once-through ventilation systems (e.g., gloveboxes and fume hoods) for confinement to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing autoclaves and other uranium processing areas. The ventilation system for these rooms use once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters, and pressure control to assure air flow from areas of low hazard to areas of high hazard. The Uranium Product Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including grouting areas, MgF_2 areas, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a higher pressure than the rest of the building. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The UF_6 reactor, HF condenser, and off-gas scrubbing areas of the Process Building have high chemical hazard potential, and will be served by a separate once-through air conditioning system. HF monitors in these rooms will automatically shut down the ventilation system and isolate the room in the event of a leak of HF.

2.2.7 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on Figure 3-1, Site Map. This figure also identifies the effluent air release points (ventilation and boiler stacks).

Table 2-3 summarizes the characteristics of the effluent air release points.

Table 2-3, Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	119	80	60
Boiler	100	33	500	60

3.0 Site Map and Land Use Requirements

3.1 SITE MAP

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to the facility and Uranium Product, HF, and MgF_2 from the facility. Air emission points are shown from the Process Building ventilation exhaust stack and the facility boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 LAND AREA REQUIREMENTS DURING OPERATION

As shown in Figure 3-1, the total land area required during operations is approximately 700,600 ft^2 or about 16.1 acres.

3.3 LAND AREA REQUIREMENTS DURING CONSTRUCTION

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 23.3 acres. Construction areas required in addition to the site structures and facilities are as follows:

- A construction laydown area for temporary storage of construction materials, such as structural steel, pipe, lumber for concrete forms, and electrical conduit
- Temporary construction offices for housing onsite engineering support, construction supervision, and management personnel
- Temporary parking for construction craft workers and support personnel
- Temporary holding basins for control of surface water runoff during construction
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

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

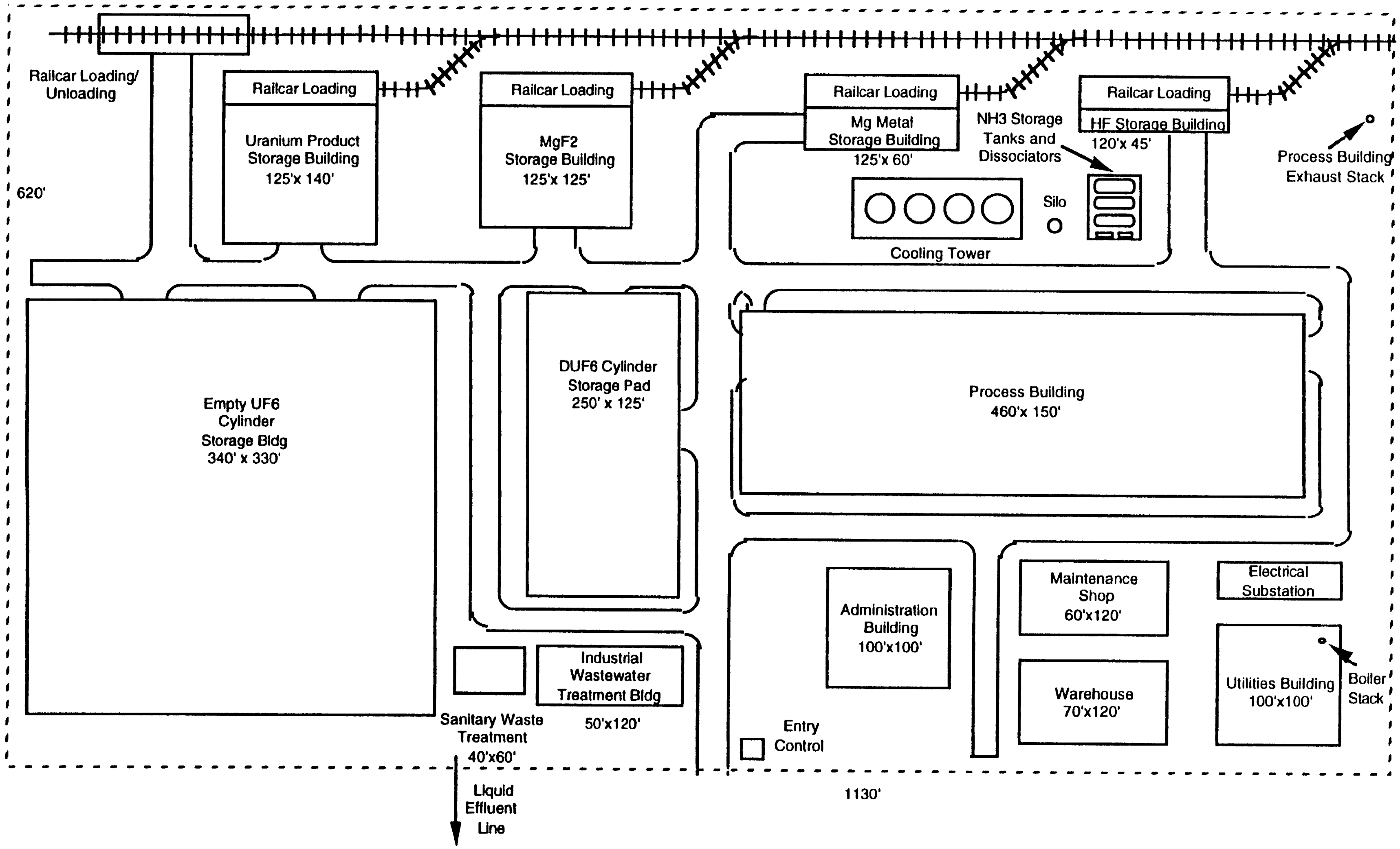

FIGURE 3-1 SITE MAP
BATCH REDUCTION TO URANIUM METAL

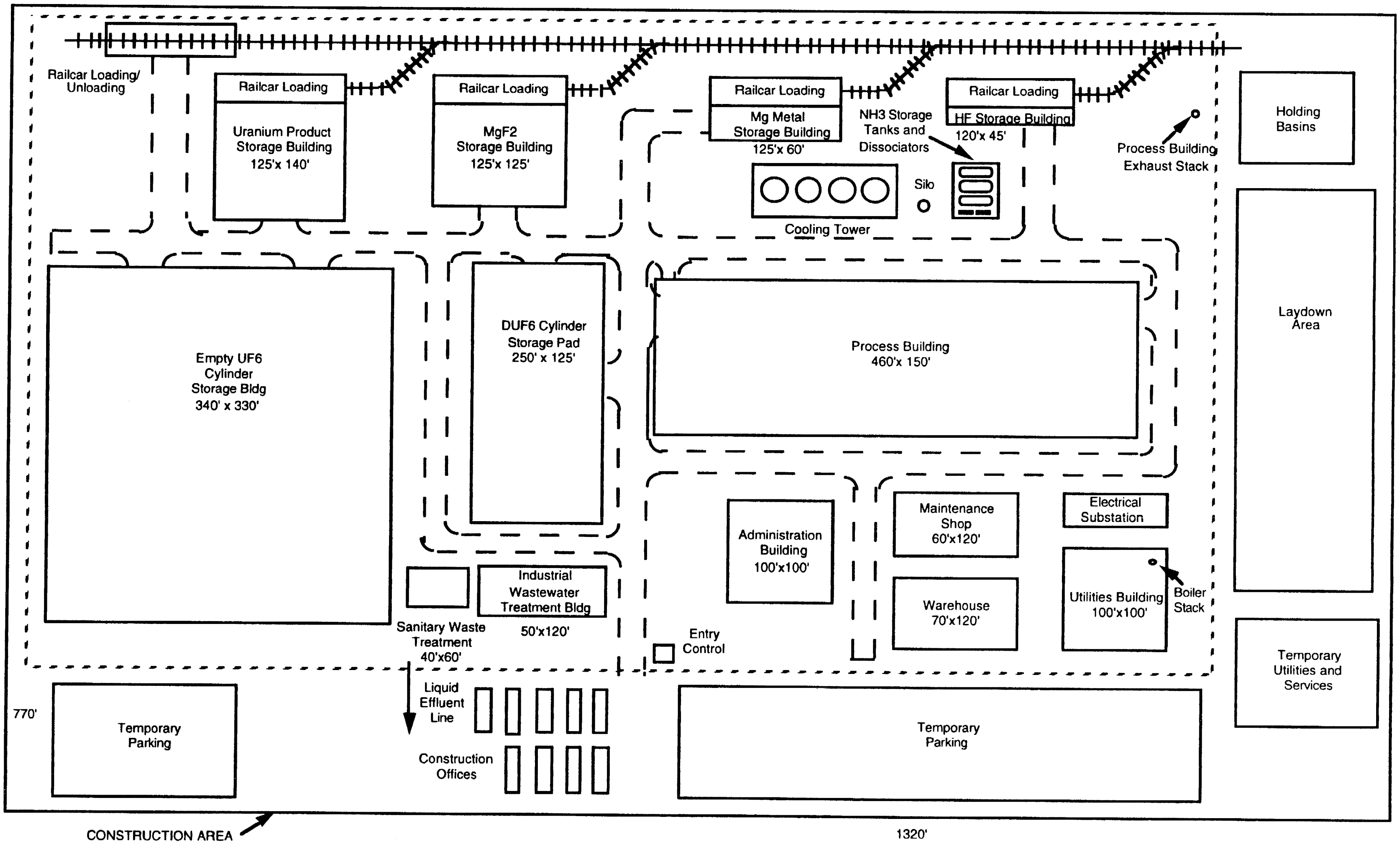

FIGURE 3-2 SITE MAP DURING CONSTRUCTION BATCH REDUCTION TO URANIUM METAL

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is reduced with hydrogen and magnesium to produce uranium metal, anhydrous HF, and magnesium fluoride (MgF_2). The MgF_2 is leached with nitric acid to reduce its uranium content to enable the MgF_2 to be disposed of in a landfill. The process is shown in Figures 4-1 to 4-3. The material balance is in Appendix A.

The UF_6 is first converted to UF_4 in a continuous process. The UF_6 is vaporized using steam-heated autoclaves and fed to the reactor, where it is mixed with hydrogen and nitrogen. Solid UF_4 and gaseous HF are produced. The UF_4 is discharged from the reactor, cooled, and collected. Vapor containing HF, unreacted hydrogen, and nitrogen is cooled in a condenser to recover HF. Uncondensed off-gas is sent to the HF scrubber system. The anhydrous HF recovered is stored and then loaded into railcars for shipment to customers.

The remaining traces of HF in the off-gas are removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution. The CaF_2 precipitate is dried and packaged in drums for sale.

The UF_4 is reduced to uranium metal in a batch operation. The UF_4 is blended with magnesium metal particles and loaded into small steel retort vessels. Heating the retort initiates an exothermic reaction, in which molten uranium metal forms and settles to the bottom of the retort to form a derby (ingot). MgF_2 forms as a slag above the derby. After cooling, the derby and slag are removed from the retort and separated for further processing.

The surface of the derby is cleaned by heating in a furnace to form an oxide layer, which is then removed by quenching in water. The 1,400 lb uranium derby is dried, boxed, and sent to storage and shipping.

The MgF_2 slag is crushed and screened to recover small pieces of uranium metal. The metal is loaded in an induction furnace and cast into a derby. The MgF_2 is then roasted in air to oxidize residual uranium to oxide, followed by milling to produce fine particles suitable for leaching. The MgF_2 particles are leached with hot nitric acid and washed with water to reduce the uranium content to less than 90 ppm. The MgF_2 is separated by filtration, dried, and packaged in drums for storage and disposal.

The uranium-bearing leach solution is evaporated and calcined, and the calcined solids are grouted with cement in drums for disposal as low-level waste. Vapors from evaporation and calcining are sent to a distillation column to recover nitric acid and water, which are reused in the leaching process. Non-condensible off-gases are treated in a water absorber to remove NO_x, filtered, and discharged to atmosphere.

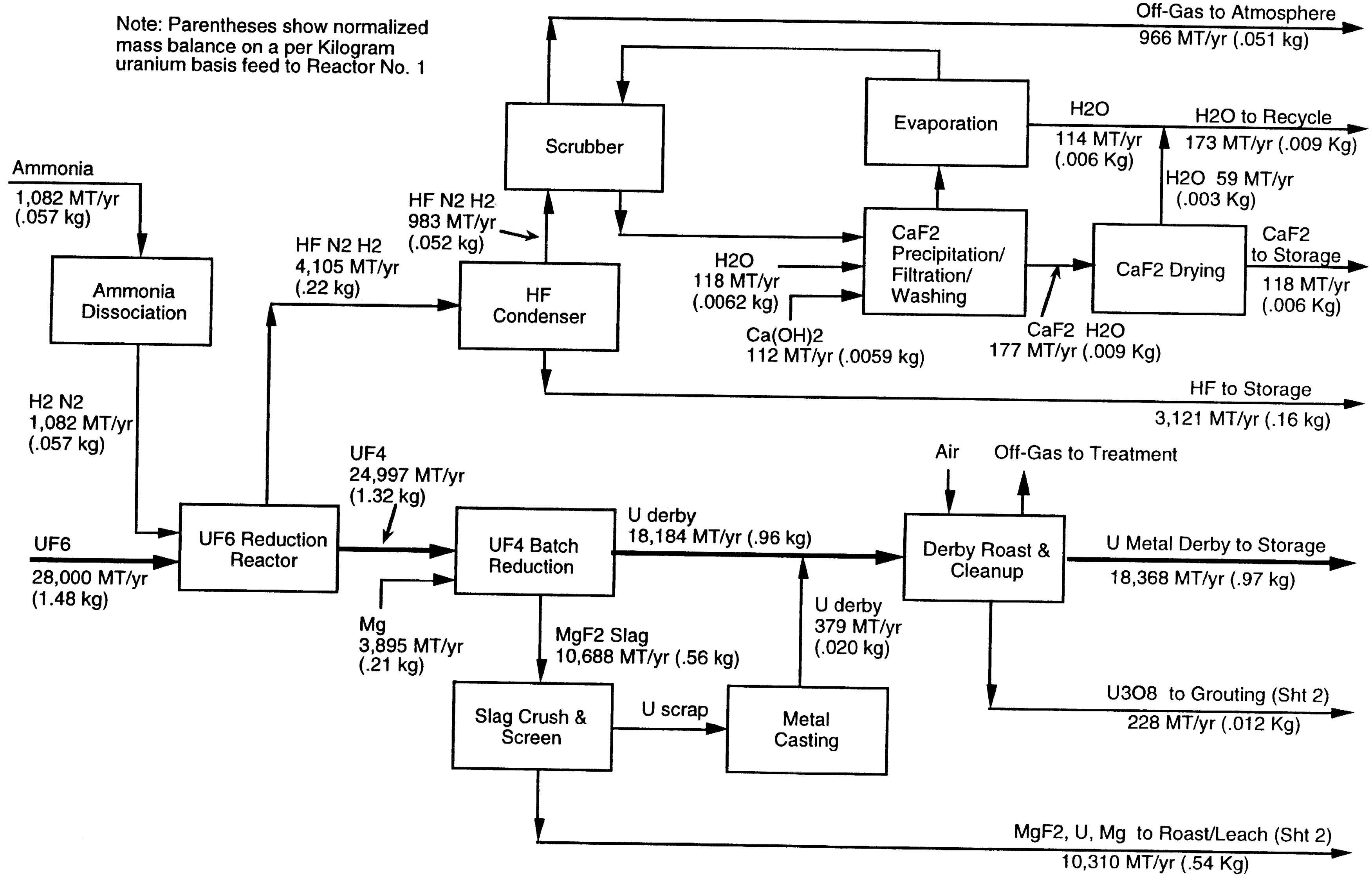

Figure 4-1 Batch Reduction to Uranium Metal Block Flow Diagram - Sheet 1

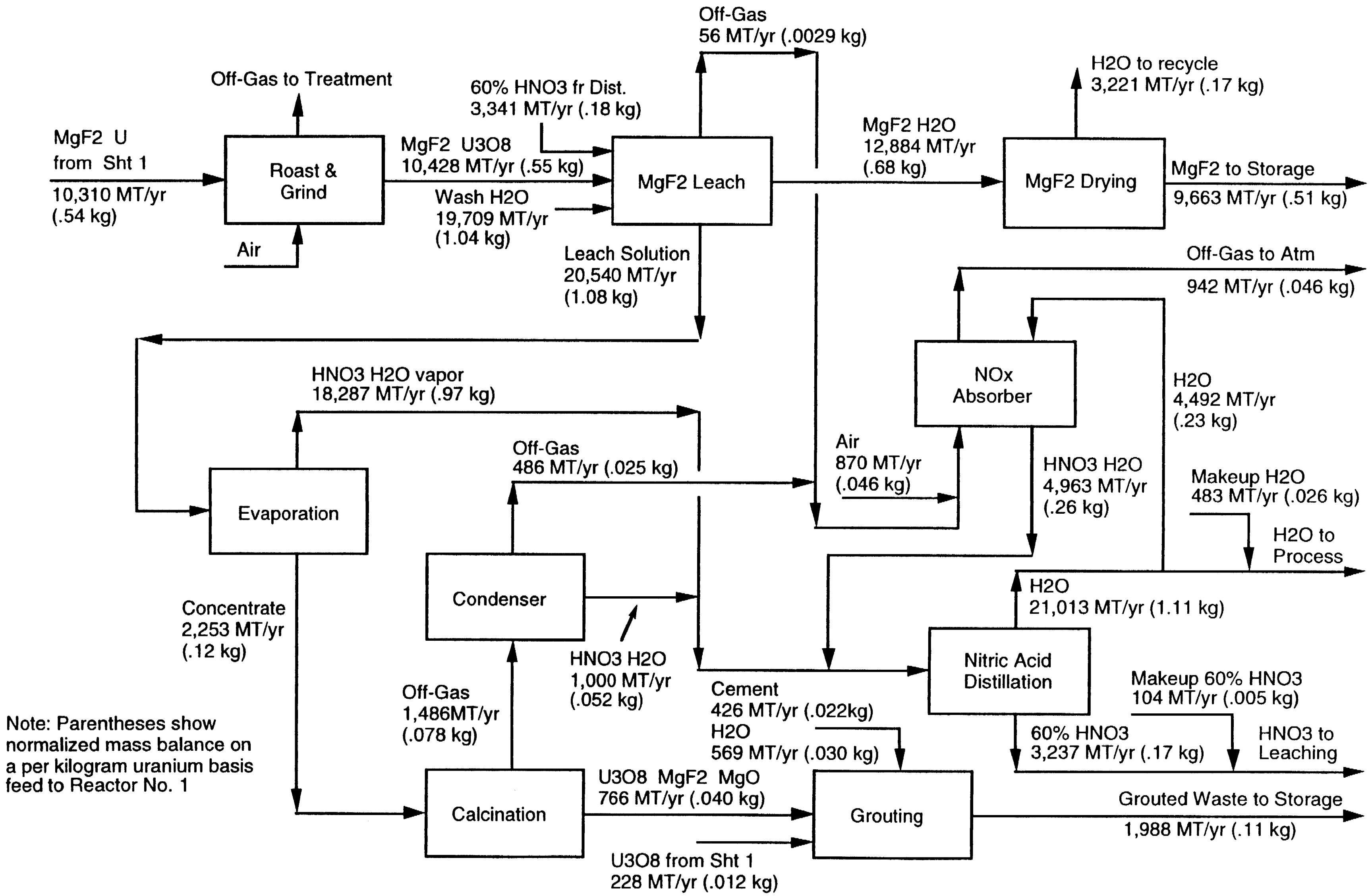

Figure 4-2 Batch Reduction to Uranium Metal Block Flow Diagram - Sheet 2

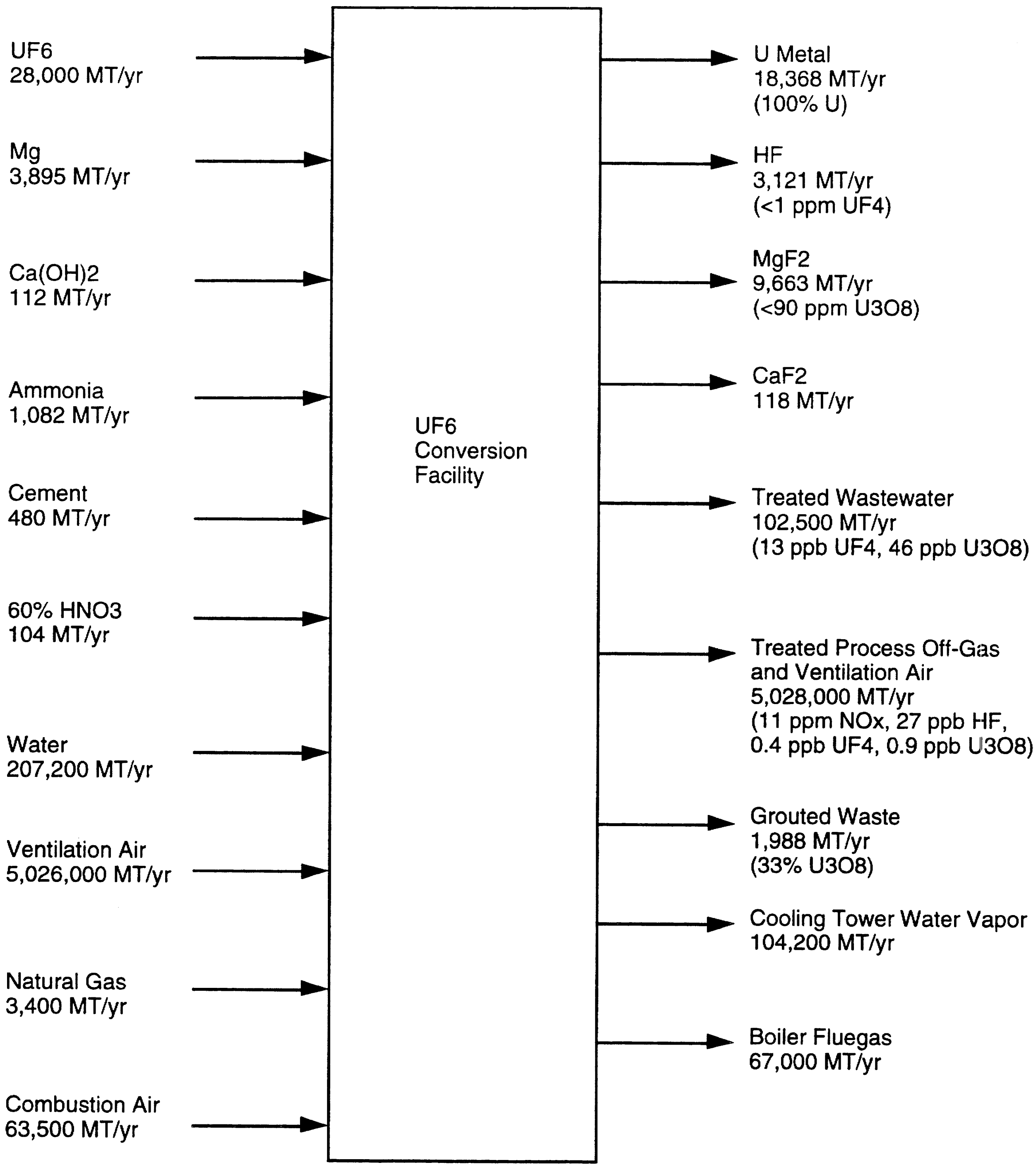

Figure 4-3 Batch Reduction to Uranium Metal Input/Output Diagram

The facility has two reactor trains for the conversion from UF_6 to UF_4. Multiple filling stations, reaction furnaces, and unloading stations are provided for UF_4 reduction to metal. The MgF_2 leaching system and support systems are single train. Critical equipment, such as a blowers or filters, have spares installed in parallel. The conversion of UF_6 to uranium metal is similar to a process currently used in the uranium fabrication industry. The leaching of MgF_2 is similar to a process being planned for implementation in industry.

4.1 UF_6 REDUCTION AND HF RECOVERY

The UF_6 Reduction Reactor converts UF_6 feed into UF_4 and HF in a tower reactor. The chemical reaction is $UF_6 + H_2 \text{--->} UF_4 + 2HF$. This system is shown in Figure 4-4.

Depleted UF_6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in steam-heated autoclaves and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is heated and vaporized (sublimed) at 140°F. Gaseous UF_6 flows out of the cylinder and is fed by a compressor into a reactor tower. Eleven UF_6 cylinders feed simultaneously to provide the required feed rate of 8,800 lb/hr. Hydrogen reacts with the UF_6 to form solid UF_4 and gaseous HF. The reaction is exothermic, with the temperature in the tower ranging from 800 to 1150°F. The tower has electric heaters to maintain a hot wall and has vibrators that are used intermittently to dislodge buildup of UF_4 on the walls.

Solid UF_4 is discharged from the reactor, cooled, and conveyed to a storage bin. There is also a drum loading station to provide interim storage of UF_4 in drums as necessary. After cooling, empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

The off-gas stream containing HF, unreacted hydrogen, and nitrogen flows through a cyclone and sintered metal filter to remove UF_4 particles. The off-gas is cooled to 100°F in a heat exchanger and flows through a refrigerated condenser operating at about -90°F to recover HF. Uncondensed off-gas flows to the HF scrubber system. The anhydrous HF condensate, which contains about 200 ppm water, is collected and sampled in a hold tank that is cooled with chilled water. Upon satisfactory analysis, the anhydrous HF is transferred via pipeline to a storage tank cooled with chilled water in the HF storage building. The HF is loaded into railroad tank cars or tank trucks for delivery to customers.

Hydrogen for the reactor is provided from a packaged ammonia dissociator unit. The chemical reaction is $2NH_3 \text{--->} N_2 + 3H_2$. Liquid ammonia is vaporized and fed to the dissociator, which decomposes the

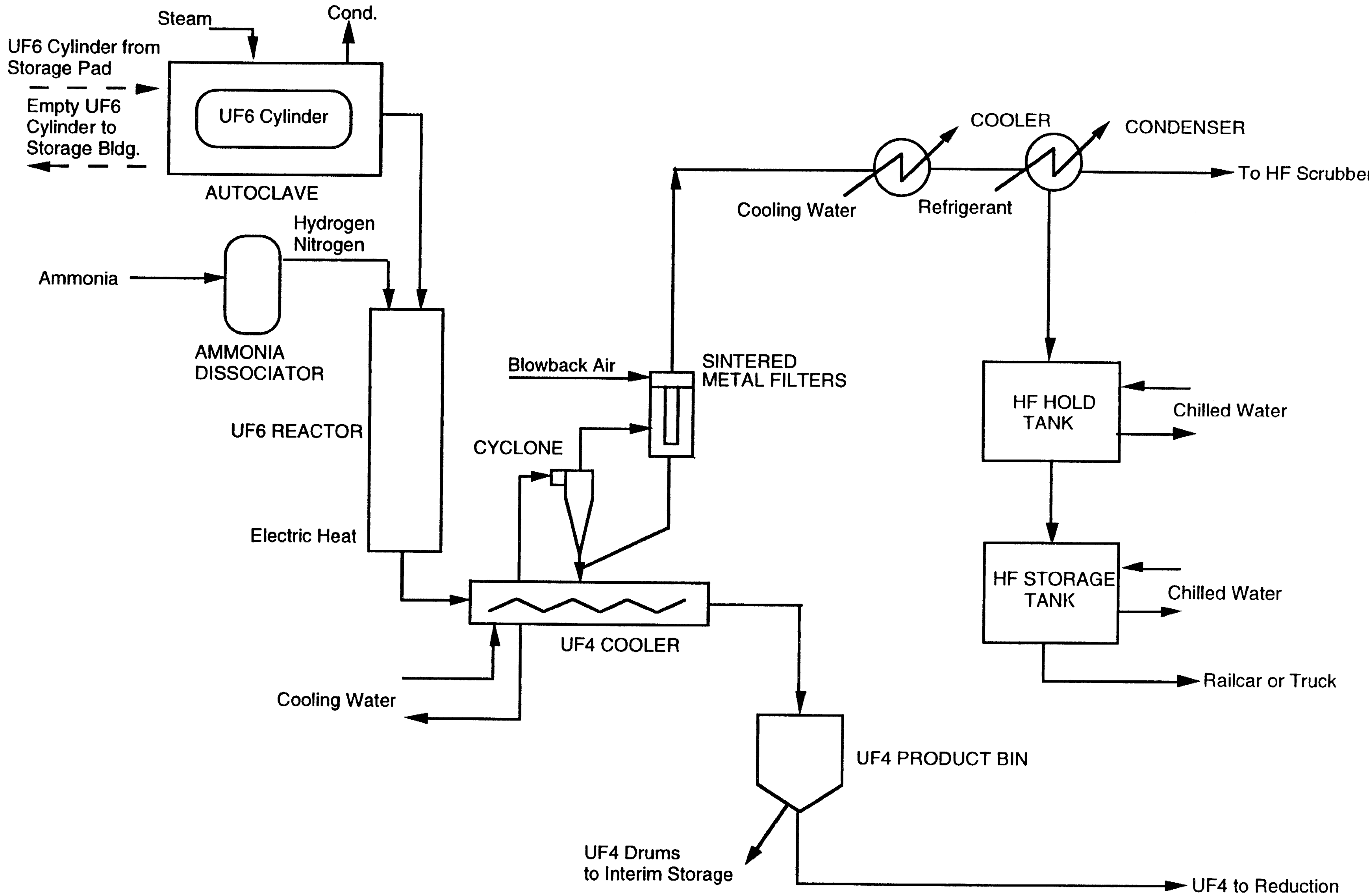

Figure 4-4 UF6 Reduction and HF Recovery Process Flow Diagram

ammonia at 1600°F in a catalyst bed. The hydrogen/nitrogen mixture is fed to the reactor.

Preliminary major equipment includes 14 autoclaves and UF_6 compressors, two 21 in. top dia by 35 in. bottom dia by 27 ft high Monel tower reactors, an 8 ft dia by 23 ft high 1,000 ft^3 UF_4 storage silo, a 1 ft 6 in. dia by 6 ft long 200 ft^2 Monel off-gas cooler, a 2 ft dia by 6 ft long 250 ft^2 Monel off-gas condenser, two 5 ft dia by 8 ft long 1,100 gal steel HF hold tanks, four 8 ft dia by 48 ft long 18,000 gal steel HF storage tanks, three 8 ft dia by 40 ft long 15,000 gal steel ammonia storage tanks, and three 83 kW ammonia dissociators.

4.2 UF_4 REDUCTION TO METAL

UF_4 is reduced to uranium metal in small batches using magnesium metal. The chemical reaction is $UF_4 + 2Mg \dashrightarrow U + 2MgF_2$. The system is shown in Figure 4-5.

The UF_4 is reduced to uranium metal in a batch operation. About 1,900 lb of UF_4 is charged into a double-cone mixer. A preweighed can containing about 297 lb of magnesium metal particles is also charged into the mixer. After blending, the mixed solids are charged into an empty, graphite-lined, 27 in. dia by 52 in. tall, steel retort vessel. The filling station vibrates the retort to increase the solids packing density. The filled retort is moved to the capping station, where a graphite lid is inserted and a steel lid is bolted on. To prevent pressurization of the retorts, no gasket is used, which allows gases to leak through the flange.

The retort is lowered into an electric furnace and heated to and held at 1,000-1,200°F for several hours to induce the reduction reaction. A rapid, spontaneous, exothermic reaction heats the retort contents up to 3,000°F. Molten uranium metal forms and settles to the bottom of the retort to form a derby (ingot). MgF_2 forms as a solid slag above the derby. Total cycle time in the furnace is about 13 hours. The furnace is vented to an off-gas system that filters the off-gas from the retort. The retort is removed from the furnace and placed in an air cooling chamber. When the skin temperature has decreased to 1,000°F, the retort is placed in a water bath for cooling to ambient temperature.

The retort is moved to a breakout station, where the lid is removed, and the retort is inverted and jolted. The derby and slag are separated from the retort. The derby is sent to derby cleanup and the slag is sent to slag processing. The retort is sent to a refurbishment station, where it is cleaned of residual material and inspected. Retorts in satisfactory condition are reused. It is assumed that the graphite liners will last 20 runs (batches), and the steel retorts will last 100 runs. The failed liners and retorts are low-level waste.

There are multiple pieces of each equipment to provide the required throughput. Conveyors and remote handling equipment move the process materials through each step. Preliminary major equipment includes three 30 ft^3 solids blenders, three retort filling stations and capping stations, fifty-

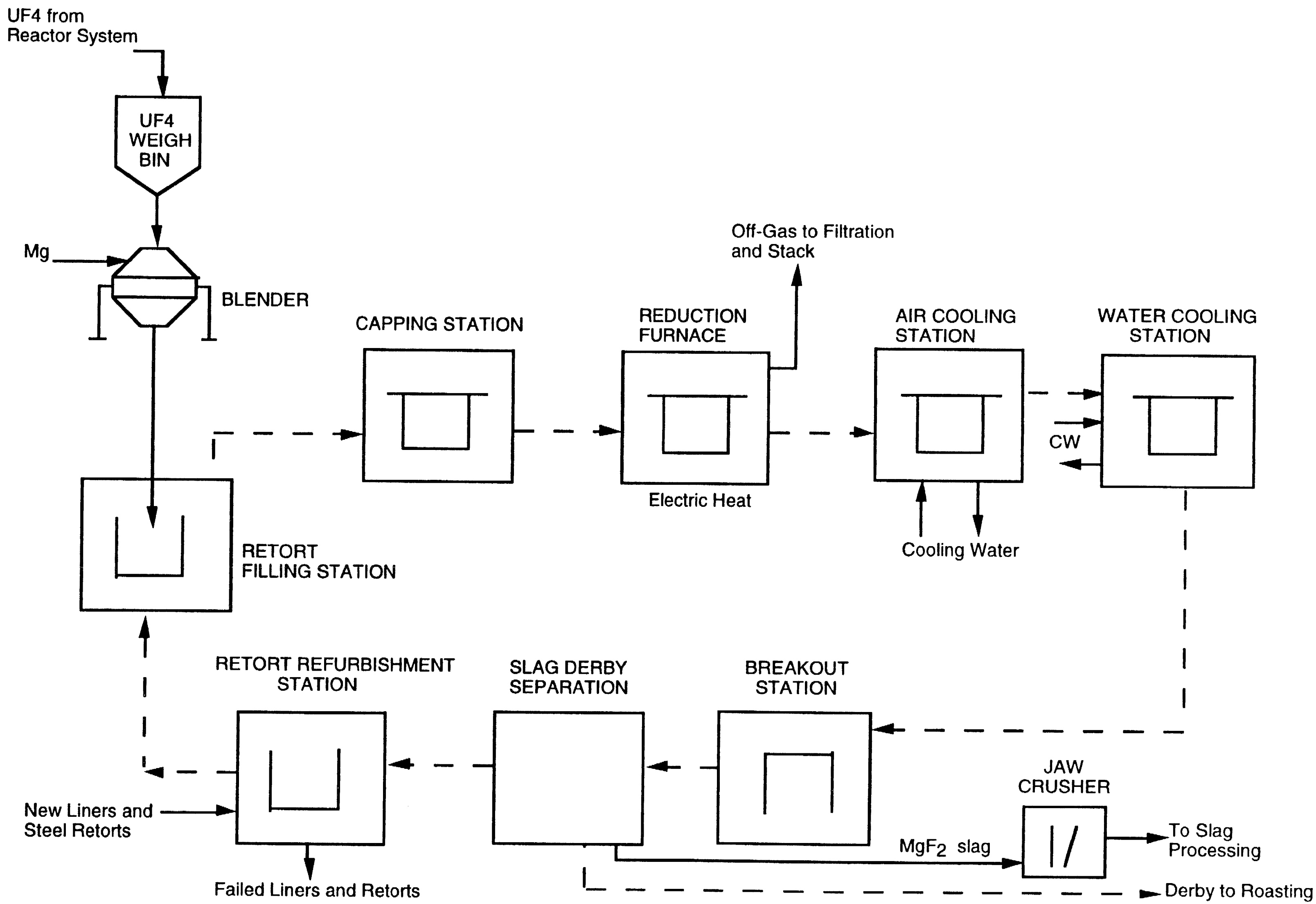

Figure 4-5 UF4 Reduction to Metal Process FlowDiagram

four 7 ft x 7 ft x 9 ft high 25 kW reduction furnaces, a water cooling station, an air cooling station, three breakout stations, a slag/derby sorting station, a retort refurbishment station, and material movement equipment including cranes, conveyors, and robot arms.

4.3 SLAG PROCESSING AND URANIUM CASTING

The MgF_2 slag is crushed and screened to recover small pieces of uranium metal, which are cast into a derby. The MgF_2 is then roasted and size reduced. The chemical reactions for roasting are $3U + 4O_2 \text{--->} U_3O_8$ and $2Mg + O_2 \text{--->} 2MgO$. The system is shown in Figure 4-6.

The MgF_2 slag from breakout is fed to a crusher, which produces 1/4 in. pieces of MgF_2 and deforms the uranium metal into larger sizes. The crushed slag is fed to a vibrating screen, where the MgF_2 passes through but the metal pieces are removed. After sufficient metal has been collected, the uranium metal is loaded into an induction furnace and cast into a derby. The derby is sent to the derby cleanup system.

To improve leachability, the MgF_2 is roasted at 1,000°F in a rotary kiln furnace to oxidize residual uranium and unreacted excess magnesium. After cooling, the roasted oxide is size reduced in a hammer mill and ball mill to produce fine MgF_2 particles smaller than 40 microns. The MgF_2 particles are sent to the leaching system.

Preliminary major equipment includes crushers, a 7 ft dia by 20 ft high 650 ft^3 steel slag bin, a 4 ft dia vibrating screen separator, a 50 kW induction casting furnace, a 4 ft dia by 17 ft long 100 kW Inconel rotary kiln, a 6 ft dia by 4 ft long 75 hp ball mill, and an 8 ft dia by 23 ft high 1,200 ft^3 steel MgF_2 storage bin.

4.4 DERBY CLEANUP

The derbies from breakout and casting are cleaned to remove adhering slag and other surface impurities. The system is shown in Figure 4-7.

The derby is placed in a furnace and heated to 1,200°F, which causes the derby surface to oxidize. The hot derby is placed in a water quench tank, which causes the oxide layer to spall off. The derby, which weighs about 1,400 lb and is about 20 in. dia by 6.7 in. high, is dried in an oven, wired brushed for final cleanup, and packaged for storage and shipment. The quench water is sent to a rotary drum filter to remove the uranium oxide (U_3O_8), cooled, and returned to the quench tank. The oxide is dried in a rotary dryer and sent to grouting.

Preliminary major equipment includes two 30 kW derby roasting furnaces, a 10 ft dia by 5 ft high 3,000 gal steel derby quench tank, a drying oven, cleanup station and loading station, a rotary drum filter and dryer, and material movement equipment.

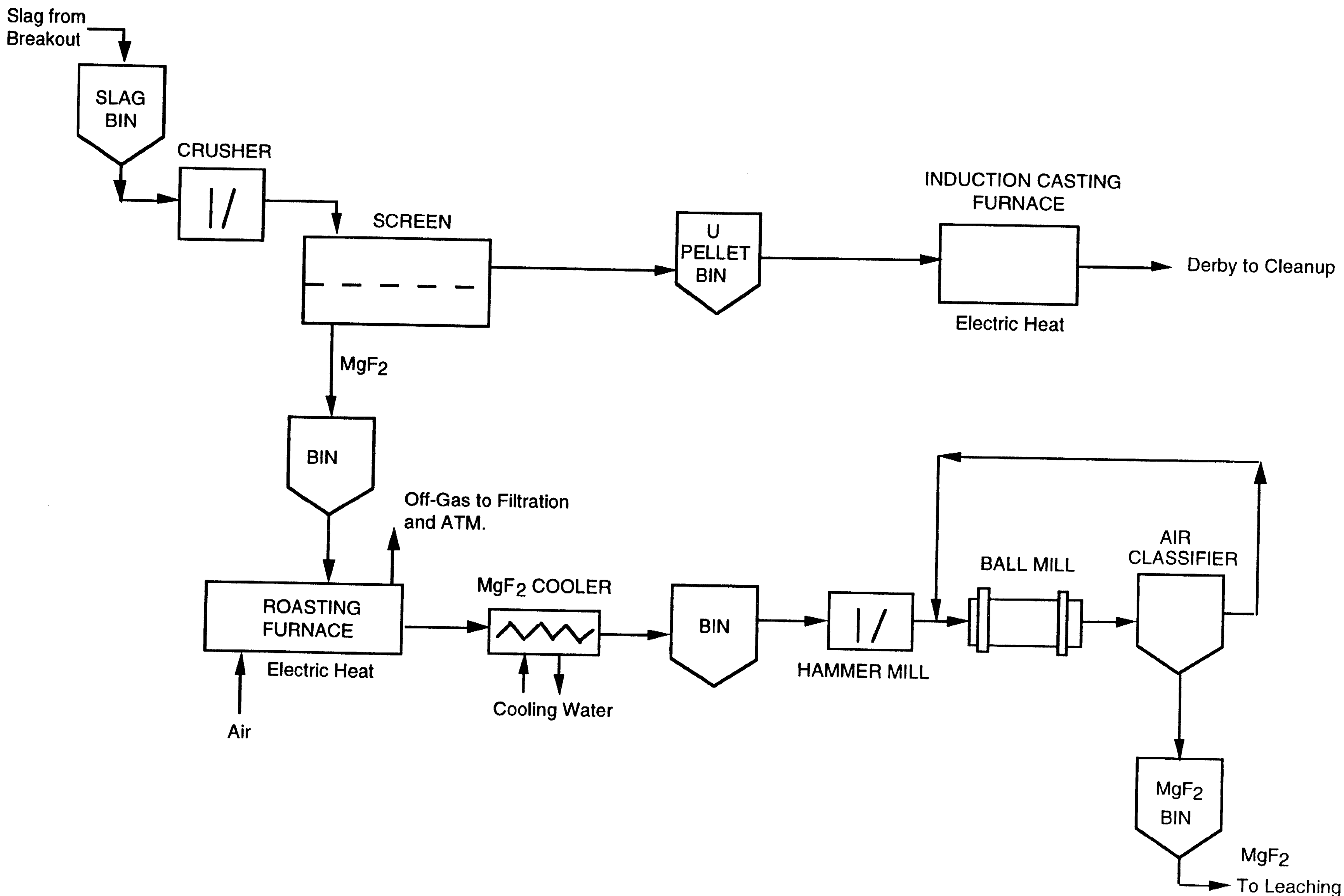

Figure 4-6 Slag Processing and Uranium Casting Process Flow Diagram

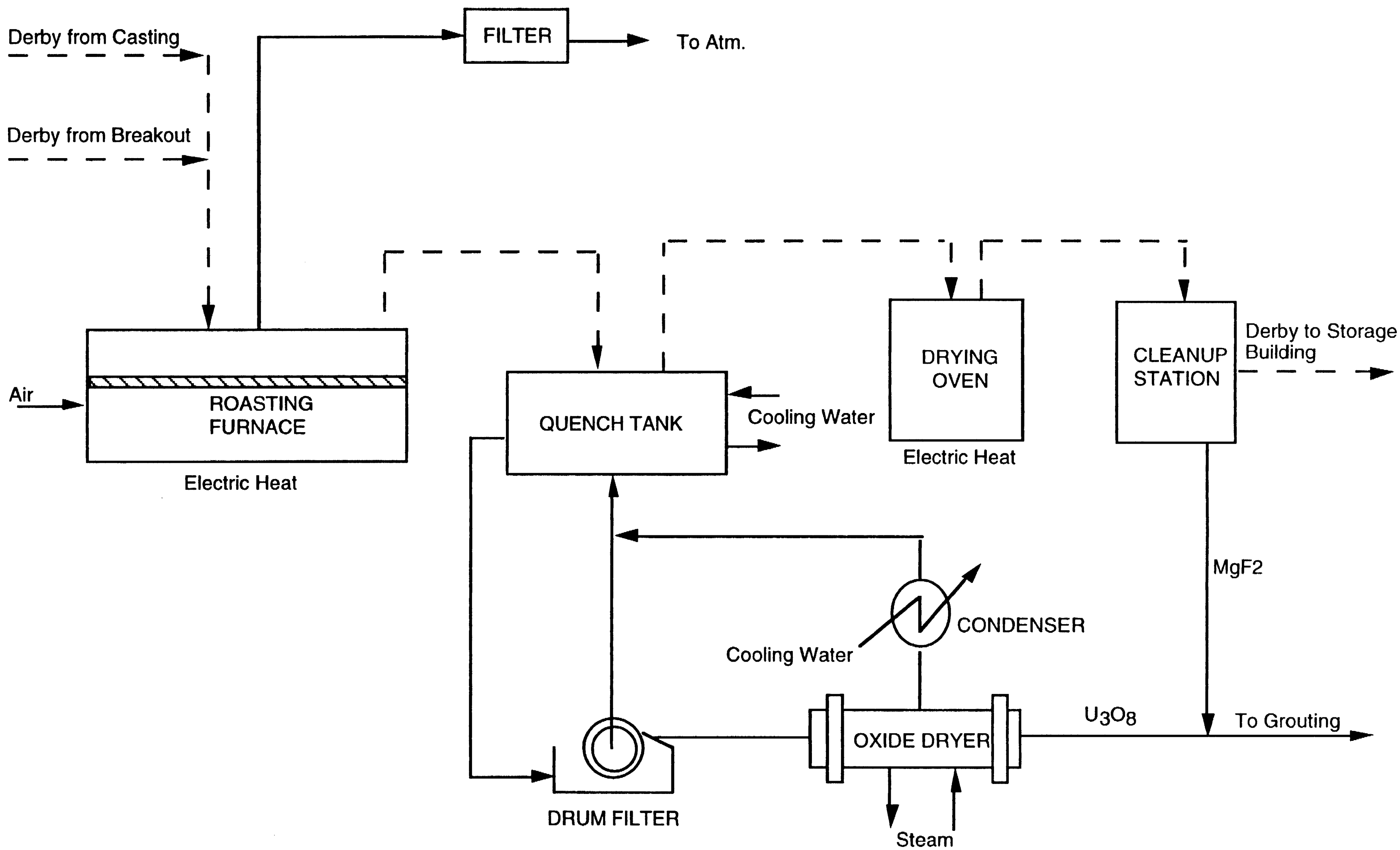

Figure 4 -7 Derby Cleanup Process Flow Diagram

4.5 MAGNESIUM FLUORIDE LEACHING

The MgF_2 is leached with nitric acid to reduce the uranium content to less than 90 ppm so that it can be disposed of in an ordinary landfill. The chemical reactions are $U_3O_8 + 8HNO_3 \text{ ---> } 3UO_2(NO_3)_2 + 2NO_2 + 4H_2O$ and $MgO + 2HNO_3 \text{ ---> } Mg(NO_3)_2 + H_2O$. The system is shown in Figure 4-8.

The MgF_2 is fed to a three-stage, countercurrent leaching system consisting of agitated tanks, rotary drum filters and transfer pumps. MgF_2 is fed to the first stage leach tank, while hot 60% nitric acid at about 175°F is fed to the third stage leach tank. The slurry from each leach tank is sent to a drum filter, which separates the MgF_2 solids from the leach solution. Pumps then transfer the MgF_2 slurry and filtrate to the next stage. The MgF_2 from the third stage leach tank is sent to a wash tank for water washing. The MgF_2 is washed and dewatered in a rotary drum filter, and dried in a steam-heated rotary tube dryer. After cooling, the MgF_2 is packaged in drums and sent to the storage building. The uranium-bearing leach solution and wash effluent are sent to the evaporation system.

Preliminary major equipment includes four 6 ft dia by 6 ft high 1,200 gal 304L stainless steel leach and wash tanks, four 6 ft dia by 4 ft long 304L stainless steel rotary drum filters, a 4 ft 6 in. dia by 20 ft long rotary steam tube dryer, and a drum loading station.

4.6 EVAPORATION, CALCINATION, AND GROUTING

The uranium-bearing leach solution is evaporated, calcined, and grouted for disposal as low-level waste. The principal chemical reactions in calcination are $UO_2(NO_3)_2 \text{ ---> } UO_3 + 2NO_2 + 0.5O_2$, $3UO_3 \text{ ---> } U_3O_8 + 0.5O_2$ and $Mg(NO_3)_2 \text{ ---> } MgO + 2NO_2 + 0.5O_2$. This system is shown in Figure 4-9.

The spent leach solution containing nitric acid and uranium is fed to an evaporator for volume reduction. The evaporator overhead vapor, composed of nitric acid and water, is sent to the nitric acid recovery system. The evaporator bottoms, which is a nitric acid solution containing uranium, magnesium and solid impurities, are fed to a zone-heated, rotary calciner. Denitration to UO_3 occurs at 480°F, and conversion to U_3O_8 occurs at 1,200°F. Solids, primarily U_3O_8, MgO, and MgF_2, are discharged from the calciner. The calciner off-gas, containing nitric acid, water, nitrogen oxides, and oxygen, flows to a condenser. The condensate, which contains nitric acid and water, is sent to the nitric acid recovery system. The uncondensed off-gas is sent to the NO_x absorption system.

The solids from the calciner and oxide from derby cleanup are mixed with water and cement in a drum. The drum is sealed and tumbled for mixing. The solidified waste drum is sent to the storage building. The composition of the grout is 33% U_3O_8, 29% H_2O, 21% cement, 10% MgF_2, and 7% MgO.

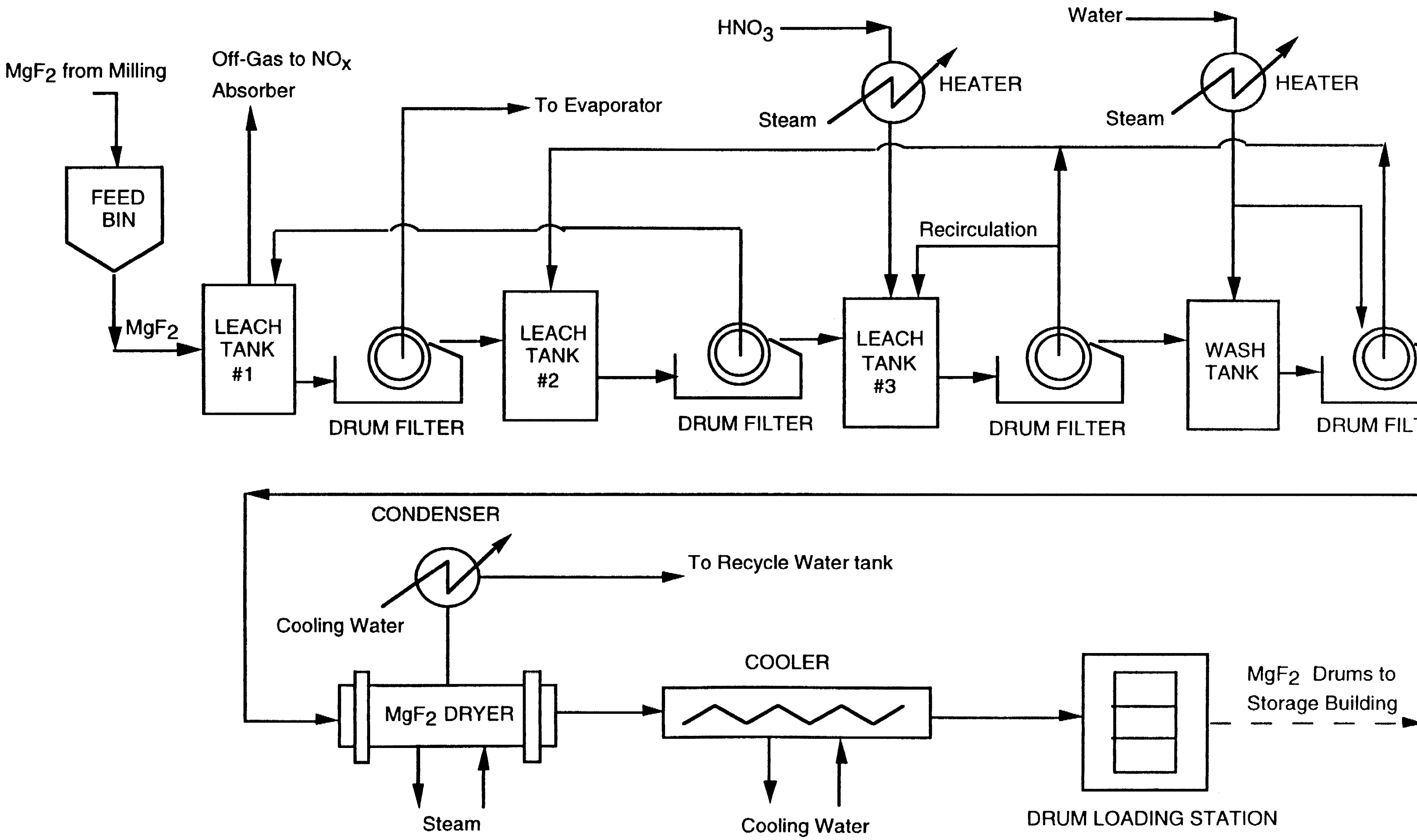

Figure 4-8 MgF_2 Leaching Process Flow Diagram

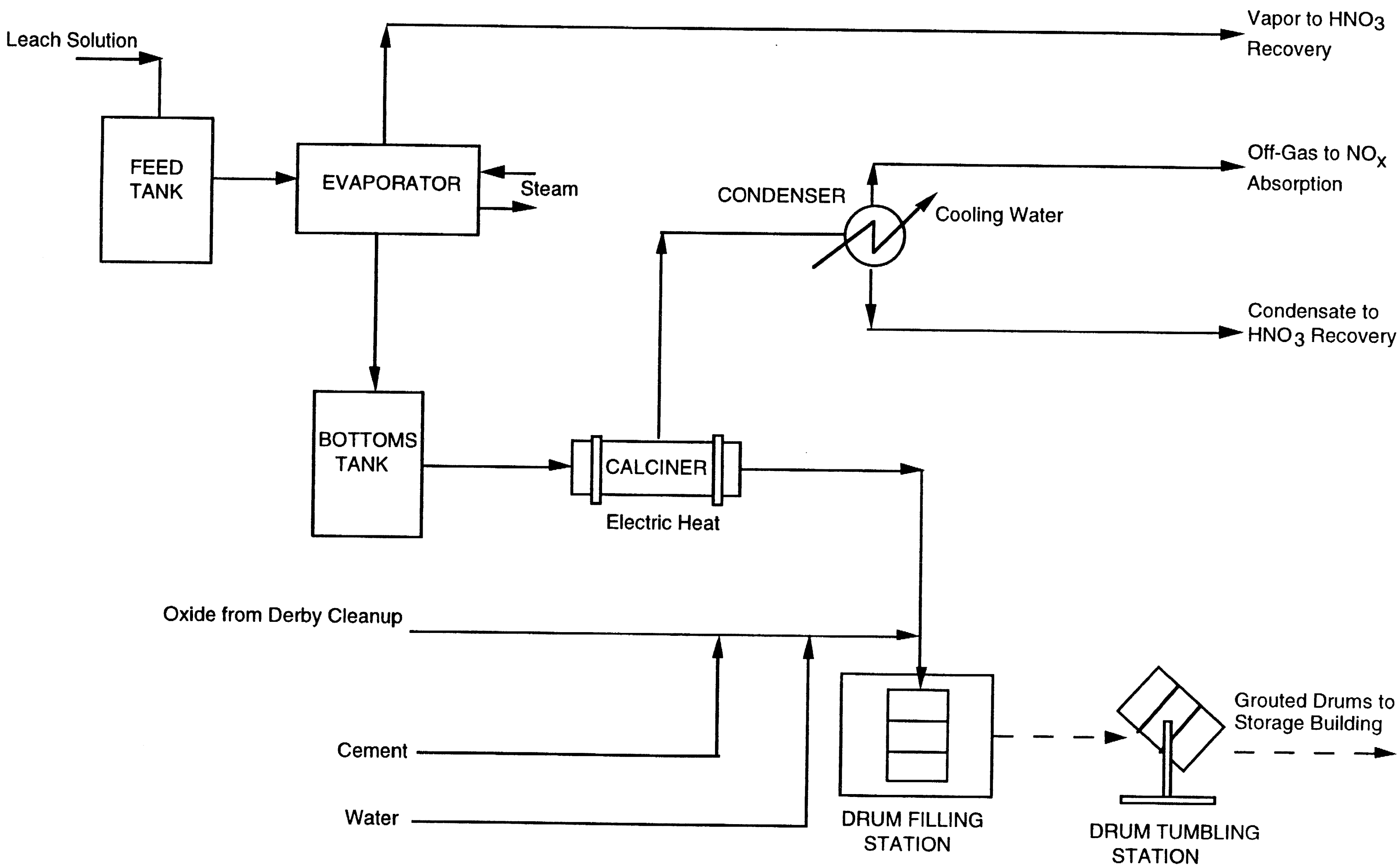

Figure 4-9 Evaporation, Calcination and Grouting Process Flow Diagram

Preliminary major equipment includes two 12 ft dia by 15 ft high 12,000 gal 304L stainless steel evaporator feed tanks, a 350 ft^2 304L stainless steel evaporator, a 2 ft dia by 8 ft long 300 kW Inconel rotary calciner, a drum tumbling station, and associated feed tanks, product tanks, and pumps.

4.7 NO_X ABSORPTION AND NITRIC ACID RECOVERY

An NO_x absorption system to treat process off-gases and a nitric acid recovery system are provided. The simplified chemical reaction for NO_x absorption is $4NO_2 + 2H_2O + O_2 \text{--->} 4HNO_3$. Both systems are shown in Figure 4-10.

Off-gases from the leaching system and the calciner are mixed with air and fed to the NOx absorption column. The column has trays and uses water as the scrub solution. About 90% of the nitrogen dioxide is absorbed into the liquid phase. The off-gas leaving the absorber passes through a HEPA filter to remove particles, and is discharged to the process stack. The scrub solution leaving the absorber is sent to nitric acid recovery.

Vapor from the evaporator, condensate from the calciner condenser, and scrub solution from the NO_x absorber are fed to a nitric acid distillation column. The overhead product is water with a trace of nitric acid, and the bottoms product is 60% nitric acid. The nitric acid and water are collected, stored in tanks, and reused in the leaching process. A small amount of fresh water and nitric acid are added to makeup for losses.

Preliminary major equipment includes a 1 ft dia by 30 ft high 304L stainless steel NO_x absorber column, a 4 ft 6 in. dia by 36 ft high 304L stainless steel nitric acid distillation column, an 8 ft dia by 8 ft high 3,000 gal 304L stainless steel nitric acid storage tank, and a 15 ft dia by 19 ft high 25,000 gal steel water storage tank.

4.8 HF SCRUBBING SYSTEM

Off-gas from HF condensation is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The system is shown in Figure 4-11.

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction $HF + KOH \text{--->} KF + H_2O$. The treated off-gas is filtered, mixed with ventilation exhaust air to dilute the hydrogen to a safe concentration, and discharged to atmosphere. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction $2KF + Ca(OH)_2 \text{--->} CaF_2 + 2KOH$. A minimum level of KF is maintained in the scrub solution by adding less than the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out of the CaF_2 product and the packed bed scrubber.

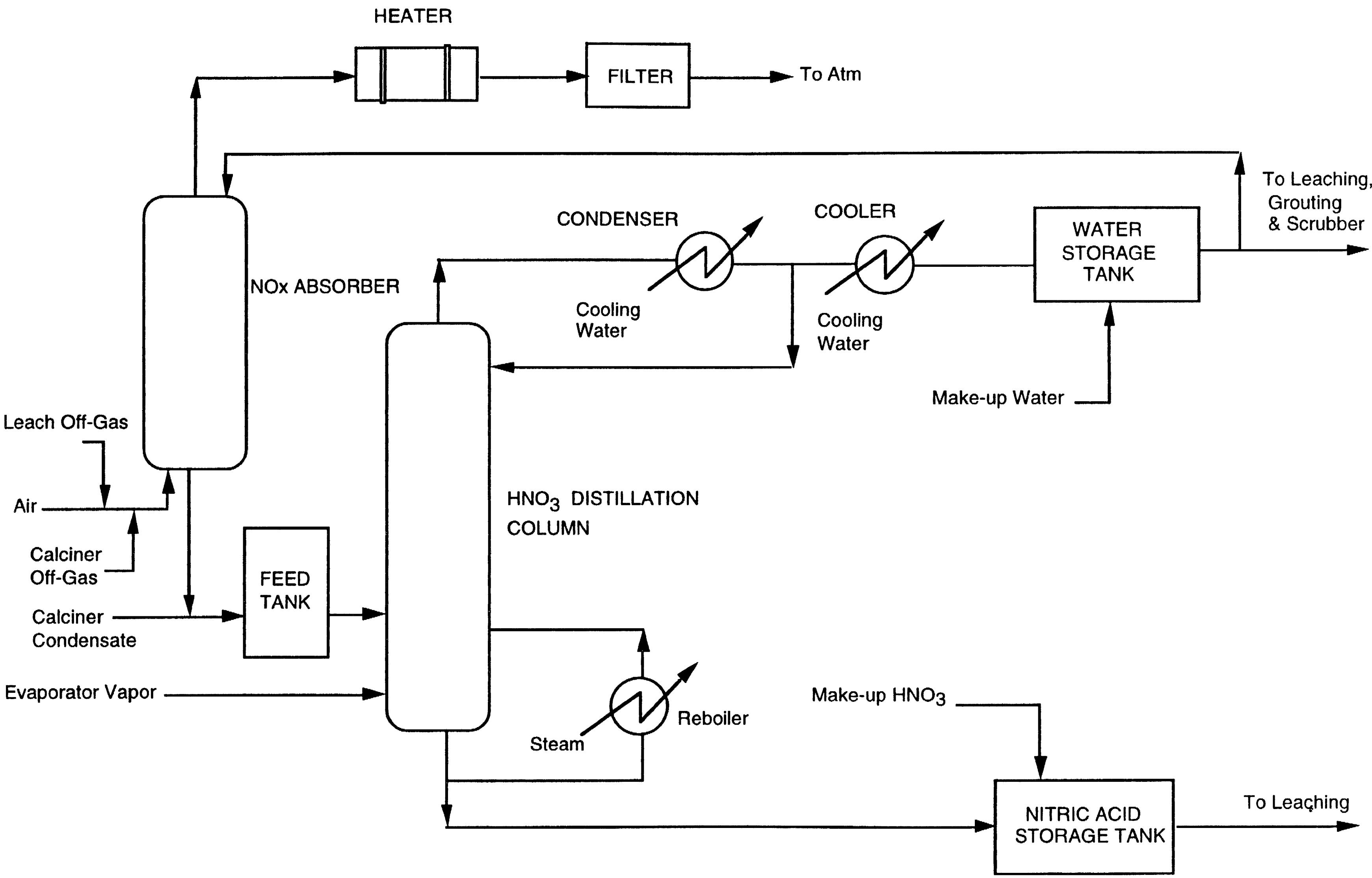

Figure 4-10 NOx Absorption and Nitric Acid Recovery Process Flow Diagram

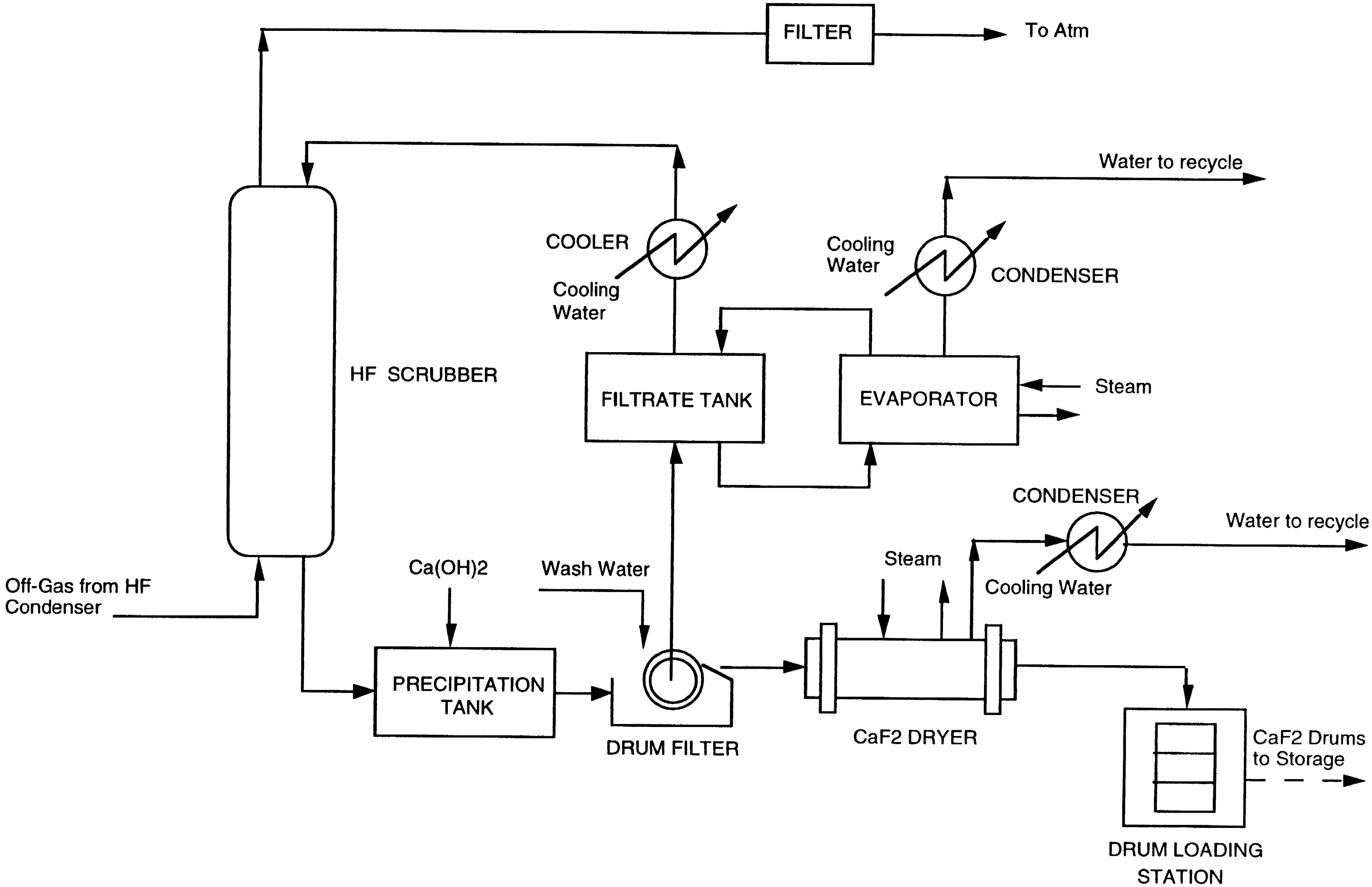

Figure 4-11 HF Scrubbing Process Flow Diagram

The scrub solution slurry is filtered in a rotary drum vacuum filter or a pressure filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities and dried in a steam-heated rotary tube dryer. After cooling, the CaF_2 is packaged in drums and sent to the storage building.

The KOH and wash water filtrate are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and the water added for CaF_2 washing. The filtrate is then cooled and pumped back to the scrubber as scrub solution.

Preliminary major equipment includes a 1 ft dia by 15 ft high Monel HF scrubber with plastic packing, 4 ft dia by 5 ft high 500 gallon Monel precipitation and filtrate tanks, a 3 ft dia by 3 ft 6 in. long Monel rotary drum filter, a 1 ft 6 in. dia by 4 ft Monel evaporator/condenser unit, a 2 ft dia by 6 ft long steel rotary dryer, and associated tanks and pumps.

4.9 UF_6 CYLINDER HANDLING SYSTEMS

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4.10 WASTE MANAGEMENT

The primary wastes produced by the process are empty UF_6 cylinders, nonhazardous MgF_2, failed graphite liners and steel retorts, and grouted uranium residue. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, and paints. Other radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing, packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low-level radioactive waste will be shipped to an off-site disposal facility. Hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

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

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	25 GWh	3.3 MW
Liquid Fuel	9,500 gals	NA
Natural Gas[2]	167×10^6 scf	NA
Raw Water	55×10^6 gals	NA

1 Peak demand is the maximum rate expected during any hour.
2 Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual water balance for the facility. This balance is based on the greenfield generic midwestern U.S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5-2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6). The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14-ton DOT approved carbon steel containers.

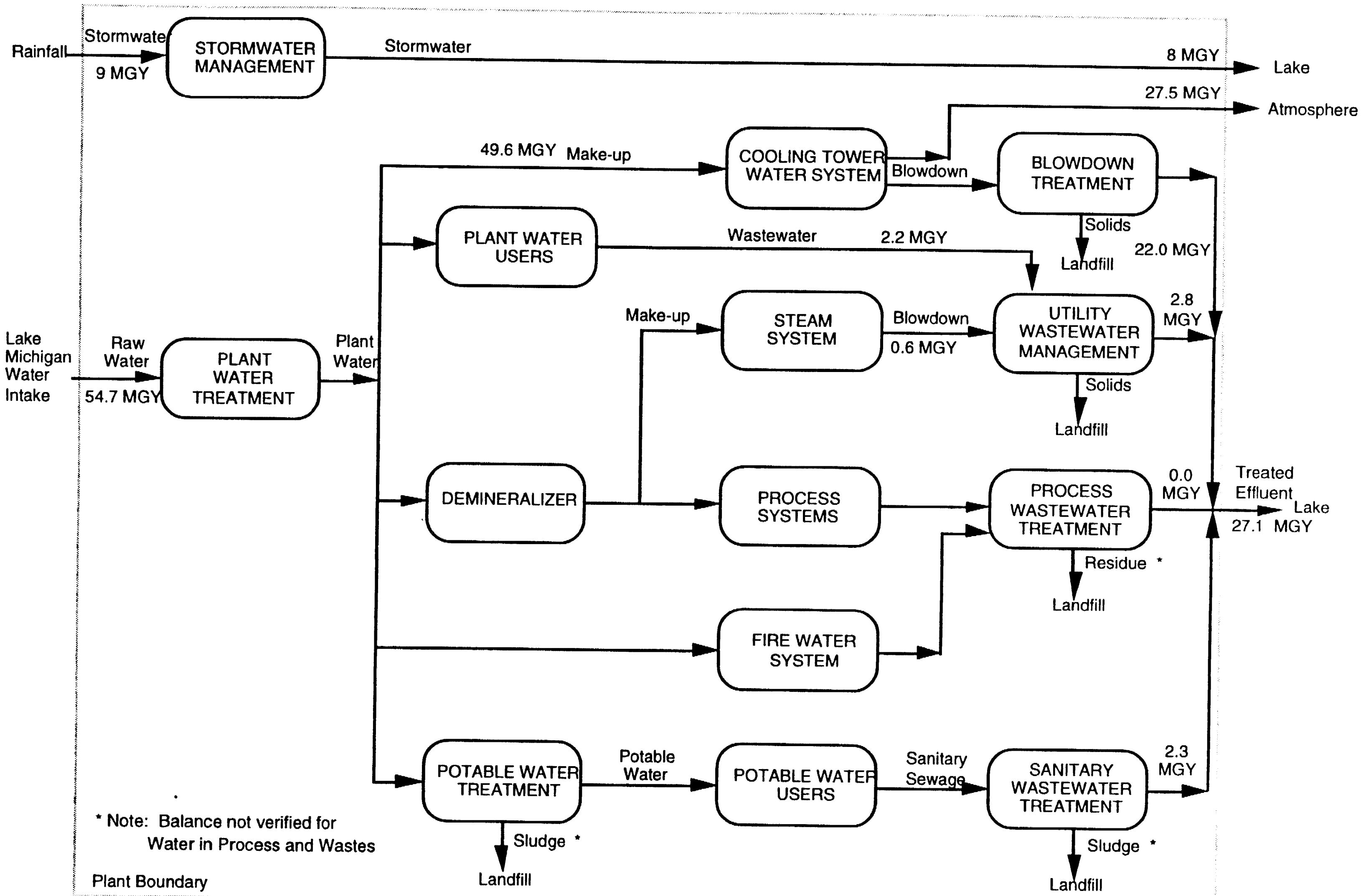

Figure 5-1 Preliminary Water Balance Batch Reduction to Uranium Metal

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	**Quantity (lb/yr)**
Solid	
Magnesium (99.8% min., -10/+60 mesh)	8,600,000
Cement	940,000
Calcium Hydroxide (Hydrated Lime)	247,000
Detergent	700
Liquid	
Ammonia (99.95% min. NH_3)	2,400,000
Nitric Acid (60% HNO_3)	230,000
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	5,300
Sodium Hydroxide (50% NaOH)	4,200
Sodium Hypochlorite	5,500
Copolymers	9,200
Phosphates	920
Phosphonates	920
Gaseous	NA
Containers and Consumables[1]	**Quantity (containers/yr)**
Graphite Liners	1,443
Steel Retorts	289
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 56 and 90 ft^3 boxes - see also Table 9-1)	7,043 drums 185 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

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

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	45,000 MWh	2.5 MW
Water	12 x 10^6 gal	800 gal
Solids		NA
Concrete	23,000 yd^3	
Steel (carbon or mild)	10,000 tons	
Electrical raceway	30,000 yd	
Electrical wire and cable	75,000 yd	
Piping	50,000 yd	
Steel decking	30,000 yd^2	
Steel siding	16,000 yd^2	
Built-up roof	23,000 yd^2	
Interior partitions	2,000 yd^2	
Lumber	7,000 yd^3	
HVAC ductwork	200 tons	
Special coatings	2,000 yd^2	
Asphalt paving	300 tons	
Liquids		
Fuel[2]	2 x 10^6 gals	
Gases		
Industrial Gases (propane)	5,500 gal	

1 Peak demand is the maximum rate expected during any hour.
2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used construction material (e.g., steel,) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for equipment fabrication is approximately 20 tons of Monel and 4 tons of Inconel.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 EMPLOYMENT NEEDS DURING OPERATION

Table 6-1, On-Site Employment During Operation, provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	12
Professionals	12
Technicians	44
Office and Clerical	34
Craft Workers (Maintenance)	12
Operators / Line Supervision	190/34
Security	35
TOTAL EMPLOYEES (for all on-site facilities)	373

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 EMPLOYEES AT RISK OF RADIOLOGICAL EXPOSURE

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF (e.g., connecting the tank car loading hose), the operator will wear acid-resistant protective gear including a respirator.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4 (1)
Process Building	80	54	54	54
HF Storage Building	2	1	1	1
Mg Metal Storage Building	1	1	1	1
Uranium Product Storage Building	3	1	1	1
MgF_2 Storage Building	1	1	1	1
Cylinder Storage Pad and Building	7	3	3	3
Utilities/Services/Admin Areas	66	10	10	10
TOTAL EMPLOYEES	160	71	71	71

1 The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	200	330	600	290
Construction Management and Support Staff	50	70	100	60
TOTAL EMPLOYEES	250	400	700	350

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

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

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

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

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility work force.

7.1.2.1 Low-Level Wastes

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

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	100/60
Nitrogen Dioxide	Process Stack / Boiler Stack / Grade	117,000/ 14,000/600
Hydrocarbons	Boiler Stack / Grade	290/500
Carbon Monoxide	Boiler Stack / Grade	6,700/3,900
Particulate Matter PM-10	Boiler Stack / Grade	500/120
OTHER POLLUTANTS		
HF	Process Bldg. Stack	300
UF_4	Process Bldg. Stack	3.8
U_3O_8	Process Bldg. Stack	9.6
Copolymers	Cooling Tower	1,900
Phosphonates	Cooling Tower	180
Phosphates	Cooling Tower	180
Calcium	Cooling Tower	3,300
Magnesium	Cooling Tower	900
Sodium and Potassium	Cooling Tower	330
Chloride	Cooling Tower	600
Dissolved Solids	Cooling Tower	18,000

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	2.0×10^{-3}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	2.0×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	400,000	185	47 lb U3O8	684 55-gal drums
Combustible solid	Crushed graphite liners	577,000	361	577 lb U	1,324 55-gal drums
Metal, surface contaminated	Failed equipment	81,000	50	96 lb U3O8	185 55-gal drums
Metal, surface contaminated	Failed steel retorts	318,000	483	318 lb U	145 6x3x5 ft boxes (3/4" plywood)
Noncombustible, compactible solid	HEPA filters	17,000	82	750 lb UF4 1,900 lb U3O8	40 4x2x7 ft boxes (3/4" plywood)
Noncombustible, noncompactible solid	Grouted waste See Sect. 4-6	4,383,000	1,304	1,466,000 lb U3O8	4,788 55-gal drums
Other	LabPack (chemicals plus absorbent)	4,400	2.7	5 lb U3O8	10 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint	5,300	3.5 (710 gal)	See description	13 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	11,000	7	11 lb HF 11 lb NaOH	26 55-gal drums
Combustible debris	Wipes, etc.	700	1.3	1 lb HF 1 lb NaOH	5 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb U3O8 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb U3O8 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	270	0.5	0.1 lb U3O8 0.1 lb Acetone	2 55-gal drums

1 All wastes are in solid form unless noted otherwise.

Table 7-4 Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	2.3×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	8,580 (1)	24.8×10^6
Recyclable Wastes	370	-

1 Includes 7,650 yd^3 of solid MgF_2.

7.1.2.3 Hazardous Wastes

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

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

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

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, and other items generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 Wastes and Emissions Generated During Construction

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	3
Nitrogen Dioxide	40
Hydrocarbons	12
Carbon Monoxide	270
Particulate Matter PM-10	60

7.2.2 Solid and Liquid Wastes

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

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction of the facility since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil and lubricants for construction vehicles, will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	80 yd^3
Hazardous Liquids	32,000 gals
Nonhazardous Solids	
Concrete	170 yd^3
Steel	50 tons
Other	1,300 yd^3
Nonhazardous Liquids	
Sanitary	4×10^6 gals
Other	2×10^6 gals

7.2.2.3 Nonhazardous Wastes

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

8.0 Accident Analysis

8.1 BOUNDING ACCIDENTS

The DUF_6 Conversion Facility buildings include areas with hazard categories of chemically high hazard (HH) for buildings containing HF and radiologically moderate hazard (HC2) for buildings containing DUF_6 and uranium metal product. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgment and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment (because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques)
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere, taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following structures, systems, and components (SSCs) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant quantities of HF, NH_3, or HNO_3, because a rupture could release some contents with unacceptable consequences
- Vessels containing significant inventories of UF_6 at elevated temperatures, because their rupture could release HF and/or uranium with unacceptable consequences
- The Process Building, HF Storage Building, and Uranium Product Storage Building structures, because they house large inventories of HF and uranium, and building collapse could result in significant damage with consequential releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Airborne Material Released to Environment
Earthquake	Extremely Unlikely	5.6×10^{-2} lb U_3O_8
Tornado	Extremely Unlikely	No Release
Flood	Incredible	No Release
HF System Leak	Anticipated	3.6 lb HF
UF_4 Drum Spill	Anticipated	1.5×10^{-4} lb UF_4
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	17 lb HF
Hydrogen Explosion	Extremely Unlikely	5×10^{-2} lb UF_4 2 lb HF
Ammonia Release	Unlikely	255 lb NH_3
Nitric Acid Release	Unlikely	6 lb HNO_3
Reactor Rupture	Extremely Unlikely	1.7×10^{-3} lb U_3O_8
Uranium Metal Fire	Unlikely	5.6×10^{-2} lb U_3O_8
HF Pipeline Rupture	Unlikely	500 lb HF to soil
HF Storage Tank Overflow	Unlikely	45 lb HF

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > \text{frequency} \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > \text{frequency} \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > \text{frequency} \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > \text{frequency}$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	47,600 lb U (56,200 lb U_3O_8)	1×10^{-3} (a)	1×10^{-3}	30 min
Tornado	No Release	NA	NA	NA
Flood	No Release	NA	NA	NA
HF System Leak	9 lb HF	1	.4 (b)	15 min
UF_4 Drum Spill	735 lb UF_4	2×10^{-4} (c)	1×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	17 lb HF	1	1	2 min
Hydrogen Explosion	1,000 lb UF_4 2 lb HF	.05 (d) 1	1×10^{-3} 1	30 min
Ammonia Release	255 lb NH_3	1	1	1 min
Nitric Acid Release	6 lb HNO_3	1	1	2 min
Reactor Rupture	1,400 lb U (1,650 lb U_3O_8)	1×10^{-3} (a)	1×10^{-3}	15 min
Uranium Metal Fire	47,600 lb U (56,200 lb U_3O_8)	1×10^{-3} (a)	1×10^{-3}	30 min
HF Pipeline Rupture	500 lb HF	(e)	(e)	10 min
HF Storage Tank Overflow	830 lb HF	.22 (f)	.25 (g)	15 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).

2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).

3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on thermal stress (oxidation) of uranium in DOE-HDBK-0013-93, p. 4-2.

b. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

c. Based on powder spill in NUREG-1320, *Nuclear Fuel Cycle Accident Analysis Handbook*, May 1988, p. 4.71. Also consistent with free-fall spill of powders in DOE-HDBK-0013-93, *Recommended Values and Technical Bases for Airborne Release Fractions, Airborne Release Rates and Respirable Fractions at DOE Non-Reactor Nuclear Facilities*, July 1993, p. 4-5.

d. Based on deflagration of large volume of flammable mixture above powder in DOE-HDBK-0013-93, p. 4-5. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

e. Assume 100% of the HF drains into the ground at a point 3 ft below grade during a 10 minute period. The contaminated soil is removed after 48 hrs.

f. Airborne release fraction is .22 based on 0.06 lb/min-sq ft evaporation rate, 200 sq ft spill area and 15 minute duration, using method in D. G. Gray, *Solvent Evaporation Rates*, American Industrial Hygiene Association Journal, November 1974. Fraction in respirable range is 1.

g. Based on 3 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234 and Pa-234m) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium, hydrofluoric acid, and nitric acid are the primary hazardous chemical materials handled in this facility. Uranium is toxic, and hydrofluoric and nitric acids are both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Structures, systems, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Structures in high hazard areas of the Process Building and HF Storage Building (i.e., in areas with high inventories of HF or UF_6 at elevated temperatures) are designed for the performance category PC-4 DBE. Therefore, failure of these structures in the event of the DBE is incredible. In the extremely unlikely event that an earthquake exceeding the PC-3 DBE or failure of PC-3 SSCs in the Process Building occurs, it is postulated that a fire occurs in the metal storage area. The resulting consequences would be bounded by the fire scenario described in Section 8.1.3.10.

The Uranium Product Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, some of the boxes could be sufficiently damaged to cause loss of containment. Because the boxes contain a uranium metal derby, which is a heavy, dense, metallic object weighing 1400 lb, an insignificant fraction of uranium would be broken into sizes that could become airborne respirable particles.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Structures, systems, and components are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Structures in high hazard areas of the Process Building and HF Storage Building (i.e., in areas with high inventories of HF or UF_6 at elevated temperatures) are designed for the performance category PC-4 DBT. Therefore, failure of these structures in the event of the DBT is incredible.

The Uranium Product Storage Building is designed for the performance category PC-3 DBT for radiologically moderate hazard structures. The DBT defined for this facility would not cause sufficient damage to compromise the building confinement of hazardous materials. However, in the extremely unlikely event of a DBT exceeding the PC-3 level or failure of PC-3 SSCs, a tornado wind-driven missile could impact and damage a uranium product storage box. Because the boxes contain a uranium metal derby, which is a heavy, dense, metallic object weighing 1400 lb, an insignificant fraction of uranium would be broken into sizes that could become airborne respirable particles. Therefore the tornado would result in no release.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF_6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Structures, systems, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility will be located at a site that precludes severe flooding.

8.1.3 OTHER POSTULATED EVENTS

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF System Leak

Gaseous HF is produced from the reactions in the UF_6 reduction process. The HF is condensed and collected. Possible accidents include leakage from a vessel, pump, or pipe.

It is postulated that the off-gas line from a reactor to the condenser leaks 5% of its flowing contents for 10 minutes, thus releasing 9 lb of HF into the process building. After the leak is detected by air monitoring instruments, the reactor feed is halted to stop the leak. It is assumed that about 40% of the HF vapor (3.6 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 UF_4 Drum Spill

Solid UF_4 is produced in the Process Building. It is stored in a large bin for feeding to the metal reduction process. There is also a drum loading station to provide the capability to store additional quantities of UF_4 in drums. The drums are located in the Process Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the floor. A drum contains 1,470 lb UF_4. It is assumed that 50% of the UF_4 is released from the drum and 0.02% becomes respirable airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne UF_4. Thus 1.5×10^{-4} lb of UF_4 is discharged through the Process Building HVAC exhaust stack to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.4 Loss of Off-Site Electrical Power

An uninterruptible power supply and diesel generator provide backup electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a release to the environment.

8.1.3.5 Loss of Cooling Water

Pressure relief valves are provided to protect the reactors, vessels, and equipment. Loss of cooling water to the UF_6 reactor HF cooler or condenser would cause the reactor pressure to rise and the relief valve to open.

It is postulated that cooling water is lost and all of the hot off-gas flows through the relief valve for one minute, releasing 17 lb of HF. High temperature and pressure alarms and interlocks would shut down the feed input to the reactor to stop the release. The HF scrubber would also condense some of the HF to prevent overpressure. About 17 lb of HF would be discharged through the relief valve and released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.6 Hydrogen Explosion

Hydrogen is fed to the reduction reactors as a reagent to react with UF_6. There are two reactors in parallel, and each reactor receives about 30 lb/hr of hydrogen.

Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. The reactor vapor space normally contains excess unreacted hydrogen, HF, and nitrogen. There is normally no air in the reactor.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the reactor, air to leak into the reactor, and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

Assuming the reactor normally contains a 15 minute holdup of material, the reactor contains about 2,000 lb of UF_4. It is assumed that 50% of the uranium is released into the room, and that 100% of that material becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the uranium. Thus, 5×10^{-2} lb of UF_4 would be discharged through the Process Building exhaust stack. Also, assuming the reactor contains 2 lb of HF, this would also be released in this accident. This accident is judged to be extremely unlikely.

8.1.3.7 Ammonia Release

Ammonia is stored as a liquid in three 15,000 gallon pressure vessels located outdoors in the yard. The ammonia pressure increases as the ambient temperature increases. Tank pressure would be 93 psig if the tank contents are at 60°F, and 166 psig at 90°F. Ammonia is toxic but is not considered flammable.

A leak in an ammonia system can be readily detected by odor. Ammonia vapor or gas is lighter than air, so it will tend to rise and dissipate. Ammonia is highly soluble in water and water sprays are effective in absorbing ammonia vapor. The ammonia tank outlets are equipped with an excess flow valve, which would close and stop the ammonia flow in the event the outlet piping was cleanly broken off.

It is postulated that the ammonia supply truck fill line for an ammonia storage tank is momentarily disconnected during fill operations. The release is detected by an operator who is required to be present to monitor the unloading operations per ANSI Standard K61.1, "Safety Requirements for the Storage and Handling of Anhydrous Ammonia", Section 5.10.

Assuming a flow of 50 gpm for one minute, 255 lb of ammonia is released to atmosphere at grade. This accident is judged to be unlikely.

Catastrophic failure of an ammonia tank is considered incredible since the fabrication and installation of the tank will follow ANSI Standard K61.1, which requires ASME Code fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and contain leakage. Also, vegetation and other flammable materials will be excluded from the immediate storage tank area.

8.1.3.8 Nitric Acid Release

Hot nitric acid (60% HNO_3) is used in the MgF_2 leaching process. The spent nitric acid along with wash water are fed to an evaporator. The evaporator vapor is sent to a distillation column, which purifies and concentrates the nitric acid for reuse in the leaching process. Pressure relief valves are provided to protect vessels and columns.

It is postulated that the evaporator overhead vapor line is blocked due to equipment failure or human error. Assuming 100% of the vapor flows through the relief valve for one minute, about 6 lb of nitric acid and 90 lb of steam are released. High pressure alarms and interlocks would shut down the steam to the evaporator to stop the release. Thus 6 lb of nitric acid would be discharged through the relief valve and released to atmosphere through the Process Building exhaust stack. This accident has been judged to be unlikely.

8.1.3.9 Reactor Rupture

Hot molten uranium metal is produced in the furnaces in the Process Building. In the event that the retorts containing the molten uranium are damaged or breached due to mishandling or other causes, the molten metal could become exposed to air, oxidize, and be released as airborne particles. A retort contains about 1,400 lb of uranium. A fraction of 0.1% is assumed to be released as respirable airborne particles in this event, with 99.9% filtration efficiency in the building HVAC system, resulting in about 1.4×10^{-3} lb of uranium (1.7×10^{-3} lb U_3O_8) being released to the atmosphere through the Process Building exhaust stack. This accident has been judged to be extremely unlikely.

8.1.3.10 Uranium Metal Fire

Most of the areas where uranium and other hazardous materials are handled do not contain combustible materials that would support a fire of any significant magnitude. In the uranium product loading area however, the uranium derbies are packaged in wooden boxes. In the event that a fire occurs in this area, it is postulated that up to one shift's production of uranium derbies may accumulate in the area (34 derbies each weighing 1,400 lb). A fraction of 0.1% is assumed to be released as respirable airborne particles in this event, with 99.9% filtration efficiency in the building HVAC system, resulting in about 4.8×10^{-2} lb of uranium (5.6×10^{-2} lb U_3O_8) being released to the atmosphere through the Process Building exhaust stack. This accident has been judged to be unlikely.

8.1.3.11 HF Pipeline Rupture

Anhydrous HF is pumped from the Process Building to the HF Storage Building through an underground pipeline. The pipe is double-walled to contain possible leakage and has a leak detection alarm. It is postulated that an earthquake ruptures the pipeline and its outer pipe. Assuming it takes 5 minutes to stop the HF pump, the pipeline is 1 inch diameter and 200 ft long, and the pump runs at 10 gpm, it is estimated that approximately 60 gallons (500 lb) of anhydrous HF is released into the ground in a 10 minute period. The contaminated soil is removed after 48 hours. This accident is judged to be unlikely.

8.1.3.12 HF Storage Tank Overflow

Anhydrous HF is stored in four 18,000 gallon tanks in the HF Storage Building. Each tank contains about 143,000 lb of HF. The tanks and building are cooled to about 50°F to reduce the amount of HF that would vaporize if a spill should occur. The tanks are performance category PC-4, have high-level alarms and interlocks that stop the transfer pump, and are surrounded by dikes to contain any spillage. The building has HF air monitoring instruments and a water spray system that can be activated to absorb HF.

It is postulated that during filling, a storage tank overflows at 10 gpm for 10 minutes and releases 100 gallons (830 lb) of HF. The HF spills onto the floor and drains to a covered sump. The HF evaporates at a rate of 12 lb/min for 15 minutes, based on an evaporation rate of 0.06 lb/min-sq ft and a spill area of 200 sq ft. The building HVAC system discharges 25% of the HF vapor (45 lb) to atmosphere in a 15 minute period, based on 3 air changes/hr and a mixing factor of 0.33. The building HVAC system is then shut down to stop further releases and the building water spray system is activated to absorb HF vapor remaining in the building. The release point is the Process Building exhaust stack. This accident has been judged to be unlikely.

9.0 Transportation

9.1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, uranium metal product in wooden boxes (crates) from the Process Building to the Uranium Product Storage Building, and low-level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car or truck transport of uranium product to the plant boundary. Hazardous waste materials, such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, and laboratory wastes, requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary (for further transport to off-site hazardous waste treatment, storage, and disposal facilities).

9.2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product, and waste materials are shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH), hydrochloric acid (HCl), ammonia (NH_3), and nitric acid (HNO_3). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium metal (uranium product), hydrofluoric acid (HF), low-level radioactive wastes, hazardous wastes, and grouted wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Input Material #5
Transported Materials					
Type	UF_6	HCl	NaOH	NH_3	HNO_3
Physical Form	Solid	Liquid	Liquid	Liquid	Liquid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	NH_3 / 100°F, 197 psig (max.)	HNO_3 / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	Rail Car 11,000 gal	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	105S-300-W	TBD
Container Weight (lb)	2,600	50	50	TBD	50
Material Weight (lb)	27,000	540	660	52,000	625
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	100% NH_3	60% HNO_3
Shipments					
Average Volume (ft^3)/Year	323,000	74	44	67,600	2,690
Packages/Year	2,322	10	6	46	366
Packages/Life of Project	46,440	200	120	920	7,320
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	5	3	1	46
Shipments/Year	2,322 (truck) or 49 (rail)	2	2	46	8
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	40	920	160
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Rail	Truck
Destination - Facility Type	NA	NA	NA	NA	NA

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	Uranium Metal	Hydrofluoric Acid	Low-Level Rad Waste	Hazardous Waste	Mixed Waste
Physical Form	Solid	Liquid	Solid	Solid & Liquid	Solid
Chemical Composition / Temperature, Pressure	Uranium / ambient	HF / ambient	See Table 7-3	See Table 7-3	See Table 7-3
Packaging					
Type	Box 2' x 2' x 1'	Rail Car 11,000 gal	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	TBD	105A-300-W	Varies	Varies	Varies
Container Weight (lb)	50	TBD	50/300	50	50
Material Weight (lb)	1,400	84,000	See Table 7-3	See Table 7-3	See Table 7-3
Chemical Content (%)	100% Uranium	100% HF	See Table 7-3	See Table 7-3	See Table 7-3
Shipments					
Average Volume (ft^3)/Year	117,000	120,600	66,700	338	44
Packages/Year	29,160	82	6,991/185	46	6
Packages/Life of Project	583,200	1,640	139,820/3,700	920	120
Packages/Shipment	28 (truck) or 80 (railcar), 4 cars/train	6 railcars / train	40/10	23	6
Shipments/Year	1,042 (truck) or 92 (rail)	14	173/19	2	1
Shipments/Life of Project	20,840 (truck) or 1,840 (rail)	280	3,460/380	40	20
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Rail	Truck	Truck	Truck
Destination - Facility Type	TBD	Customer	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #6
Transported Materials	
Type	Empty UF_6 Cylinders
Physical Form	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient
Packaging	
Type	14 MT Cylinder
Certified by	DOT
Identifier	48G
Container Weight (lb)	2,600
Material Weight (lb)	22
Chemical Content (%)	100% UF_6 (Note 1)
Shipments	
Average Volume (ft^3)/Year	323,000
Packages/Year	2,322
Packages/Life of Project	46,440
Packages/Shipment	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	387 (truck) or 49 (rail)
Shipments/Life of Project	7,740 (truck) or 980 (rail)
Form of Transport/Routing	
Form of Transportation	Truck/Rail
Destination - Facility Type	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

10.0 References

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
CaF_2	calcium fluoride
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt hour(s) (1×10^9 watt-hour)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MgF_2	magnesium fluoride
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

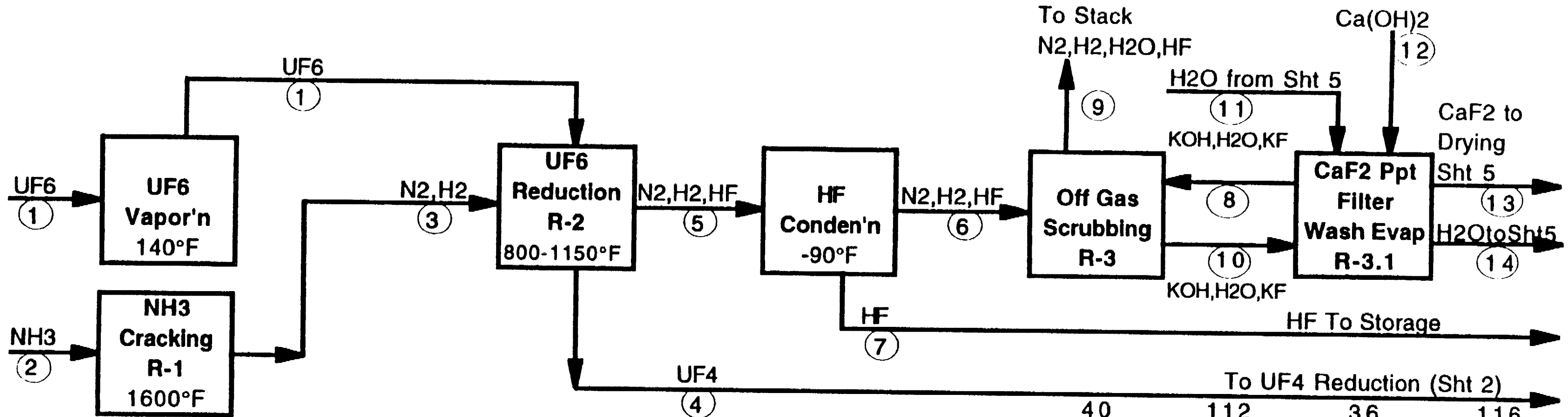
ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
UF6 Reduction with Hydrogen

	116	74	78	112
R-3.1:	2 KF +	Ca(OH)2 ->	CaF2 +	2 KOH
	176	112	118	170



	34	28	6
R-1:	2 NH3 -->	N2 +	3 H2
	1,082	891	191

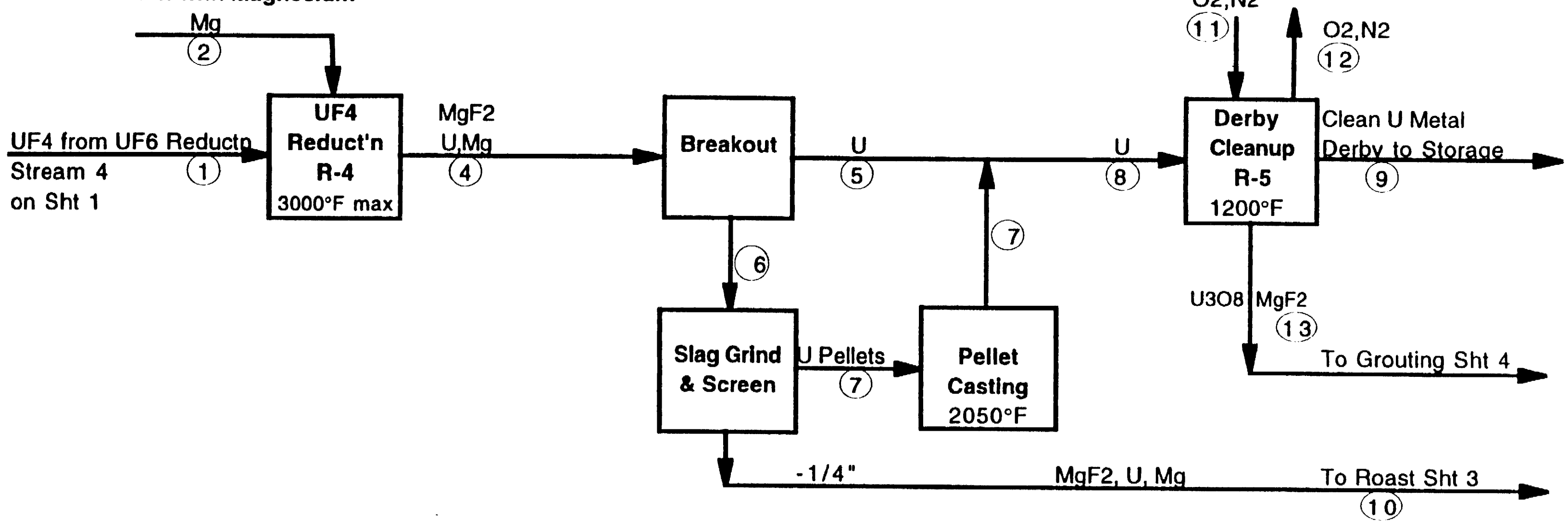
	352	2	314	40
R-2:	UF6 +	H2 -->	UF4 +	2 HF
	28,000	159	24,977	3,182

	40	112	36	116
R-3:	2 HF+	2 KOH--->	2 H2O +	2 KF
	61	170	55	176

	(11)	(12)	(13)	(14)
Ca(OH)2		112		
CaF2			118	
H2O	118		59	114
Total MT/yr	118	112	177	114
kg/kg U	0.0062	0.0059	0.0094	0.0060

	MW	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
UF6	352	28,000									
UF4	314				24,977						
HF	20					3,182	61	3,121		0.061	
NH3	17		1,082								
N2	28			891		891	891			891	
H2	2			191		32	32			32	
KOH	56								204		34
KF	58								10		186
H2O	18								9,227	43	9,282
Total MT/yr		28,000	1,082	1,082	24,977	4,105	983	3,121	9,441	966	9,502
kg/kg U		1.48	0.057	0.057	1.32	0.22	0.052	0.16	0.50	0.051	0.50

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
UF4 Reduction with Magnesium



	314	48	124	238
R-4:	UF4 +	2 Mg -->	2 MgF2 +	U
	24,977	3,818	9,864	18,932
	714	128	842	
R-5:	3 U +	4 O2 --->	U3O8	
	186	33	219	

	(11)	(12)	(13)
O2	67	33	
N2	219	219	
U			
U3O8			219
Mg			
MgF2			9
Total MT/yr	285	252	228
kg/kg U	0.015	0.013	0.012

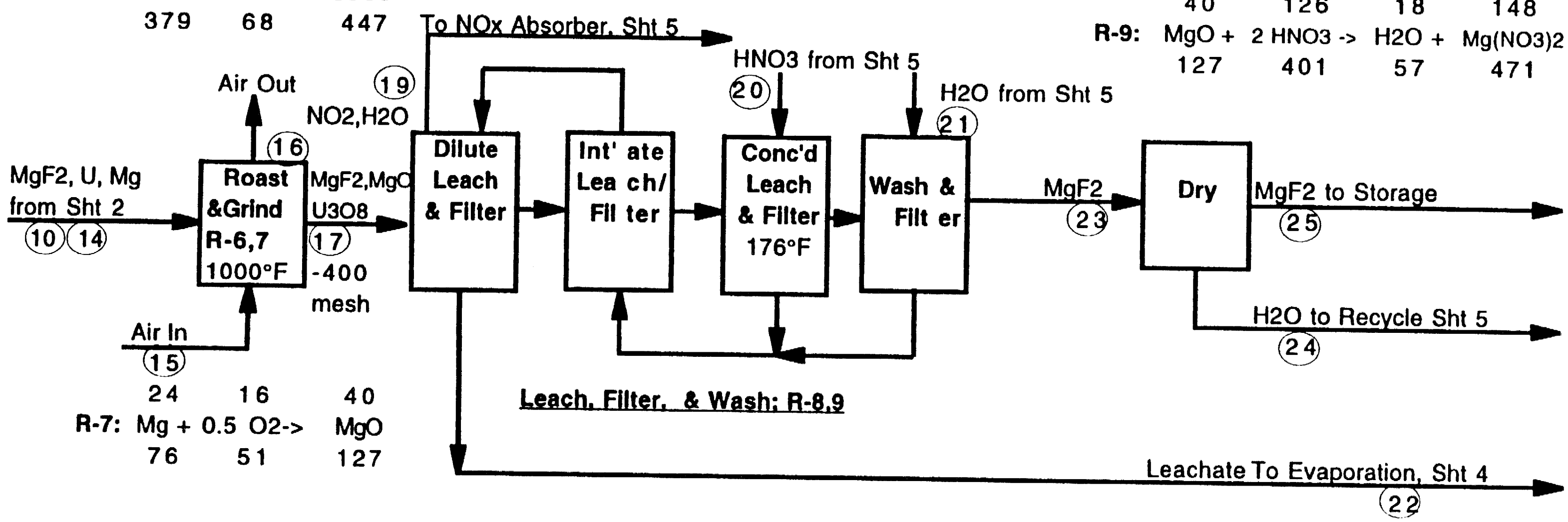
	MW	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
U	238				18,932	18,175	757	379	18,553	18,368	379
UF4	314	24,977									
Mg	24		3,895		76		76				76
MgF2	62				9,864	9	9,855		9		9,855
Total MT/yr		24,977	3,895	0	28,872	18,184	10,688	379	18,562	18,368	10,310
kg/kg U		1.32	0.21	0.00	1.53	0.96	0.56	0.020	0.98	0.97	0.54

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Magnesium Fluoride Leach

	714	128	842
R-6:	3 U +	4 O2 ->	U3O8
	379	68	447

	842	504	1,182		92	72
R-8:	U3O8 +	8 HNO3 ->	3UO2(NO3)2	+	2 NO2 +	4 H2O
	447	267	627		49	38

	40	126	18	148
R-9:	MgO +	2 HNO3 ->	H2O +	Mg(NO3)2
	127	401	57	471

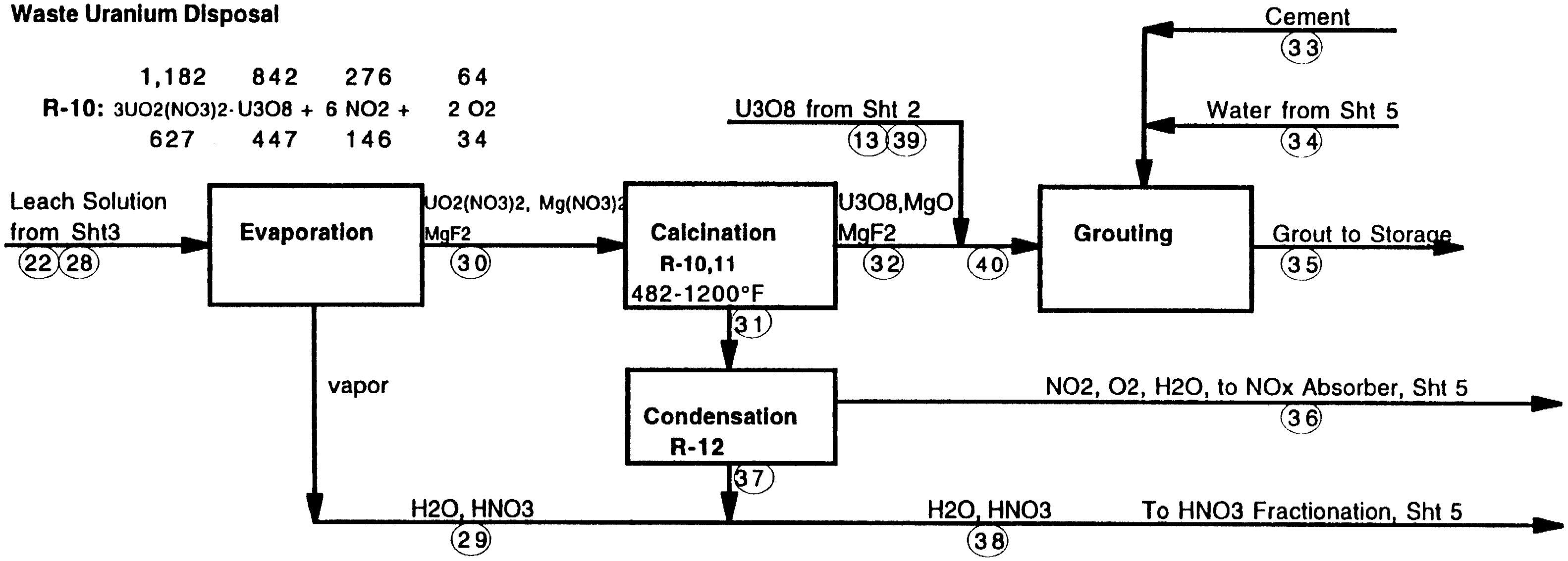


	24	16	40
R-7:	Mg +	0.5 O2->	MgO
	76	51	127

	MW	14	15	16	17	18	19	20	21	22	23	24	25	26	27
U	238	379													
U3O8	842				447						1.14		1.14		
UO2(NO3)2	394									627					
Mg	24	76													
MgO	40				127										
MgF2	62	9,855			9,855					192	9,662		9,662		
Mg(NO3)2	148									471					
HNO3	63							2,005		1,336					
H2O	18						6.8	1,336	19,709	17,913	3,221	3,221			
NO2	46						49								
H2	2														
O2	32		238	119											
N2	28		782	782											
Total MT/yr		10,310	1,020	901	10,428	0	56	3,341	19,709	20,540	12,884	3,221	9,663	0	0
kg/kg U		0.54	0.054	0.05	0.55	0.00	0.0029	0.18	1.04	1.08	0.68	0.17	0.51	0.00	0.00

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Waste Uranium Disposal

	1,182	842	276	64
R-10:	$3UO_2(NO_3)_2$ -	U_3O_8 +	$6\ NO_2$ +	$2\ O_2$
	627	447	146	34

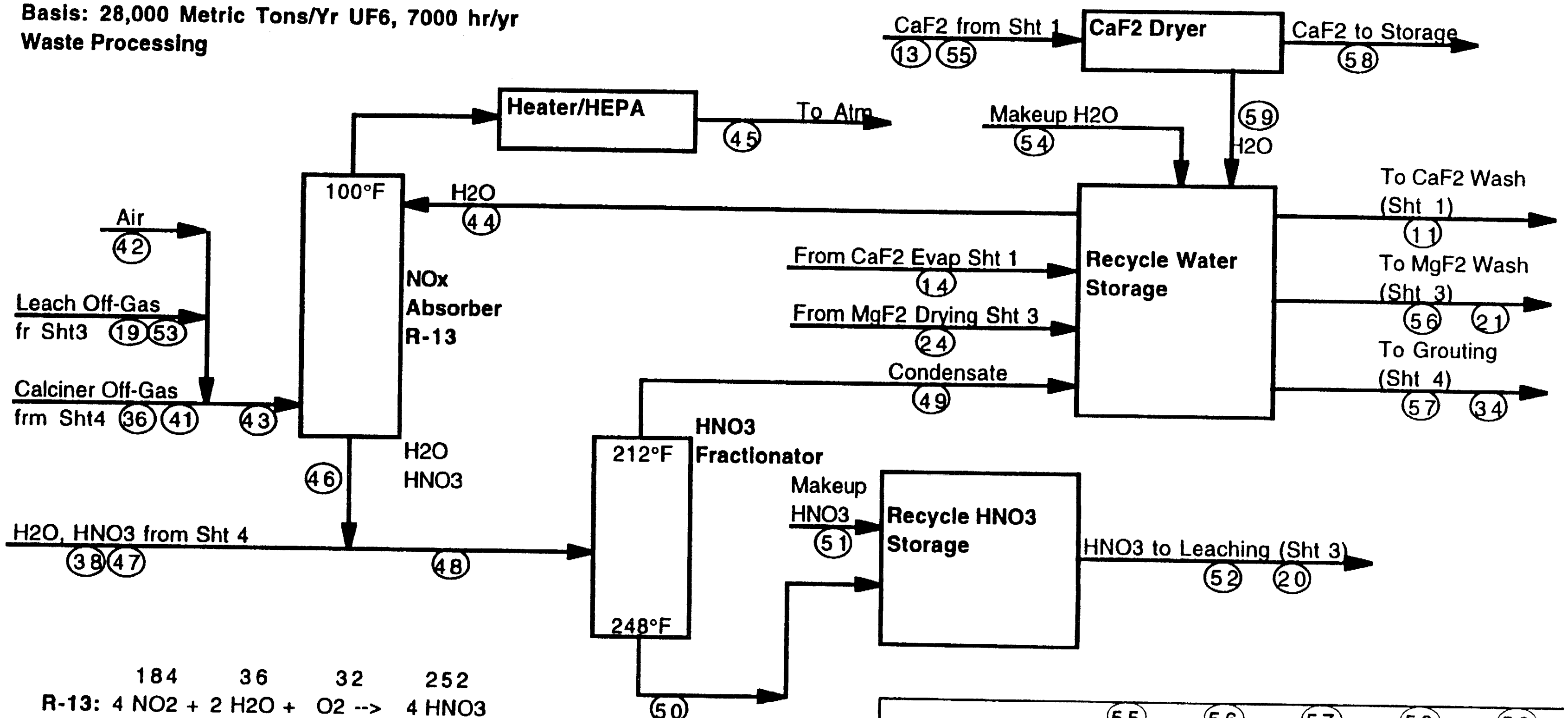


	148	40	92	16
R-11:	$Mg(NO_3)_2$ ->	MgO +	$2\ NO_2$ +	$0.5\ O_2$
	471	127	293	51

	184	36	32	252
R-12:	$4\ NO_2$ +	$2\ H_2O$ +	O_2 ->	$4\ HNO_3$
	43.91	8.59	7.64	60.14

	MW	28	29	30	31	32	33	34	35	36	37	38	39	40
UO3	286								0					0
UO2(NO3)2	394	627		627										
MgF2	62	192		192		192			202				9	202
Mg(NO3)2	148	471		471										
MgO	40					127			127					127
HNO3	63	1,336	1,144	192	192						253	1,397		
H2O	18	17,913	17,143	770	770			569	569	14	748	17,891		
NO2	46				439					395				
O2	32				85					77				
U3O8						447			665				219	665
Cement							426		426					
Total MT/yr		20,540	18,287	2,253	1,486	766	426	569	1,988	486	1,000	19,288	228	994
kg/kg U		1.08	0.97	0.12	0.079	0.040	0.022	0.030	0.11	0.026	0.053	1.02	0.012	0.053

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Waste Processing



R-13: 4 NO2 + 2 H2O + O2 --> 4 HNO3

	4 NO2	2 H2O	O2	4 HNO3
	184	36	32	252
R-13:	400	78	69	547

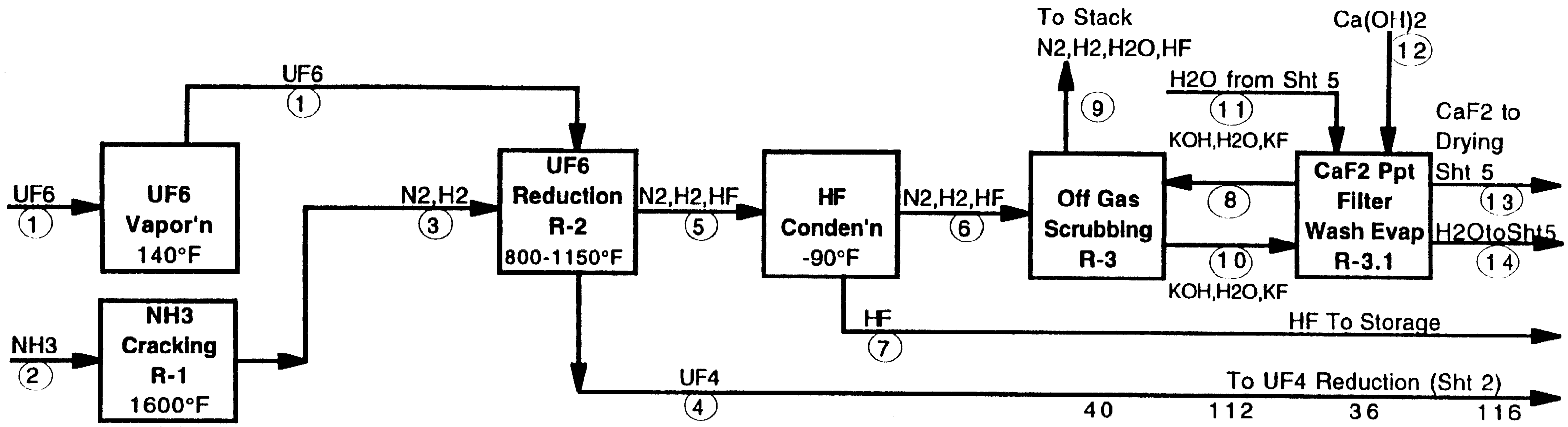
	55	56	57	58	59
CaF2	118			118	
H2O	59	19,709	569		59
Total MT/yr	177	19,709	569	118	59
kg/kg U	0.0094	1.04	0.030	0.0062	0.0031

	MW	41	42	43	44	45	46	47	48	49	50	51	52	53	54
HNO3	63			0			547	1,397	1,944	1.32	1,942	62	2,005		
H2O	18	14	9	29	4,492	28	4,415	17,891	22,306	21,011	1,295	41	1,336	7	483
NO2	46	395		444		44									
O2	32	77	201	278		208								49	
N2	28		661	661		661									
Total MT/yr		486	870	1,412	4,492	942	4,963	19,288	24,250	21,013	3,237	104	3,341	56	483
kg/kg U		0.026	0.046	0.075	0.24	0.050	0.26	1.02	1.28	1.11	0.17	0.0055	0.18	0.0029	0.026

3-Ma.. Balance lb/hr

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
UF6 Reduction with Hydrogen

	116	74	78	112
R-3.1:	2 KF +	Ca(OH)2 ->	CaF2 +	2 KOH
	55	35	37	53



	34	28	6
R-1:	2 NH3 -->	N2 +	3 H2
	340	280	60

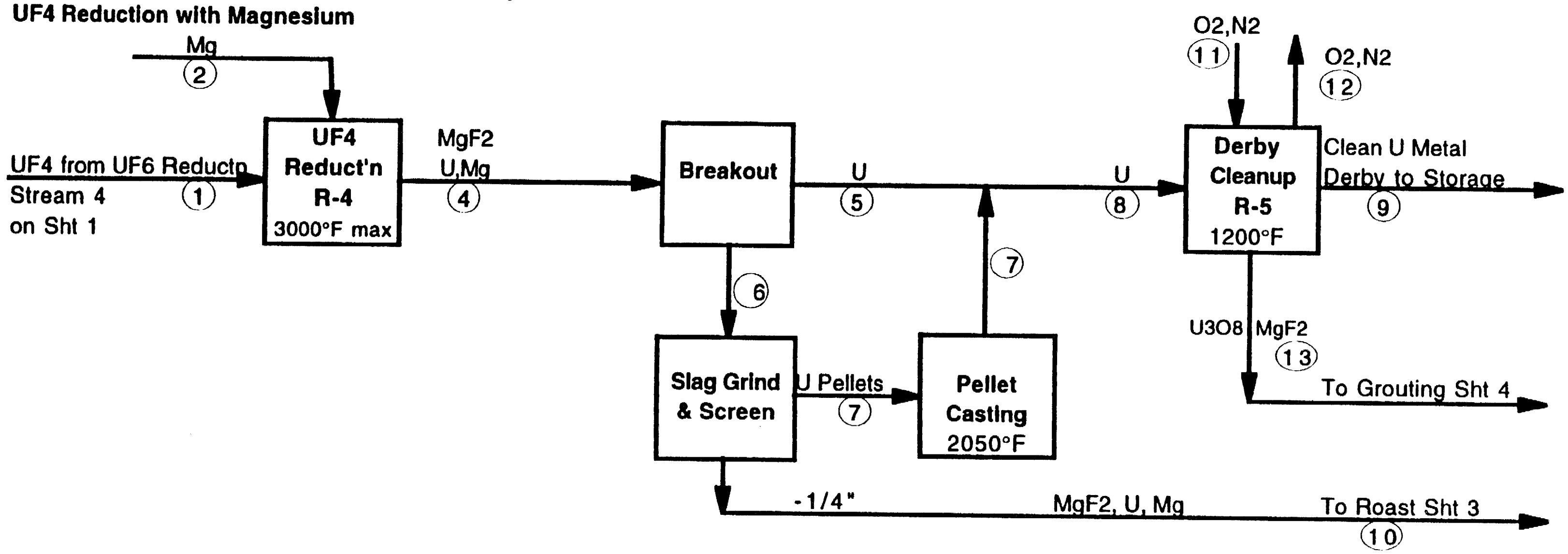
	352	2	314	40
R-2:	UF6 +	H2 -->	UF4 +	2 HF
	8,800	50	7,850	1,000

	40	112	36	116
R-3:	2 HF+	2 KOH--->	2 H2O +	2 KF
	19	53	17	55

	(11)	(12)	(13)	(14)
Ca(OH)2		35		
CaF2			37	
H2O	37		19	36
Total lb/hr	37	35	56	36
kg/kg U	0.0062	0.0059	0.0094	0.0060

	MW	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
UF6	352	8,800									
UF4	314				7,850						
HF	20					1,000	19	981		0.019	
NH3	17		340								
N2	28			280		280	280			280	
H2	2			60		10	10			10	
KOH	56								64		11
KF	58								3		59
H2O	18								2,900	14	2,917
Total lb/hr		8,800	340	340	7,850	1,290	309	981	2,967	304	2,986
kg/kg U		1.48	0.057	0.057	1.32	0.22	0.052	0.16	0.50	0.051	0.50

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
UF4 Reduction with Magnesium



	314	48	124	238
R-4:	UF4 +	2 Mg -->	2 MgF2 +	U
	7,850	1,200	3,100	5,950
	714	128	842	
R-5:	3 U +	4 O2 --->	U3O8	
	58	10	69	

	11	12	13
O2	21	10	
N2	69	69	
U			
U3O8			69
Mg			
MgF2			3
Total lb/hr	90	79	72
kg/kg U	0.015	0.013	0.012

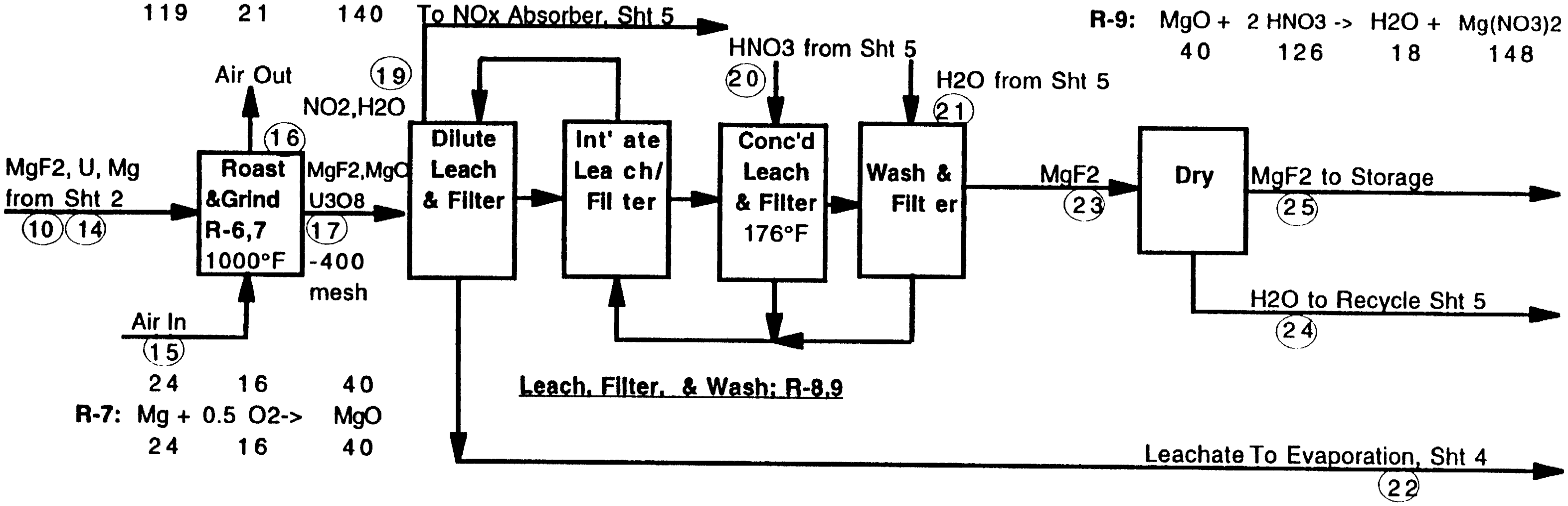
	MW	1	2	3	4	5	6	7	8	9	10
U	238				5,950	5,712	238	119	5,831	5,773	119
UF4	314	7,850									
Mg	24		1,224		24		24				24
MgF2	62				3,100	3	3,097		3		3,097
Total lb/hr		7,850	1,224	0	9,074	5,715	3,359	119	5,834	5,773	3,240
kg/kg U		1.32	0.21	0.00	1.53	0.96	0.56	0.020	0.98	0.97	0.54

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Magnesium Fluoride Leach

	714	128	842
R-6:	3 U +	4 O2 ->	U3O8
	119	21	140

	842	504	1,182		92	72
R-8:	U3O8 +	8 HNO3 ->	3UO2(NO3)2	+	2 NO2 +	4 H2O
	140	84	197		15	12

	40	126	18	148
R-9:	MgO +	2 HNO3 ->	H2O +	Mg(NO3)2
	40	126	18	148

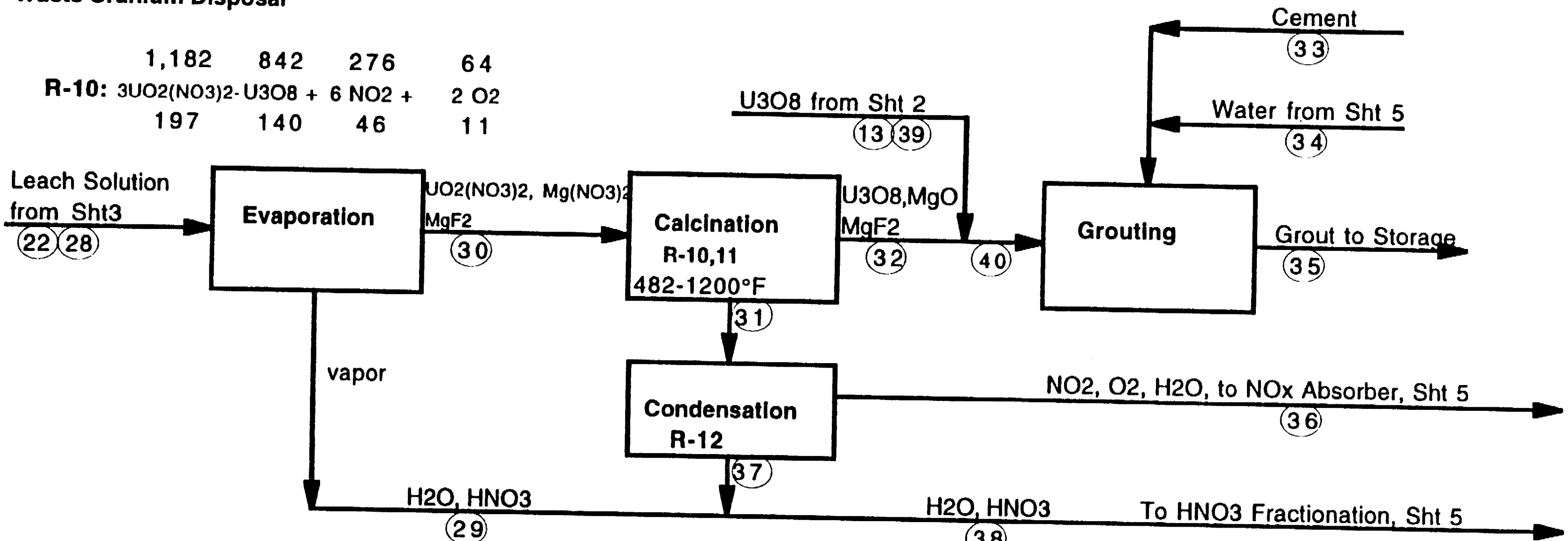


	24	16	40
R-7:	Mg +	0.5 O2->	MgO
	24	16	40

	MW	14	15	16	17	18	19	20	21	22	23	24	25	26	27
U	238	119													
U3O8	842				140						0.36		0.36		
UO2(NO3)2	394									197					
Mg	24	24													
MgO	40				40										
MgF2	62	3,097			3,097					60	3,037		3,037		
Mg(NO3)2	148									148					
HNO3	63							630		420					
H2O	18						2.1	420	6,194	5,630	1,012	1,012			
NO2	46						15								
H2	2														
O2	32		75	37											
N2	28		246	246											
Total lb/hr		3,240	320	283	3,277	0	17	1,050	6,194	6,455	4,049	1,012	3,037	0	0
kg/kg U		0.54	0.054	0.05	0.55	0.00	0.0029	0.18	1.04	1.08	0.68	0.17	0.51	0.00	0.00

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Waste Uranium Disposal

	1,182	842	276	64
R-10:	3UO2(NO3)2-	U3O8 +	6 NO2 +	2 O2
	197	140	46	11

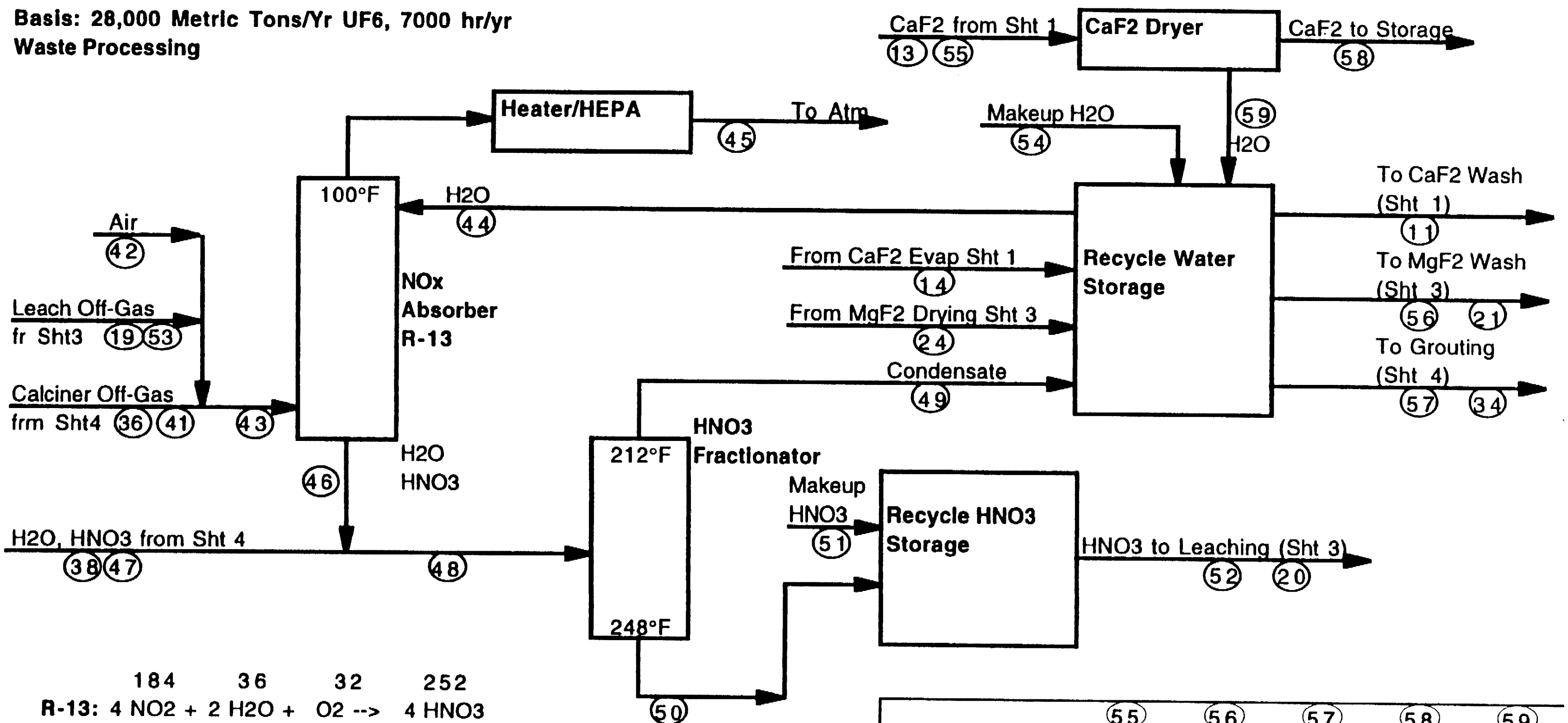


	148	40	92	16
R-11:	Mg(NO3)2->	MgO +	2 NO2 +	0.5 O2
	148	40	92	16

	184	36	32	252
R-12:	4 NO2 +	2 H2O +	O2 ->	4 HNO3
	13.80	2.70	2.40	18.90

	MW	28	29	30	31	32	33	34	35	36	37	38	39	40
UO3	286													
UO2(NO3)2	394	197		197					0					0
MgF2	62	60		60		60			63				3	63
Mg(NO3)2	148	148		148										
MgO	40					40			40					40
HNO3	63	420	360	60	60						79	439		
H2O	18	5,630	5,388	242	242			179	179	4	235	5,623		
NO2	46				138					124				
O2	32				27					24				
U3O8						140			209				69	209
Cement							134		134					
Total lb/hr		6,455	5,747	708	467	241	134	179	625	153	314	6,062	72	312
kg/kg U		1.08	0.97	0.12	0.079	0.040	0.022	0.030	0.11	0.026	0.053	1.02	0.012	0.053

BATCH REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Waste Processing



	184		36		32		252
R-13:	4 NO2	+	2 H2O	+	O2	-->	4 HNO3
	126		25		22		172

	55	56	57	58	59
CaF2	37			37	
H2O	19	6,194	179		19
Total lb/hr	56	6,194	179	37	19
kg/kg U	0.0094	1.04	0.030	0.0062	0.0031

	MW	41	42	43	44	45	46	47	48	49	50	51	52	53	54
HNO3	63			0			172	439	611	0.42	610	20	630		
H2O	18	4	3	9	1,412	9	1,388	5,623	7,011	6,604	407	13	420	2	152
NO2	46	124		140		14								15	
O2	32	24	63	87		66									
N2	28		208	208		208									
Total lb/hr		153	274	444	1,412	296	1,560	6,062	7,621	6,604	1,017	33	1,050	17	152
kg/kg U		0.026	0.046	0.075	0.24	0.050	0.26	1.02	1.28	1.11	0.17	0.0055	0.18	0.0029	0.026

Appendix B

Equipment List

MAJOR EQUIPMENT LIST
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (14)	6'Dx18'L, carbon steel, steam-heated	Proc. Bldg
UF6 Compressor (14)	800 lb/hr UF6, 15 psig discharge	Proc. Bldg
UF6 Reduction Reactor (2)	21"Dx35"Dx27'H, 60 kw, Monel	Proc. Bldg
UF4 Product Cooler (2)	12"Dx10'L, screw conveyor with cooling water, Monel, 20 cfh	Proc. Bldg
Reactor Off-Gas Equipment	Cyclone, sintered metal filters, Monel	Proc. Bldg
UF4 Product Bin (2)	5'Dx7'H, 100 cf, steel	Proc. Bldg
UF4 Storage Bin	8'Dx23'H, 1200 cf, steel	Proc. Bldg
UF4 Drum Filling Station	5.4 drums/hr, glovebox	Proc. Bldg
UF4 Dust Collector	baghouse	Proc. Bldg
UF4 Conveyor	40 cfh, steel	Proc. Bldg
HF Cooler	1'6'Dx6'L, 200 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Refrigerated Condenser	2'Dx6'L, 250 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Hold Tanks (2)	5'Dx8'L, 1100 gal, steel	Proc. Bldg
HF Storage Tanks (4)	8'Dx48'L, 18,000 gal, steel	HF Bldg
Off-Gas Scrubber	1'Dx15'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	1 kw electric heater	Proc. Bldg
Off-Gas HEPA Filter (2)	24"x24"x12"	Proc. Bldg
Off-Gas Exhauster (2)	150 scfm	Proc. Bldg
Lime Feed Bin	3'Dx7'H, 40 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 0.5 cfh, steel	Proc. Bldg
Precipitation Tank	4'Dx5'H, 500 gal, Monel	Proc. Bldg
Rotary Drum Filter	3'Dx3.5'L, 30 sq ft, Monel	Proc. Bldg
Vacuum Pump	100 cfm	Proc. Bldg
Filtrate Tank	4'Dx5'H, 500 gal, Monel	Proc. Bldg
Scrub Solution Cooler	1'6"Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Scrub Solution Pump	6 gpm, Monel	Proc. Bldg
Evaporator	1'6"Dx4'L, 50 sq ft, Monel	Proc. Bldg
Condenser	1'6"Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Evaporator Condensate Tanks (2)	3'Dx3'H, 100 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg
CaF2 Rotary Dryer	2'Dx6'L, steel	Proc. Bldg
CaF2 Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg
CaF2 Dryer Condensate Tank	4'Dx4'H, 250 gal, steel	Proc. Bldg
CaF2 Solids Cooler	12"Dx8'L screw conveyor with cooling water, steel	Proc. Bldg
CaF2 Product Bin	4'Dx6'H, 60 cf, steel	Proc. Bldg
CaF2 Drum Filling Station	1.1 drums/hr, glovebox	Proc. Bldg
CaF2 Dust Collector	baghouse	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF4 Weigh Bin (3)	2'Dx4.5'H, 12 cf, steel, with load cells	Proc. Bldg
UF4-Mg Solids Blender (3)	30 cf double-cone blender, steel	Proc. Bldg
Retort Filling Station (3)	1.4 batches/hr per station	Proc. Bldg
Retort Capping Station (3)	1.4 caps/hr per station	Proc. Bldg
Reduction Furnace (54)	13 hr cycle time, 25 kw, 7'x7'x9'H	Proc. Bldg
Air Cooling Station	8 hr cycle time, 33 derby capacity	Proc. Bldg
Water Cooling Station	20 hr cycle time, 83 derby capacity	Proc. Bldg
Breakout Station (3)	Jolting table, 1.4 breakouts/hr per station	Proc. Bldg
Slag/derby Sorting Station	4.12 derbies/hr, glovebox	Proc. Bldg
Retort Refurbishment Station	4.12 retorts/hr, glovebox	Proc. Bldg
Derby Roasting Furnace (2)	8 derby capacity, 30 kw	Proc. Bldg
Derby Quench Tank	10'Dx5'H, 3000 gal, steel, 8 derby capacity	Proc. Bldg
Oxide Filter and Dryer		Proc. Bldg
Derby Drying Oven	4 derby capacity	Proc. Bldg
Derby Cleanup Station	4.12 derbies/hr, wire brushing, glovebox	Proc. Bldg
Derby Drum Loading Station	4.12 derbies/hr, glovebox	Proc. Bldg
Slag Jaw Crusher	3359 lb/hr, -1 inch product	Proc. Bldg
Raw Slag Bin	7'Dx20'H, 650 cf, steel	Proc. Bldg
Slag Roller Crusher	3359 lb/hr	Proc. Bldg
Vibrating Screen	4'Dx4'H, 3 hp	Proc. Bldg
Slag Product Bin	5'Dx8'H, 120 cf, steel	Proc. Bldg
U Pellet Bin	3'Dx4'H, 20 cf, steel	Proc. Bldg
Uranium Casting Furnace	50 kw, induction heated, batch furnace	Proc. Bldg
MgF2 Roasting Furnace	4'Dx17'L Inconel tube rotary kiln, 108 kw	Proc. Bldg
MgF2 Cooler	12"Dx10'L water-cooled screw conveyor	Proc. Bldg
Roasted MgF2 Storage Bin	5'Dx10'H, 150 cf, steel	Proc. Bldg
MgF2 Hammer Mill	3277 lb/hr, -1000 micron product	Proc. Bldg
MgF2 Ball Mill	6'Dx4'L, 58 bhp, -40 micron product	Proc. Bldg
Air Classifier		Proc. Bldg
MgF2 Powder Storage Bin	8'Dx23'H, 1200 cf, steel	Proc. Bldg
MgF2 Hopper and Feeder	6'Dx9'H, 200 cf, steel, 40 cfh	Proc. Bldg
MgF2 Leach and Wash Tanks (4)	6'Dx6'H, 1200 gal, 304L SS	Proc. Bldg
Leach Solution Heater (2)	1'6"Dx4'L, 50 sq ft, 304L SS tubes, steel shell	Proc. Bldg
Rotary Drum Filter (4)	6'Dx4'L, 76 sq ft, 304L SS	Proc. Bldg
Vacuum Pump (4)	100 cfm	Proc. Bldg
Filtrate Transfer Pump (4)	18 gpm, 316 SS	Proc. Bldg
MgF2 Rotary Dryer	4'6"Dx20'L, 625 sq ft steam tubes, 5 hp, steel	Proc. Bldg
MgF2 Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
MgF2 Dryer Condensate Tank	4'Dx6'H, 500 gal, steel	Proc. Bldg
MgF2 Solids Cooler	12"Dx8'L screw conveyor with cooling water, steel, 32 cfh	Proc. Bldg
MgF2 Bucket Elevator	20'H, 32 cfh, steel	Proc. Bldg
MgF2 Product Bin	4'Dx7'H, 70 cf, steel	Proc. Bldg
MgF2 Drum Filling Station	4 drums/hr, glovebox	Proc. Bldg
MgF2 Dust Collector	baghouse	Proc. Bldg
Evaporator Feed Tank (2)	12'Dx13'H, 11,000 gal, 304L SS	Proc. Bldg
Evaporator	300 sq ft, 304L SS	Proc. Bldg
Evaporator Bottoms Tank	4'Dx6'H, 500 gal, 304L SS	Proc. Bldg
Calciner Feed Tank	5'Dx6'H, 900 gal, 304L SS	Proc. Bldg
Calciner	2'Dx8'L Inconel tube, rotary calciner, 260 kw	Proc. Bldg
Calciner Condenser	1'6"Dx4'L, 50 sq ft, 304L SS tubes, steel shell	Proc. Bldg
Calciner Condensate Tank	4'Dx4'H, 400 gal, 304L SS	Proc. Bldg
Calciner Solids Product Bin	2'6"Dx5'H, 20 cf, steel	Proc. Bldg
Grouting Feed Tank	4'Dx6'L, 500 gal, 304L SS	Proc. Bldg
Cement Feed Bin	5'Dx8'H, 120 cf, steel	Proc. Bldg
Drum Tumbler	0.7 drums/hr	Proc. Bldg
NOx Absorber	1'Dx30'H, 304L SS	Proc. Bldg
Off-Gas Heater	1 kw electric heater	Proc. Bldg
HEPA Filter	24"x24"x12"	Proc. Bldg
Nitric Acid Column Feed Tank	6'Dx6'H, 1200 gal, 304L SS	Proc. Bldg
Nitric Acid Distillation Column	4'6"Dx36'H, 18 trays, 304L SS	Proc. Bldg
Nitric Acid Condenser	1'6"Dx8'L, 200 sq ft, 304L SS tubes, steel shell	Proc. Bldg
Condensate Cooler	1'6"Dx6'L, 150 sq ft, 304L SS tubes, steel shell	Proc. Bldg
Nitric Acid Reboiler	2'Dx6'L, 300 sq ft, 304L SS tubes, steel shell	Proc. Bldg
Nitric Acid Column Cond. Tank	8'Dx10'H, 3800 gal, steel	Proc. Bldg
Nitric Acid Column Bottoms Tank	4'Dx6'H, 500 gal, 304L SS	Proc. Bldg
Recycle Water Tank	15'Dx19'H, 25,000 gal, steel	Proc. Bldg
Nitric Acid Storage Tank	8'Dx8'H, 3000 gal, 304L SS	Proc. Bldg
Cement Storage Silo	7'Dx25'H, 850 cf, steel	Yard
Ammonia Storage Tank (3)	8'Dx40'L, 15,000 gal, steel, 250 psig design	Yard
Ammonia Dissociator (3)	5000 cfh H2+N2, 83 kw	Yard

MAJOR EQUIPMENT LIST (Continued)
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Process Material Handling Systems	DUF6 cylinder handling:	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	275 storage saddle/pallets	Proc. Bldg/ Storage Areas
	Two(2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated carbon steel storage racks for 14-ton DUF_6 cylinders	Proc. Bldg
	Two(2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195 storage racks each for cylinders	Proc. Bldg/ Storage Areas
	UF4 interim drum handling:	
	-1 55 gal drum automated conveyor, 30 ft. length ea.	Proc. Bldg/
	-2 forklift trucks (for 55 gal drum pallets)	
	U Prod handling:	
	-3 flatbed trucks	Yard
	-3 overhead bridge cranes, 5 ton ea,	Proc. Bldg
	-3 automated conveyors, 30 ft. length ea.	Proc. Bldg/ U Prod Bldg
	-3 forklift trucks (for derby pallets)	Proc. Bldg/ U Prod Bldg
	Grouted waste & MgF_2 handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ MgF_2 Bldg
	Mg handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ Mg Bldg
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF_2 traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-6 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Process Control / Monitoring System	-Computer based liquid processing distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, U Prod handling, waste grouting / LLW packaging and CaF drum handling areas	Proc. Bldg
HF Storage Building Water Spray System	-Building water spray system complete with pumps, piping, vessels, alarms and controls installed in the HF storage tank area to monitor, alarm and actuate a water spray designed to mitigate the effects of an unplanned HF release	HF Bldg & Proc Bldg (HF Areas only)
Sampling / Analytical Systems	-6 local sampling glove boxes equipped with laboratory liquid / powder sampling hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and U Prod pallets	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and U Prod tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/Yard

MAJOR EQUIPMENT LIST (Continued)
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 31,000 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2@ 300 cfm 150 psig	Util. Bldg
	Breathing air compressors- 2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, minus 40°F dew point	Util. Bldg
	Demineralized water system - 2000 gpd	Util. Bldg
	Sanitary water treatment system - 6300 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 75,000 gpd	Wastewater Treatment area
	Electrical substation - 3300 kW	Substation
	Emergency generators - 2 @ 500kW	Substation
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 33 MM Btu/hr, 3300 gpm	Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2,& fume hoods 4-2000 cfm, 5 HP exhaust fans	Proc. Bldg gloveboxes

MAJOR EQUIPMENT LIST (Continued)
Batch Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
HVAC SYSTEMS		
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 4-50,000 cfm, 125 HP exhaust fans, 4-50,000 cfm 60 HP supply air units	U Areas DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-30,000 cfm, 20 HP exhaust fans, 2-30,000 cfm, 30 HP supply air units, 2-10,000 cfm, 10 HP exhaust fans, Process'g 2-10,000 cfm, 15 HP supply air units	Grout, CaF_2, MgF_2 Areas Waste Control Room Support Areas
HF Area HVAC	2-10,000 cfm, 10 HP exhaust fans, 2-10,000 cfm, 15 HP supply air units, Emergency shutdown on HF leak	HF Areas
HVAC Chillers	3-460 ton chillers	
Circulating Pumps	3-750 gpm, 25 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

<u>Assumptions / Basis for Exposure Tables</u>

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

BATCH REDUCTION TO URANIUM METAL - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 27)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 28)	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4"+1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	20	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25"	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	36	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	36	6	Steel	1/4"	3483.0
UF6 reduction / HF recovery surveillance	1	0.50	1752	6	3	Monel	3/4"	876.0
Transfer UF4 drums to interim storage	2	0.50	360	9,10	3	Steel	0.06"	360.0
UF4 drum interim storage surveillance	1	0.50	2190	10	3	Steel	0.06"	1095.0
Transfer UF4 drums to UF4 reduction	2	0.50	360	9	3	Steel	0.06"	360.0
Retort filling, capping, and reduction	8	7000.00	Continuous	11	3	Steel	1/4"	56000.0
Cooling, breakout, and slag/derby separation	10	7000.00	Continuous	17,18	4	Steel	1/4"	70000.0
Slag Processing / Uranium Casting operations	4	7000.00	Continuous	13,14,15	4	Steel	1/4"	28000.0
Derby Cleanup operations	4	7000.00	Continuous	13	0.5	Glove	0.06"	28000.0
Transfer derby to interim storage	2	0.25	7290	13	3	Wood	3/4"	3645.0
Transfer derbies to storage building.	2	0.50	7290	25	3	Wood	3/4"	7290.0
Load derbies for shipment offsite	1	1.00	1042	26	3	Wood	3/4"	1042.0
Derby interim storage surveillance	1	0.50	2190	22	3	Wood	3/4"	1095.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 27)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 28)	PERSON HOURS
Derby & Grouted Drum storage building surveillance	1	0.50	2190	23	3	Wood	3/4"	1095.0
Mg F2 Grinding, Leaching, & packaging surveillance	1	7000.00	Continuous	31	3	Stnls Steel	1/4"	7000.0
Transfer MgF2 drums to interim storage	2	0.25	4012	33	3	Steel	0.06"	2006.0
Transfer MgF2 drums to storage building	2	0.50	4012	33	3	Steel	0.06"	4012.0
Load MgF2 drums for shipment offsite	1	1.00	702	35	3	Steel	0.06"	702.0
MgF2 drum interim storage surveillance	1	0.25	2190	34	3	Steel	0.06"	547.5
MgF2 drum storage building surveillance	1	0.50	2190	35	3	Steel	0.06"	1095.0
Calcination and grouting surveillance	1	0.50	1752	29	3	Steel	0.06"	876.0
Transfer grouted drums to interim storage	2	0.25	686	29	3	Steel	0.06"	343.0
Transfer grouted drums to storage building.	2	0.50	686	29	3	Steel	0.06"	686.0
Load grouted drums for shipment offsite	1	1.00	96	29,30	3	Steel	0.06"	96.0
Grouted drum interim storage surveillance	1	0.50	2190	29	3	Steel	1/4"	1095.0
Evap., Waste Liq. Trt, & NOx/HNO3 Processing surveillance	1	0.50	1752	12,13	30	Steel	1/4"	876.0
HF scrubbing / CaF2 processing surveillance	1	0.50	1752	8,9	20	Steel	1/4"	876.0
HF Loading for shipment offsite	2	10.00	82	12	220	Steel	1/4"	1640.0
HF storage bldg surveillance	1	0.25	2190	12	220	Steel	1/4"	547.5
Mg metal storage bldg surveillance	1	0.25	2190	4	220	Steel	1/4"	547.5
LLW processing, packaging, and shipping	4	8.00	1100	32	3	Steel	0.06"	35200.0
Process control room operations	10	8.00	1100	8,10	25	Steel	1/4",0.06"	88000.0
Laboratory operations	5	8.00	1100	12	25	Steel	1/4"	44000.0
HP	4	8.00	1100	1,2,3	25	Steel	1/4"	35200.0
Management / Professionals	24	8.00	250	11	30	Steel	1/4"	48000.0
Accountability	4	2.00	1100	3,4,23	3	Steel	1/4",0.06"	8800.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 27)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 28)	PERSON HOURS
Industrial and sanitary waste treatment	4	8.00	1100	5	50	Steel	1/4"	35200.0
Utilities operations	4	8.00	1100	22	175	Wood	3/4"	35200.0
Administration	34	8.00	250	10,11	140	Steel	0.06",1/4"	68000.0
Guardhouse / Process Bldg.	8	8.00	1100	5	175	Steel	1/4"	70400.0
Maintenance								17776.0
								737673.1

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UF6 reactor; there are 2 reactors.
7) UF4 product bin; there are 2 bins.
8) UF4 storage bin.
9) A single drum of UF4.
10) There are up to 1 weeks supply of UF4 in the Interim Storage Area = 345 drums.
11) Inventory of UF4 in Retort Filling Area,
12) There are 54 reduction furnaces.
13) A uranium derby.
14) Raw slag bin
15) Uranium pellet bin.
16) Uranium casting furnace
17) Water cooling station; capacity = 83 derbies.
18) Air cooling station; capacity = 33 derbies.
19) Derby roasting furnace; capacity = 8 derbies. There are 2 furnaces.
20) Derby quench tank; capacity = 8 derbies.
21) Derby drying oven; capacity = 4 derbies.
22) There are up to 33 uranium derbies in interim storage.
23) There are up to 2500 uranium derbies in the storage building.
24) Inventory in water cooling station, breakout stations, sorting, jaw crusher, and quench tank.
25) Each transfer consists of 4 derbies.

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 27)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 28)	PERSON HOURS

26) There are 28 derbies per shipment.

27) 2322 UF6 cylinders per year

365 days per yr x 3 shifts per day x 2 per shift = 2190 per year

365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year

29160 derbies/yr / 4 derbies per transfer = 7290 per year.

29160 derbies/yr / 28 derbies per transfer = 1042 per year.

82 railcars/yr of HF

28080 MgF2 drums/yr / 7 drums per transfer = 4012 transfers per year

28080 MgF2 drums/yr / 40 drums per shipment = 702 transfers per year

4800 grouted waste drums/yr / 7 drums per transfer = 686 transfers per year

4800 grouted waste drums/yr / 50 drums per shipment = 96 transfers per year

Assume 2% of UF4 is sent to interim storage in drums = 360 drums

365 days per year x 3 shifts per day x 1 per shift = 1100 per year

2000 hrs/year / 8 hrs/day x 1 per day = 250 per year

28) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.

29) Drum of grouted waste

30) There are up to 400 drums of grouted waste in the storage area

31) U3O8 inventory in MgF2 Leaching area

32) Batch of LLW

33) There are 7 drums of MgF2 per transfer

34) There are up to 35 drums of MgF2 in interim storage

35) There are up to 2400 drums of MgF2 in the storage building

36) A single 3 mo. old empty UF6 cylinder

BATCH REDUCTION TO URANIUM METAL - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 25)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 26)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4"+1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4"+1/4"	1456
UF6 Reactor (2)	2	26	2	6	3	Monel	3/4"	104
UF4 product cooler (2)	2	104	2	6,7	7	Monel, Steel	3/4",1/4"	416
UF4 off-gas equip (cyclone, sintered metal filter) (1)	2	4	1	27	1			8
UF4 conveyor (1)	2	104	1	6,7	10	Monel, Steel	3/4",1/4"	208
UF4 dust collector (cyclone, sint. mtl filt., HEPA filt.) (1)	2	4	1	27	1			8
HF cooler (1)	2	26	1	10,11	50	Steel	0.06",1/4"	52
HF refrigerated condenser (1)	2	26	1	10,11	50	Steel	0.06",1/4"	52
Off-gas scrubber (1)	2	26	1	10,11	50	Steel	0.06",1/4"	52
Off-gas heater (1)	2	26	1	10,11	50	Steel	0.06",1/4"	52
Off-gas HEPA filters (2)	2	4	2	10,11	50	Steel	0.06",1/4"	16
Off-gas exhausters (2)	2	52	2	10,11	60	Steel	0.06",1/4"	208
Lime feeder (1)	2	104	1	6,10	40	Monel, Steel	3/4",0.06"	208
Rotary drum filter (1)	2	26	1	6,10	50	Monel, Steel	3/4",0.06"	52
Vacuum pump (1)	2	52	1	6,10	50	Monel, Steel	3/4",0.06"	104
Scrub solution cooler (1)	2	26	1	6,10	35	Monel, Steel	3/4",0.06"	52
Scrub solution pump (1)	2	52	1	6,10	35	Monel, Steel	3/4",0.06"	104
Evaporator (1)	2	26	1	6,10	50	Monel, Steel	3/4",0.06"	52
Condenser (1)	2	26	1	6,10	40	Monel, Steel	3/4",0.06"	52
Condensate pump (1)	2	52	1	6,10	40	Monel, Steel	3/4",0.06"	104
UF4-Mg solids blender (3)	2	52	3	11	2	Steel	1/4"	312
Reduction furnace (54)	2	26	54	12,13	2	Steel	1/4"	2808
Water cooling station (1)	2	26	1	13,17	2	Steel	1/4"	52
Breakout station (3)	2	4	3	13,17,18	8	Steel	1/4"	24

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 25)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 26)	THICKNESS	PERSON HOURS PER YEAR
Derby roasting furnace (2)	2	26	2	13,19	3	Steel	1/4"	104
Derby drying oven (1)	2	26	1	13,21	3	Steel	1/4"	52
Oxide drum filter (1)	2	26	1	13,20	5	Steel	1/4"	52
Oxide rotary dryer (1)	2	52	1	13,20	5	Steel	1/4"	104
Slag jaw crusher (1)	2	52	1	14,15	5	Steel	1/4"	104
Slag roller crusher (1)	2	52	1	14	5	Steel	1/4"	104
Vibrating screen (1)	2	52	1	14	5	Steel	1/4"	104
Uranium casting furnace (1)	2	26	1	14,15	5	Steel	1/4"	52
MgF2 roasting furnace (1)	2	52	1	17	50	Steel	1/4"	104
MgF2 cooler (screw conveyor) (1)	2	104	1	17	45	Steel	1/4"	208
MgF2 hammer mill (1)	2	52	1	17	40	Steel	1/4"	104
MgF2 ball mill (1)	2	52	1	17	30	Steel	1/4"	104
MgF2 hopper & feeder (1)	2	52	1	24	50	Steel	1/4"	104
MgF2 leaching rotary drum filter (4)	2	26	4	24	30	Steel	1/4"	208
Leach solution heater (2)	2	26	2	24	35	Steel	1/4"	104
Vacuum pump (4)	2	52	4	24	35	Steel	1/4"	416
Filtrate transfer pump (4)	2	52	4	24	35	Steel	1/4"	416
MgF2 rotary dryer (1)	2	52	1	24	25	Steel	1/4"	104
MgF2 dryer condenser (1)	2	26	1	24	30	Steel	1/4"	52
MgF2 solids cooler (screw conveyor) (1)	2	104	1	24	30	Steel	1/4"	208
MgF2 bucket elevator (1)	2	104	1	24	30	Steel	1/4"	208
MgF2 dust collector (baghouse) (1)	2	4	1	27	1			8
Evaporator (1)	2	26	1	12,13	25	Steel	1/4"	52
Calciner (rotary) (1)	2	52	1	1,2,3	25	Steel	1/4"+1/4"	104
Calciner condenser (1)	2	26	1	1,2,3	25	Steel	1/4"+1/4"	52
Drum tumbler (1)	2	26	1	1,2,3	40	Steel	1/4"+1/4"	52
NOx absorber (1)	2	26	1	1,2,3	45	Steel	1/4"+1/4"	52
Off-gas heater (1)	2	26	1	1,2,3	45	Steel	1/4"+1/4"	52
HEPA filter (1)	2	4	1	1,2,3	45	Steel	1/4"+1/4"	8

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 25)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 26)	THICKNESS	PERSON HOURS PER YEAR
Nitric acid distillation column (1)	2	26	1	12,13	50	Steel	1/4"	52
Nitric acid reboiler (1)	2	26	1	12,13	40	Steel	1/4"	52
Nitric acid condenser (1)	2	26	1	12,13	25	Steel	1/4"	52
Condensate cooler (1)	2	26	1	12,13	25	Steel	1/4"	52
Ammonia dissociator (3)	2	26	3	12,13,24	110	Steel	1/4"	156
Boiler, Water Systems, and other Utilities	2	52	3	22	200	Wood	3/4"	312
HVAC equipment	2	520	1	12	30	Steel	1/4"	1040
Waste water treatment equipment	1	2190	1	2,5	50	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	6,7	120	Steel	3/4",1.5"	2190
Admin building	1	1000	1	2,5	50	Steel	1/4"	1000
								17776

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 25)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 26)	THICKNESS	PERSON HOURS PER YEAR

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UF6 reactor; there are 2 reactors.
7) UF4 product bin; there are 2 bins.
8) UF4 storage bin.
9) A single drum of UF4.
10) There are up to 1 weeks supply of UF4 in the Interim Storage Area = 345 drums.
11) Inventory of UF4 in Retort Filling Area,
12) There are 54 reduction furnaces.
13) A uranium derby.
14) Raw slag bin
15) Uranium pellet bin.
16) Uranium casting furnace
17) Water cooling station; capacity = 83 derbies.
18) Air cooling station; capacity = 33 derbies.
19) Derby roasting furnace; capacity = 8 derbies. There are 2 furnaces.
20) Derby quench tank; capacity = 8 derbies.
21) Derby drying oven; capacity = 4 derbies.
22) There are up to 33 uranium derbies in interim storage.
23) There are up to 3000 uranium derbies in the storage building.
24) Inventory in water cooling station, breakout stations, sorting, jaw crusher, and quench tank.
25) Average of 2 hours per week on conveyor systems
Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
10 hours per week on HVAC components
6 hours per day on waste water treatment components
6 hours per day on sanitary waste treatment components
1000 hours per year on the administration building
26) Materials do not include walls between operating areas.
27) Loaded filter/bag.

Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

Section 6.10

Continuous Reduction to Uranium Metal Facility

Draft Engineering Analysis Report
Depleted Uranium Hexafluoride Management Program

Section 6.10
Continuous Reduction to Uranium Metal Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into a uranium metal alloy product (97% uranium and 3% iron by weight) and byproducts magnesium fluoride (MgF_2) and hydrofluoric acid (HF). Due to its high density, the uranium metal product is a principal option for uranium use, particularly as a radiation shielding material. UF_6 defluorination is achieved by reduction to UF_4 with hydrogen. Anhydrous HF is recovered as a saleable material to industry. Uranium metal product is produced by the continuous reduction of UF_4 with magnesium metal.

Process Summary

The standard industrial route for the production of uranium metal is a batch process using magnesium metal (Mg) to reduce uranium tetrafluoride (UF_4) to the metal and magnesium fluoride (MgF_2) byproduct. The uranium tetrafluoride is generated by the hydrogen reduction of uranium hexafluoride (UF_6). The metallothermic reduction process described here involves the same chemistry, but the reactor is operated on a continuous basis. The reactants are fed into a vertical reactor maintained at approximately 1000°C. Due to its higher density, the molten uranium metal forms a layer at the bottom of the reactor where it is withdrawn; the molten MgF_2 forms an intermediate layer where it is separately withdrawn; and the molten Mg floats on the top. In addition to the reactants, the feed to the system contains iron (Fe) metal and an inert salt. Their addition is principally to reduce the system temperature, i.e., the Fe alloys with the uranium and lowers its melting point, while the diluent salt lowers the melting point of the MgF_2. This leads to improved materials compatibility and enables the system to operate at below atmospheric pressure. The uranium metal (alloy) product contains 3 wt% Fe. This iron content is acceptable for radiation shielding applications using uranium metal.

The molten uranium metal product is cast into ingots. The assumption is the ingots would be shipped to a separate manufacturing facility where they would be melted and recast into annular radiation shields. However, integration of the conversion and manufacturing processes into one facility would eliminate a casting and a melting step with substantial cost savings resulting.

1.0 DUF_6 Conversion Facility - Missions, Assumptions, and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Continuous Reduction to Uranium Metal Conversion Facility converts depleted UF_6 into uranium metal for use (e.g., shielding).

1.2 ASSUMPTIONS AND DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or rail. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three months supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure with an average isotopic composition as follows: 0.001% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinders, the short-lived daughter products of U-238, Th-234 and Pa-234m, are in equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- The uranium content in the slag is less than 90 ppm (<35 pCi/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is 7,000 hours based on a plant availability factor of 0.8.
- For the Continuous Reduction to Uranium Metal process, two reactor trains are needed for the conversion from UF_6 to UF_4, and three reactor trains are needed for UF_4 reduction to metal. The salt processing and support systems can be accomplished with a single train.
- The anhydrous HF produced in the process is shipped off-site in rail tank cars or tanker trucks. Indoor storage of one month's production is provided on site.

- Uranium metal product is packaged in wooden boxes, and MgF_2 and CaF_2 products are packaged in 55 gallon drums. Indoor storage space for one month's production is provided on site.
- On-site storage of one month's supply of magnesium metal, ammonia, sodium chloride, lime, and iron is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

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

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities", as defined in DOE Order 6430.1A, and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- HF Storage Building
- Uranium Product Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility, including the following:

- Mg Metal Storage Building
- MgF_2 Storage Building
- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF_6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20-year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

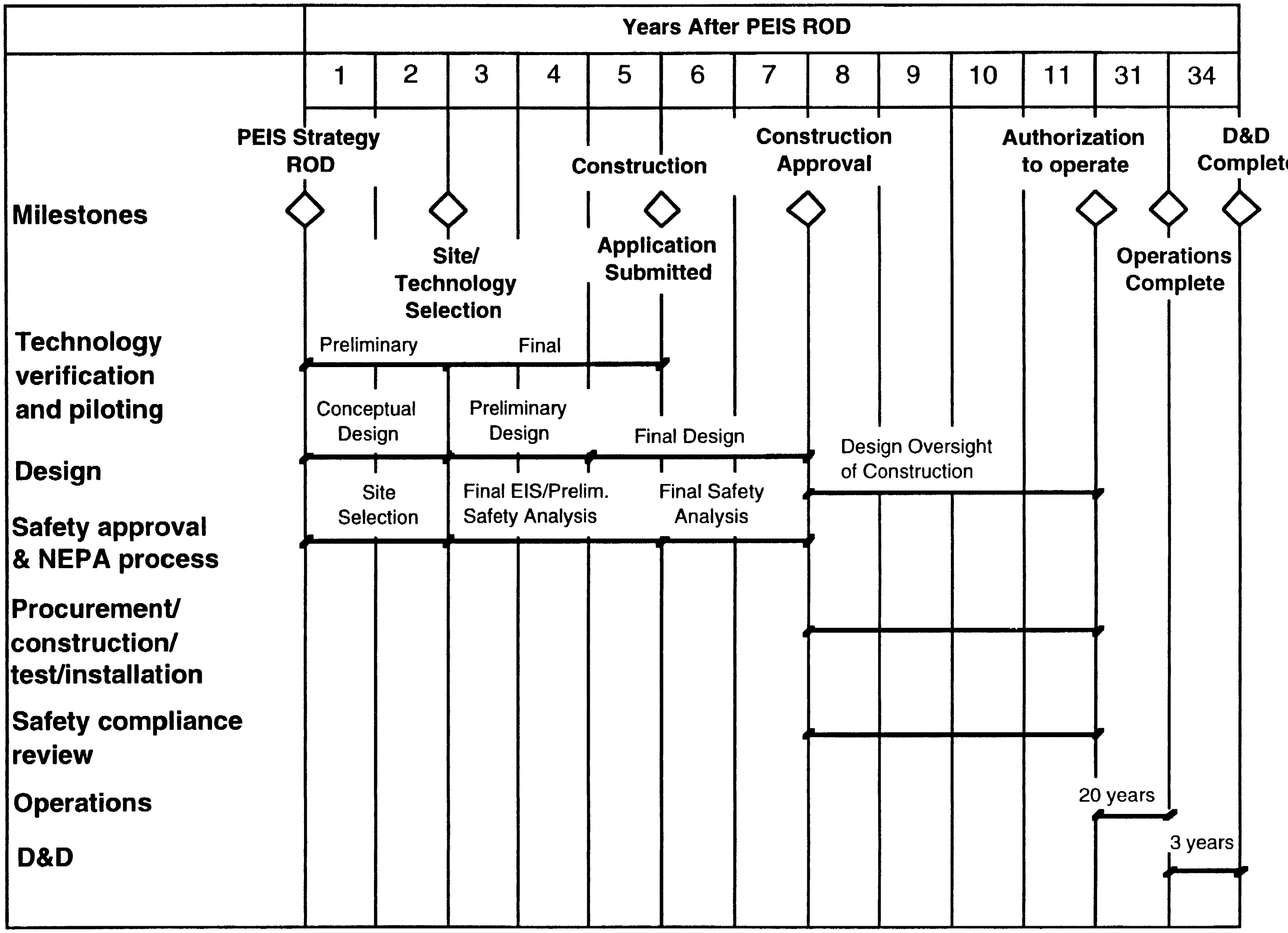


Figure 1-1 Preliminary Project Schedule

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

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

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, and guidelines, as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable Nuclear Regulatory Commission (NRC) regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*, DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, *National Environmental Policy Act.* Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection*. Also, NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders,* provides requirements applicable to the facilities handling and storing magnesium.

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements;* the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

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

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process include the following:

- The continuous reactor for UF_4 reduction to metal requires further engineering development, including significant scaleup.
- The separation of NaCl from MgF_2 for recycling uses conventional process equipment; however, this application has not been demonstrated.
- It is assumed that MgF_2 with a uranium concentration of 90 ppm or less (35 pCi/g or less) is produced in the process. It is assumed that an exemption for free release to a sanitary landfill could be obtained.
- Due to the pre-conceptual nature of the facility design, design details of process and support system equipment and components as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment, system, and facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF_6 Conversion Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium metal and magnesium fluoride (MgF_2) by reduction with hydrogen to UF_4 and subsequent reduction with magnesium to uranium metal. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the process building in a continuous process to produce UF_4, which is then reduced in a second continuous process to uranium metal. The uranium product is packaged in crates and stored on-site until it can be transported to another site for subsequent disposition (e.g., use). Anhydrous HF produced in the reaction is assumed to be shipped offsite for sale. MgF_2 byproduct is assumed to be disposed of in an ordinary landfill.

2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2-2, Plot Plan.

The plot plan shows the major structures on the site, as follows:

- Process Building
- HF Storage Building
- Mg Metal Storage Building
- Uranium Product Storage Building
- MgF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings, including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site.

Note: The size, number, and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.

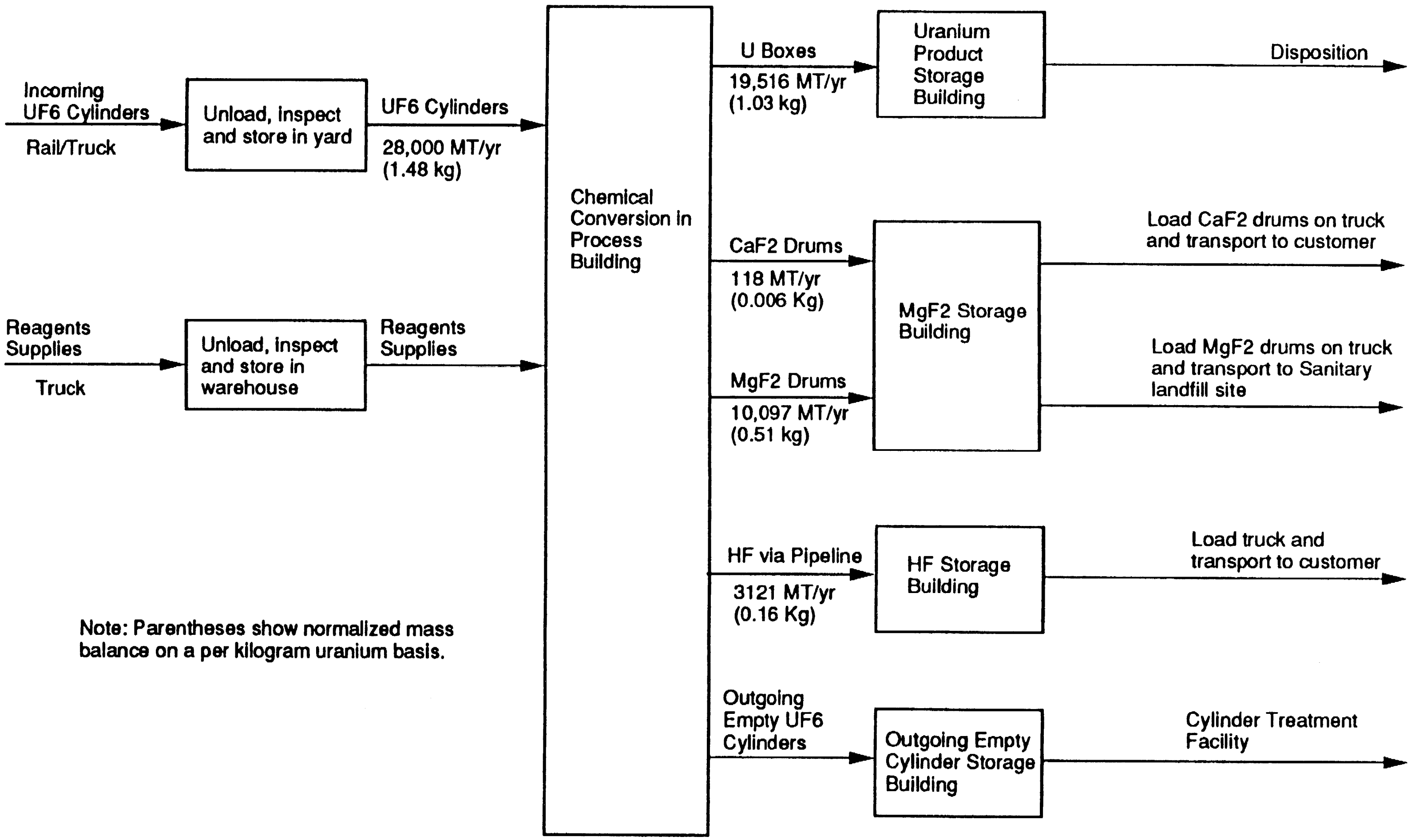


Figure 2-1 Continuous Reduction to Uranium Metal Material Flow Diagram

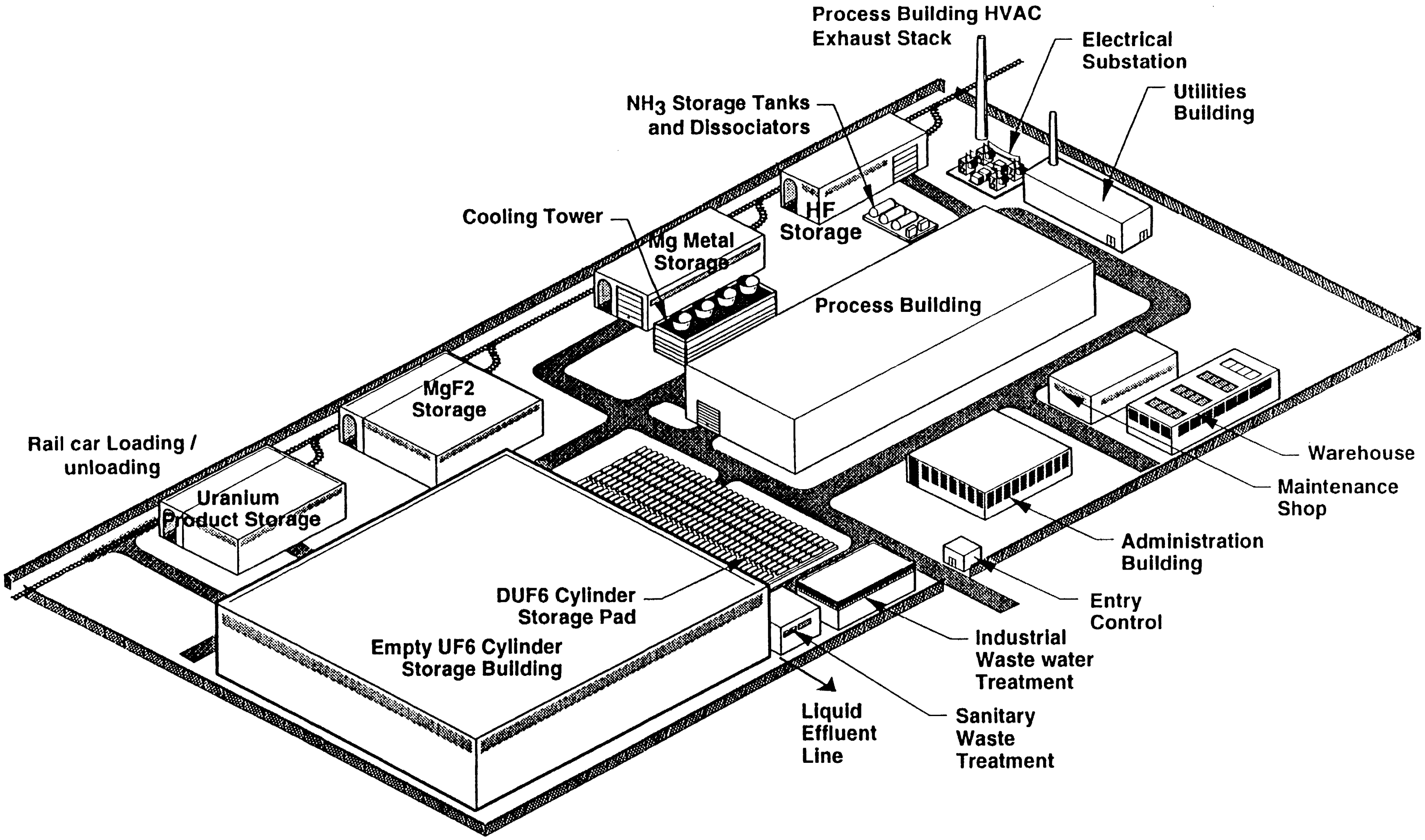


Figure 2-2 Plot Plan
Continuous Reduction to Uranium Metal

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	53,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
HF Storage Building	5,400	1	No	Yes	NA / HH	Reinforced Concrete
Mg Metal Storage Building	7,500	1	No	No	General	Metal Frame
Uranium Product Storage Building	9,400	1	Yes	Yes	HC2 / MH	Metal Frame
MgF_2 Storage Building	15,500	1	No	No	General	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	8,000	1	No	Yes	General	Metal Frame
Administration Building	10,000	1	No	No	General	Metal Frame
Maintenance Shop	6,000	1	No	Yes	General	Metal Frame
Warehouse	10,500	1	No	Yes	General	Metal Frame
Industrial Waste Building	5,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	2,000	1	No	No	General	Metal Frame
Cooling Tower	7,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard

2.1.3.1 Process Building

The layout, sections, and equipment arrangements for the Process Building are shown in Figures 2-3 through 2-6. The building is a two-story reinforced concrete structure classified radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where significant quantities of UF_6 and HF are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas, and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems, such as the heating, ventilating, and air conditioning (HVAC) systems and emergency electric power systems. HVAC system design is described in Section 2.2.5.

2.1.3.2 HF Storage Building

Due to the presence of a large inventory of HF, the HF Storage Building is classified as a nonradiological, chemically high hazard (HH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is a one-story reinforced concrete structure providing space for tanks that store one month's production of HF. The facility is provided with a rail car loading bay and space for the required storage tanks. An air refrigeration system is provided to maintain temperatures in the building in the range of 45 to 55 °F to limit vaporization of HF in the event of a spill. Also, a water spray system and floors surrounded by dikes are provided to mitigate the effects of an HF spill.

2.1.3.3 Uranium Product Storage Building

The Uranium Product Storage Building is a one-story metal-frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility, as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse that provides space for one month's production of uranium metal product. A zone 2 HVAC system with filtered exhaust air is provided (See also Section 2.2.5)

2.1.3.4 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three

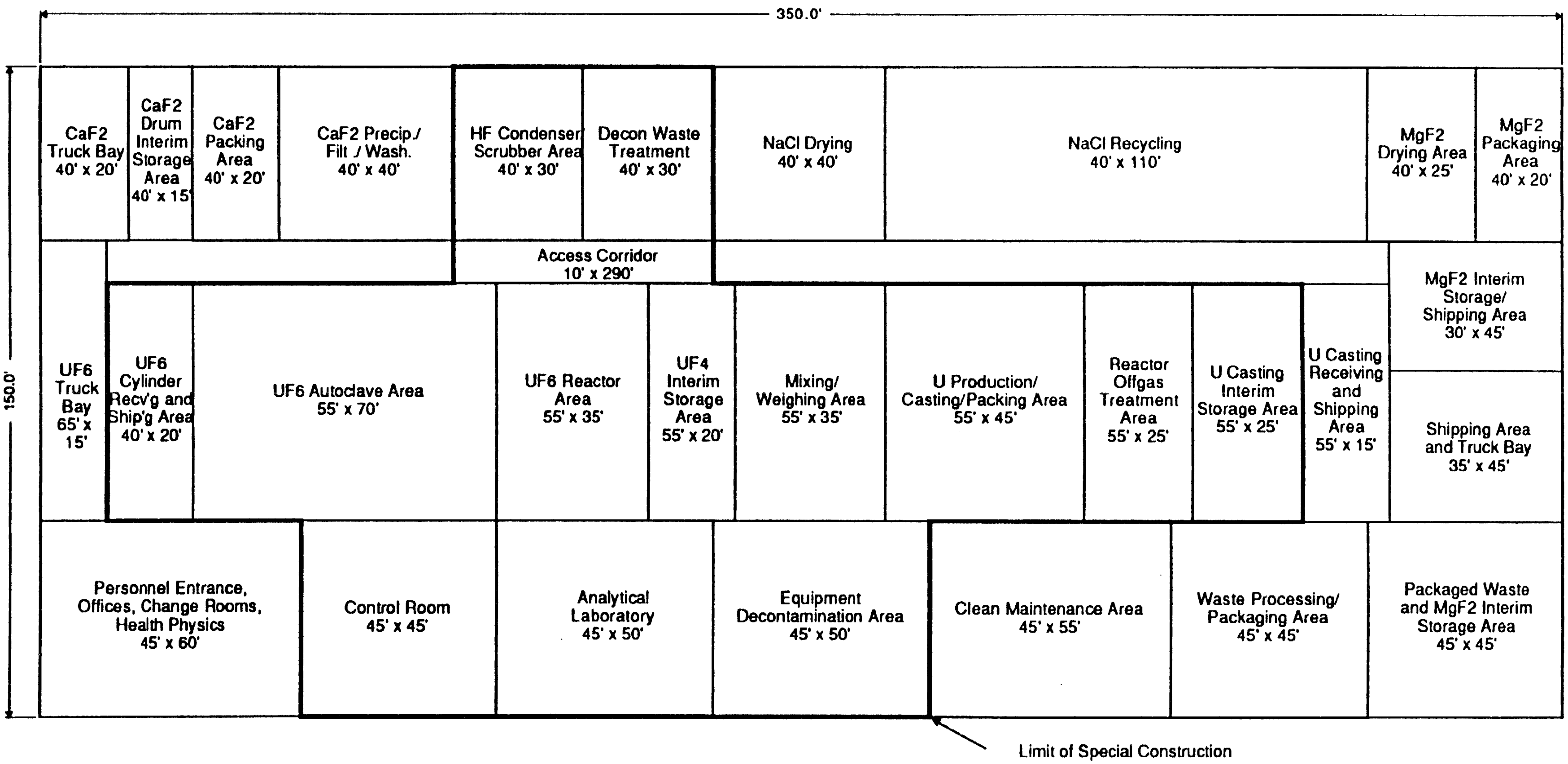


Figure 2-3 Process Building Layout
Continuous Reduction to Uranium Metal

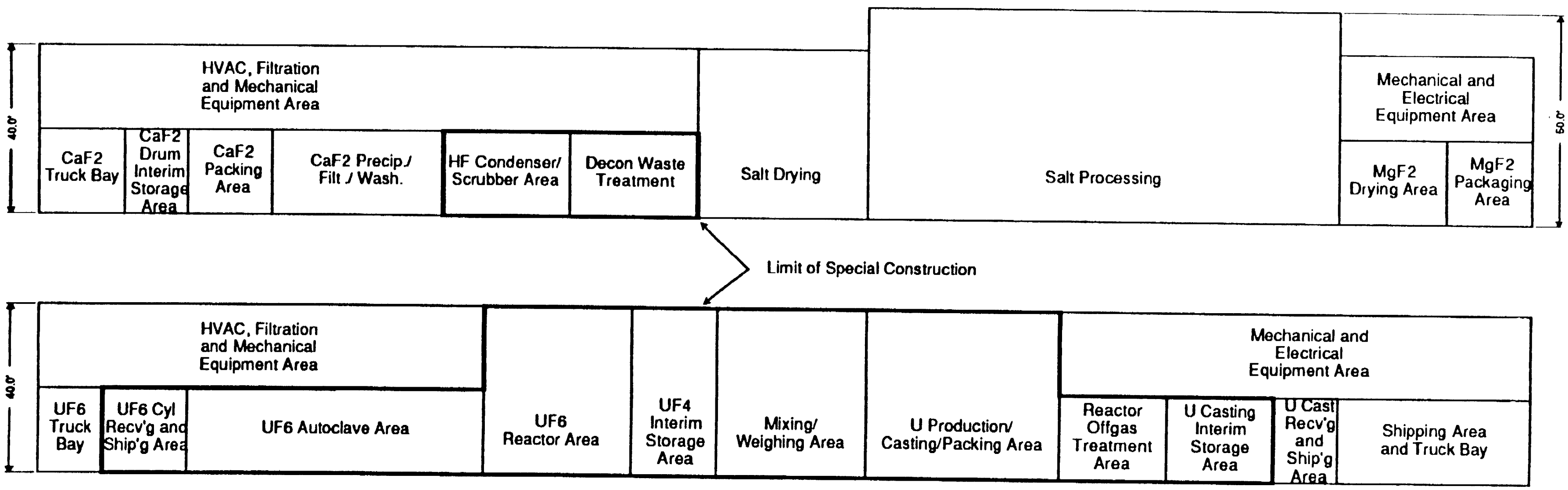
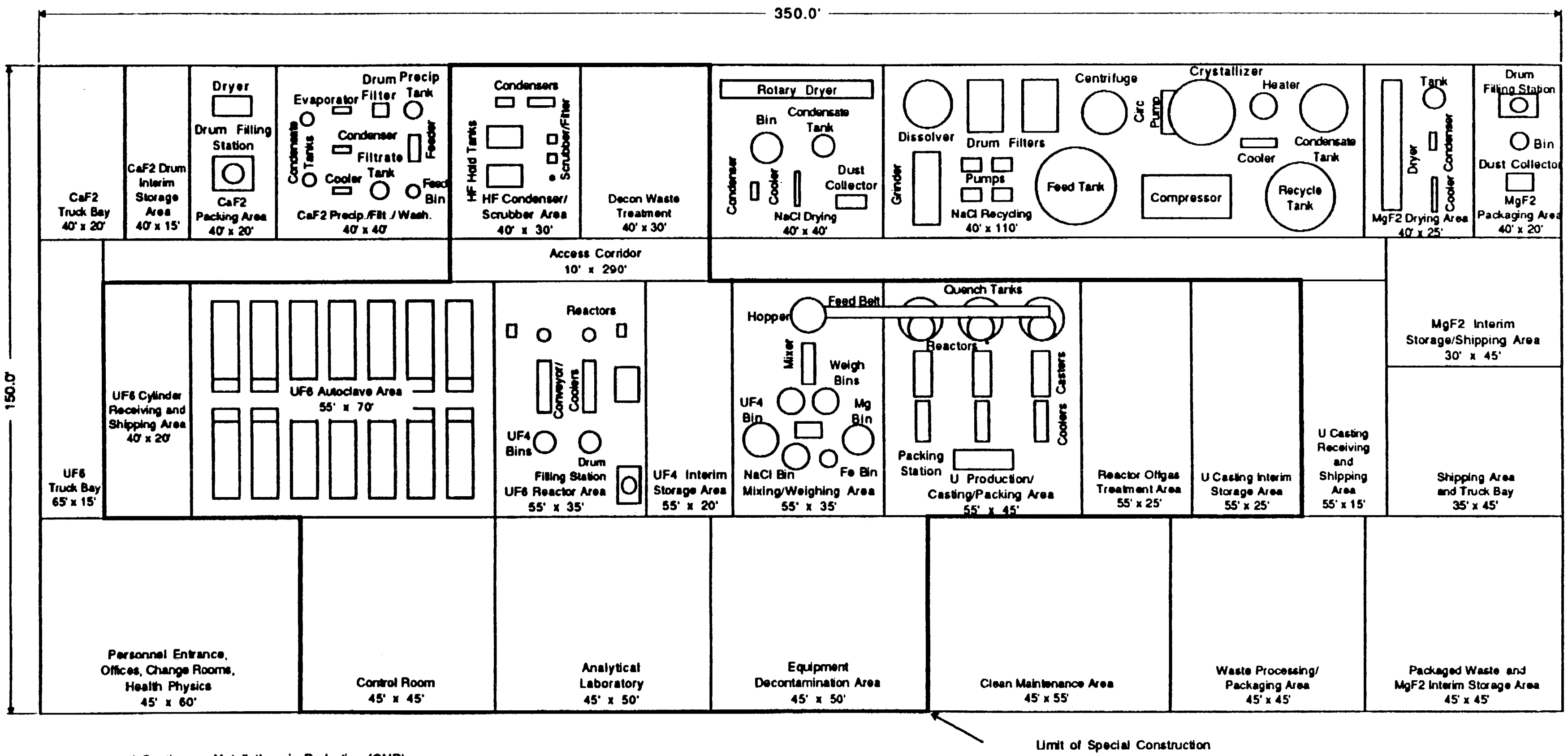


**Figure 2-4 Process Building Sections
Continuous Reduction to Uranium Metal**



* Continuous Metallothermic Reduction (CMR)

Figure 2-5 Process Equipment Arrangement - Plan
Continuous Reduction to Uranium Metal

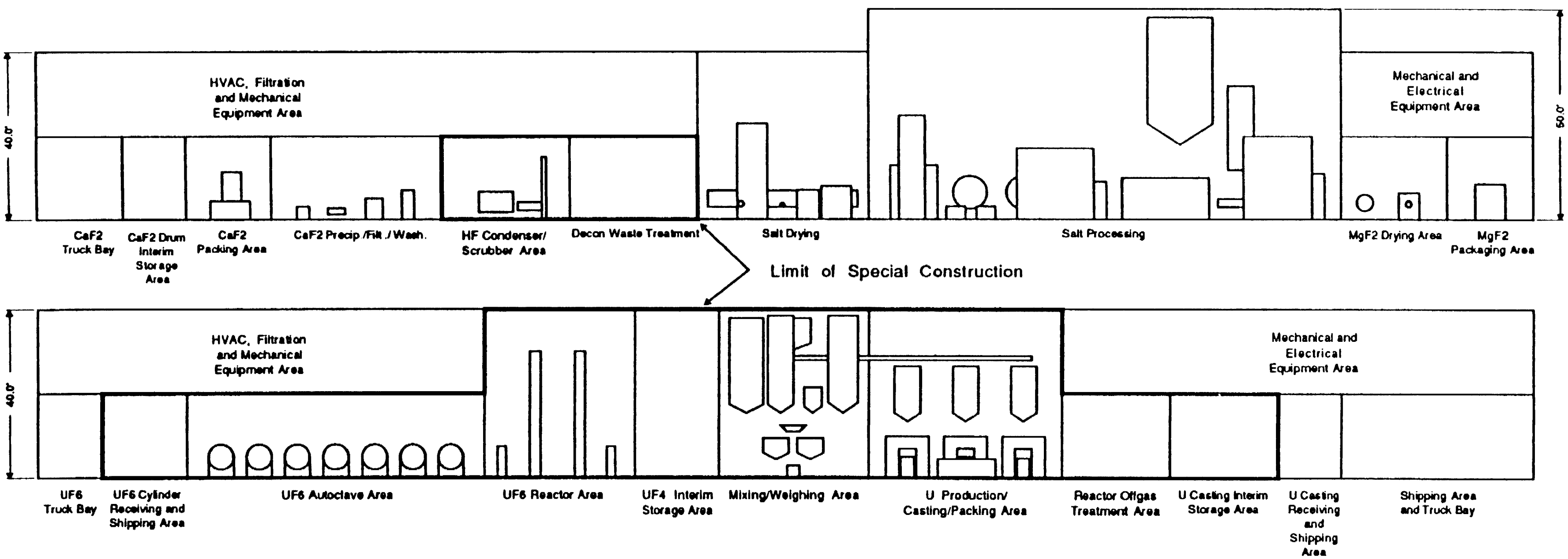


**Figure 2-6 Process Equipment Arrangement - Sections
Continuous Reduction to Uranium Metal**

months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.5 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the DUF_6 Continuous Reduction to Uranium Metal Conversion Facility includes the following facilities and systems (facilities are shown on Figure 3-1, Site Map):

A metal-frame Mg Metal Storage Building providing storage for one month's supply of magnesium. The facility includes the fire protection features required by NFPA 480.

A metal-frame MgF_2 Storage Building provides storage of one month's production of MgF_2 and CaF_2.

A metal-frame general-use Utilities Building houses raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling and steam heating boiler systems.

A metal-frame or masonry Administration Building houses the facility support personnel.

A metal-frame general-use Maintenance Shops Building for housing clean maintenance and repair shops.

A 32 MM BTU/hr multiple cell, wood construction, induced-draft, crossflow-type cooling tower and a 3,200 gpm cooling tower water circulation system provides cooling for both the process and HVAC systems

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility accommodates the receipt, treatment, and disposal of noncontaminated chemical, liquid, and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown, and cold chemical area liquid effluents, will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility is provided with a capacity of approximately 3,700 gpd.

Compressed air systems, including plant air, instrument air, and breathing air include a single set of two redundant 300 cfm reciprocating air compressors for the plant and instrument air systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in desiccant-type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

A 5,000 cfh hydrogen/nitrogen supply system consisting of three 15,000 gal steel ammonia storage tanks and three ammonia dissociators to supply hydrogen and nitrogen to the UF_6 reduction reactors.

Building HVAC systems use a central chilled water system for building cooling. Three 50% capacity, 360 ton centrifugal water chillers, and three 600 gpm circulating pumps are provided. A steel stack serves the Process Building HVAC exhaust systems. The steam plant boiler vents through a dedicated steel stack (see Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant in the Support Utilities Building produces steam for process uses and for building heating by the HVAC systems. The plant produces 20,000 lb/hr of 50 psig steam, which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration, and chlorination. The demineralized water is used in the process and for steam boiler feedwater (see also Figure 5-1).

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The electrical substation has a design capacity of 6,000 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 500 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas that require special lighting for night-time operation include the UF_6 cylinder storage pad areas, the rail spur area, the utility area, and the site entry control area.

Site security fencing as shown on Figure 3-1, Site Map, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control, and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public, and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as the following:

- Barriers to contain uncontrolled hazardous material or energy release
- Preventive systems to protect those barriers

- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Double HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Condensation Areas
Uranium Product Storage Building	Zone 2 - Moderate Hazard Building	Single HEPA Filters	PC-3 for DBE & DBT	
HF Storage Building	Zone 1 - High Chemical Hazard	Conventional	PC-4 for High Hazard Areas	Automatic water spray and shutdown of HVAC system upon HF leak
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
NH_3 Storage Tanks	NA (Located Outdoors)	NA	Per ANSI Std. K61.1, Section 5.2	Vehicle Barriers, Diked Area, Emergency Equip., etc. per ANSI Std. K61.1
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1 Natural Phenomena

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

- Earthquake
- Tornado
- Flooding.

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

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety-class structures, systems, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.2 Tornado

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Flood

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

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

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

- All buildings are subdivided by fire-rated barriers to limit the maximum possible fire loss and to protect life by providing fire-rated escape routes for operating personnel
- Fire detection and alarm systems are provided in all buildings
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.
- Automatic fire sprinkler systems are used throughout the facilities, except in areas where magnesium metal is stored and handled, per NFPA 480.
- The Mg Metal Storage Building includes suitable fire extinguishing agents, such as approved Class D agents per NFPA 480. Automatic sprinkler systems are prohibited in areas used to store magnesium metal per NFPA 480.

2.2.3 Materials Accountability and Plant Security

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3), and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., UF_4 handling, uranium casting, container loading operations, and UF_6 sampling stations).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.5 Ventilation Systems

The HVAC systems will use a combination of dividing the buildings into zones according to level of hazard, space pressure control, and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate, or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize autoclaves for confinement of DUF_6 if a cylinder is breeched or a leak develops during the transfer, once-through ventilation systems to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing gloveboxes and other uranium processing areas. The ventilation system for these rooms use once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters, and pressure control to assure air flow from areas of low hazard to areas of high hazard. The Uranium Product Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including MgF_2 areas, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a higher pressure than the rest of the building. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The UF_6 reactor and HF condenser areas and the off-gas scrubbing area of the Process Building have high chemical hazard potential, and will be served by a separate once-through air conditioning system. HF monitors in these rooms will automatically shut down the ventilation system and isolate the room in the event of a leak of HF.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on Figure 3-1, Site Map. This figure also identifies the effluent air release points (ventilation and boiler stacks).

Table 2-3 summarizes the characteristics of the effluent air release points.

Table 2-3, Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	104	80	60
Boiler	100	26	500	60

3.0 Site Map and Land Use Requirements

3.1 SITE MAP

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to the facility and Uranium Product, HF, and MgF_2 from the facility. Air emission points are shown from the Process Building ventilation exhaust stack and the facility boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 LAND AREA REQUIREMENTS DURING OPERATION

As shown in Figure 3-1, the total land area required during operations is approximately 670,000 ft^2 or about 15.4 acres.

3.3 LAND AREA REQUIREMENTS DURING CONSTRUCTION

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 26.4 acres. Construction areas required in addition to the site structures and facilities are as follows:

- A construction laydown area for temporary storage of construction materials, such as structural steel, pipe, lumber for concrete forms, and electrical conduit
- Temporary construction offices for housing onsite engineering support, construction supervision, and management personnel
- Temporary parking for construction craft workers and support personnel
- Temporary holding basins for control of surface water runoff during construction
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

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

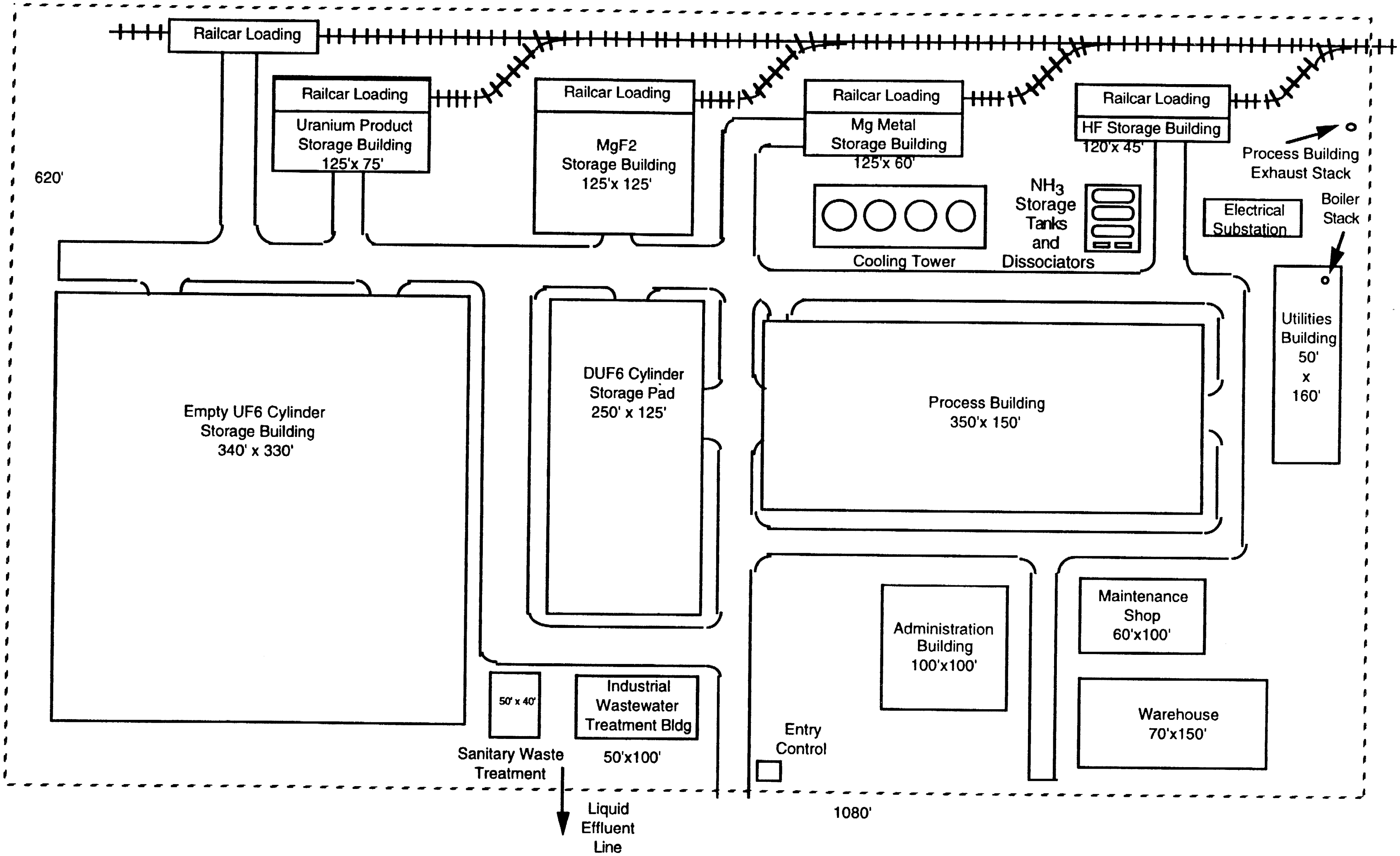


FIGURE 3-1 SITE MAP
CONTINUOUS REDUCTION TO URANIUM METAL

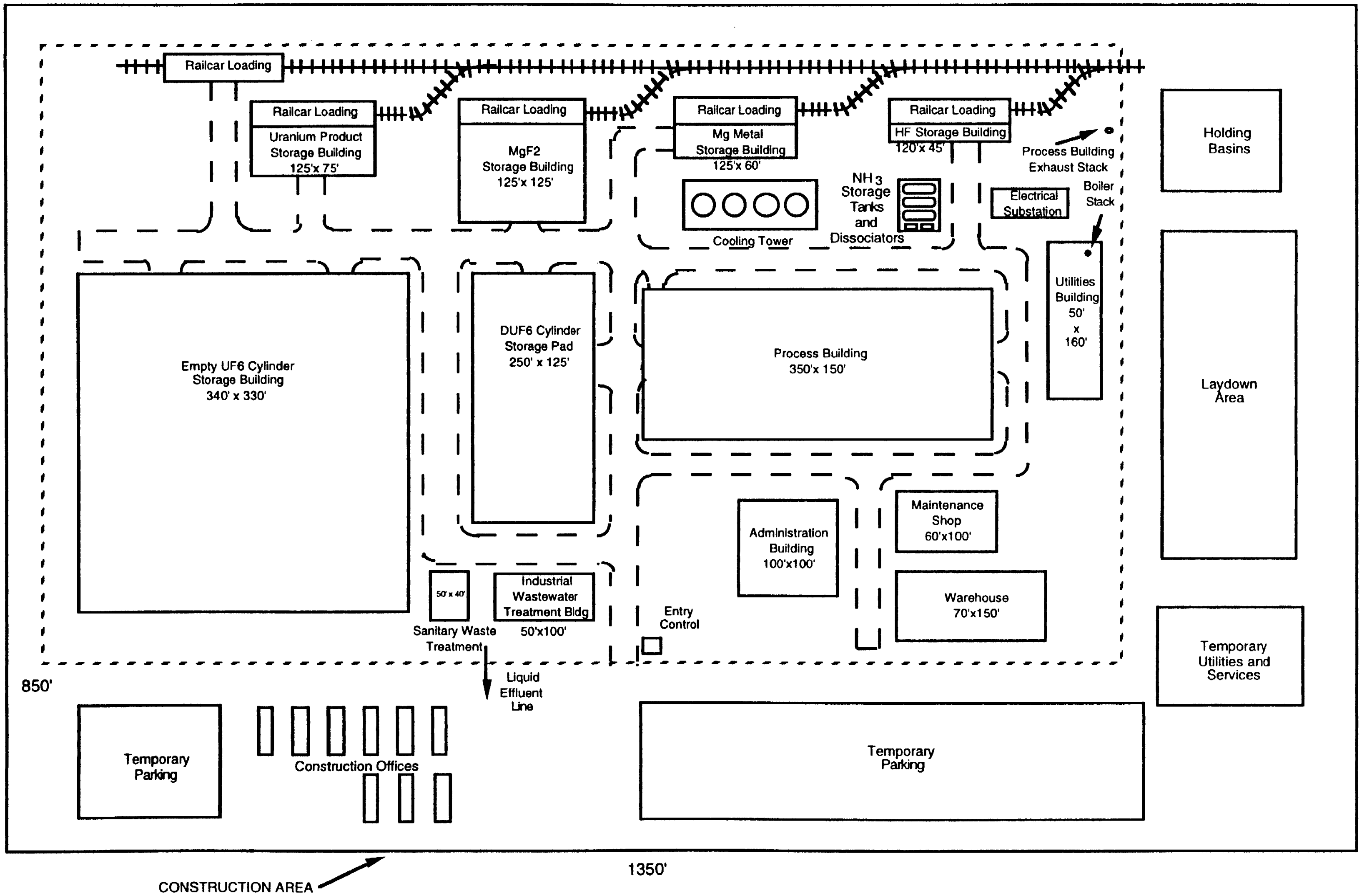


**FIGURE 3-2 SITE MAP DURING CONSTRUCTION
CONTINUOUS REDUCTION TO URANIUM METAL**

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is reduced with hydrogen and magnesium in a two-step, continuous process to produce uranium metal alloy containing 3% iron, anhydrous hydrofluoric acid (HF), and magnesium fluoride (MgF_2). The uranium content of the MgF_2 is judged to be sufficiently low for the MgF_2 to be disposed of in an ordinary landfill. The process is shown in Figures 4-1 and 4-2. The material balance is in Appendix A.

The UF_6 is first converted to UF_4 in a continuous process. The UF_6 is vaporized using steam-heated autoclaves and fed to the reactor, where it is mixed with hydrogen and nitrogen. Solid UF_4 and gaseous HF are produced. The UF_4 is discharged from the reactor, cooled, and collected. Off-gas containing HF, unreacted hydrogen, and nitrogen is cooled in a condenser to recover HF. Uncondensed off-gas is sent to the HF scrubber system. The anhydrous HF recovered is stored and then loaded into railcars for shipment offsite to customers.

The remaining traces of HF in the off-gas are removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution. The CaF_2 precipitate is dried and packaged in drums for sale.

The UF_4 is reduced to uranium metal in a continuous reactor in which UF_4 is blended with magnesium, iron, and sodium chloride (NaCl) solids. The solids are continuously fed to a reduction reactor operating at 1000°C to produce the uranium metal alloy and MgF_2 by an exothermic reaction. The molten uranium metal drains into a continuous casting machine to produce 2 in. by 3 in. by 20 in. long billets. The billets are cooled, packaged, and sent to storage and shipping.

A molten MgF_2-NaCl salt drains from the reactor into a water-filled quench tank, where the salt solidifies and shatters. The salt slurry is size-reduced in a grinding mill and then transferred to a dissolution tank, where additional water is added to dissolve the NaCl. The MgF_2 , which is not soluble in water, is removed by filtration, dried, and packaged in drums for storage and disposal.

The dissolved NaCl solution is fed to a forced-circulation, mechanical recompression crystallizer to recover the NaCl. The crystallizer evaporates water from the solution to cause NaCl crystals to form. The NaCl product slurry flows from the crystallizer to a centrifuge, which separates and recycles the liquid to the crystallizer. The NaCl solids cake is dried, cooled, and recycled to the reduction reactor. The vapor from the crystallizer is compressed, condensed to heat the crystallizer, cooled, and reused in quenching and dissolution.

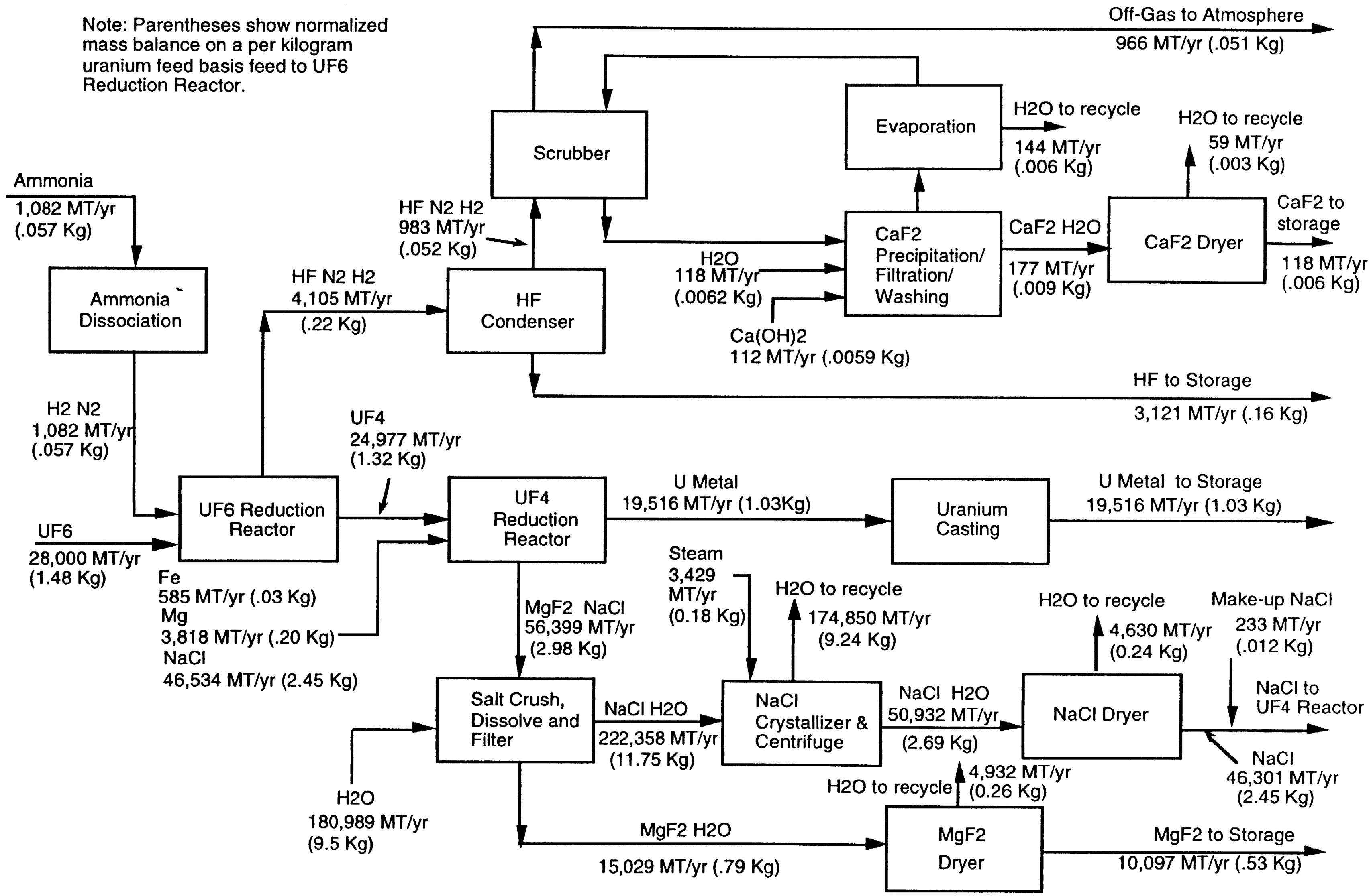


Figure 4-1 Continuous Reduction to Uranium Metal Block Flow Diagram

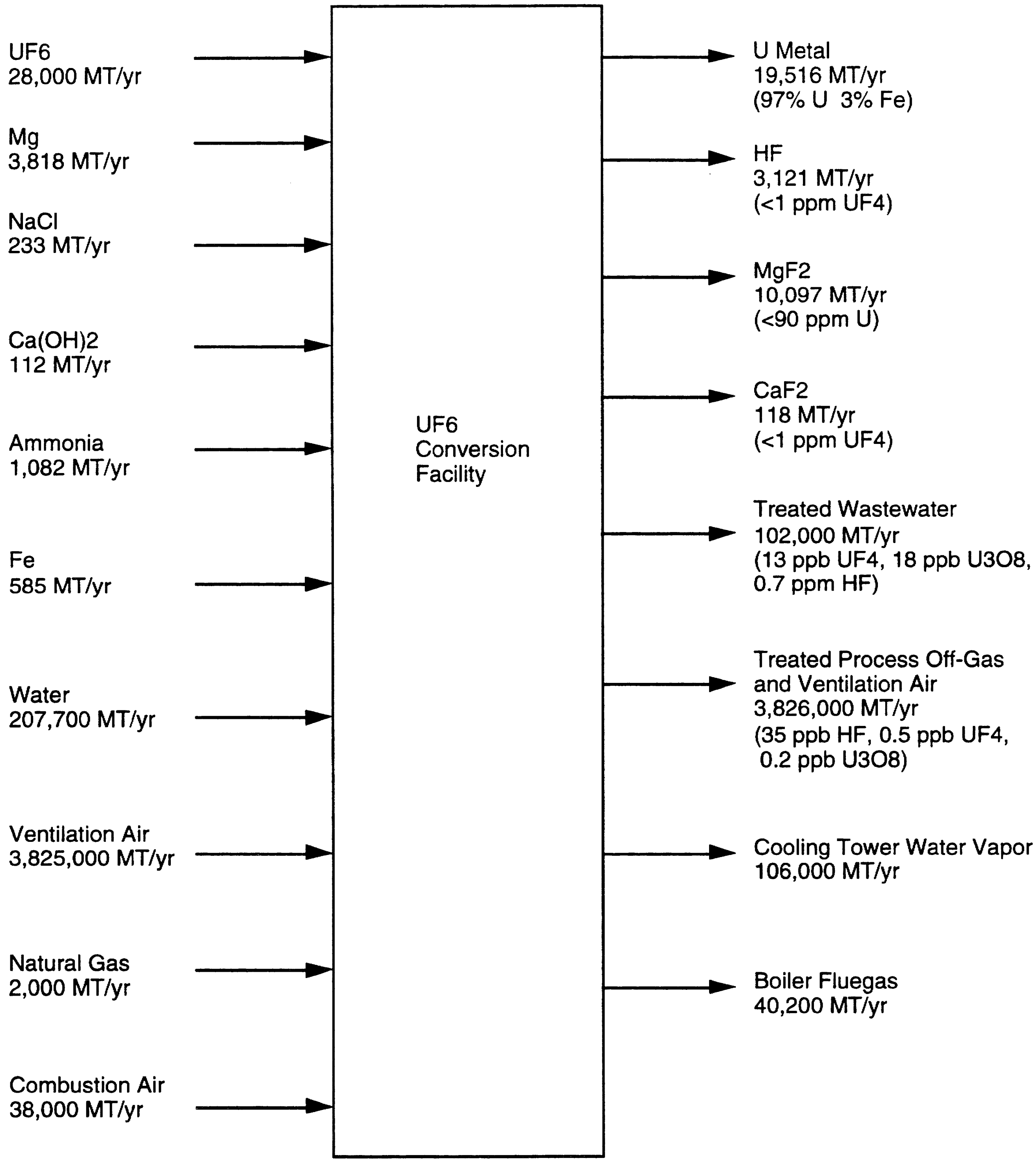


Figure 4-2 Continuous Reduction to Uranium Metal Input/Output Diagram

The facility has two reactor trains for the conversion from UF_6 to UF_4, and three reactor trains for converting UF_4 to U metal. The MgF_2 and NaCl recovery systems are single train. Critical equipment, such as blowers or filters, have spares installed in parallel. The conversion of UF_6 to UF_4 is similar to a process currently used in the uranium industry. The conversion of UF_4 to U metal in a continuous reactor has been demonstrated in laboratory and engineering-scale equipment. The crystallization of NaCl is similar to processes used in the salt industry.

4.1 UF_6 REDUCTION AND HF RECOVERY

The UF_6 Reduction Reactor converts UF_6 feed into UF_4 and HF in a tower reactor. The chemical reaction is $UF_6 + H_2 \text{--->} UF_4 + 2HF$. This system is shown in Figure 4-3.

Depleted UF_6 is received primarily in 14-ton cylinders, which are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in steam-heated autoclaves and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is heated and vaporized (sublimed) at 140°F. Gaseous UF_6 flows out of the cylinder and is fed by a compressor into a reactor tower. Eleven UF_6 cylinders feed simultaneously to provide the required feed rate of 8,800 lb/hr. Hydrogen reacts with the UF_6 to form solid UF_4 and gaseous HF. The reaction is exothermic, with the temperature in the tower ranging from 800 to 1150°F. The tower has electric heaters that keep the walls hot and has vibrators that intermittently dislodge UF_4 buildup on the walls.

Solid UF_4 is discharged from the reactor, cooled, and conveyed to a storage bin. There is also a drum loading station to provide interim storage of UF_4 in drums as necessary. After cooling, empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

The off-gas stream containing HF, unreacted hydrogen, and nitrogen flows through a cyclone and sintered metal filter to remove UF_4 particles. The off-gas is cooled to 100°F in a heat exchanger and flows through a refrigerated condenser operating at about -90°F to recover HF. Uncondensed off-gas flows to the HF scrubber system. The anhydrous HF condensate, which contains about 200 ppm water, is collected and sampled in a hold tank that is cooled with chilled water. Upon satisfactory analysis, the anhydrous HF is transferred via pipeline to a storage tank cooled with chilled water in the HF storage building. The HF is loaded into railroad tank cars or tank trucks for delivery to customers.

Hydrogen for the reactor is provided from a packaged ammonia dissociator unit. The chemical reaction is $2NH_3 \text{--->} N_2 + 3H_2$. Liquid ammonia is vaporized and fed to the dissociator, which decomposes the ammonia at 1600°F in a catalyst bed. The hydrogen/nitrogen mixture is fed to the reactor.

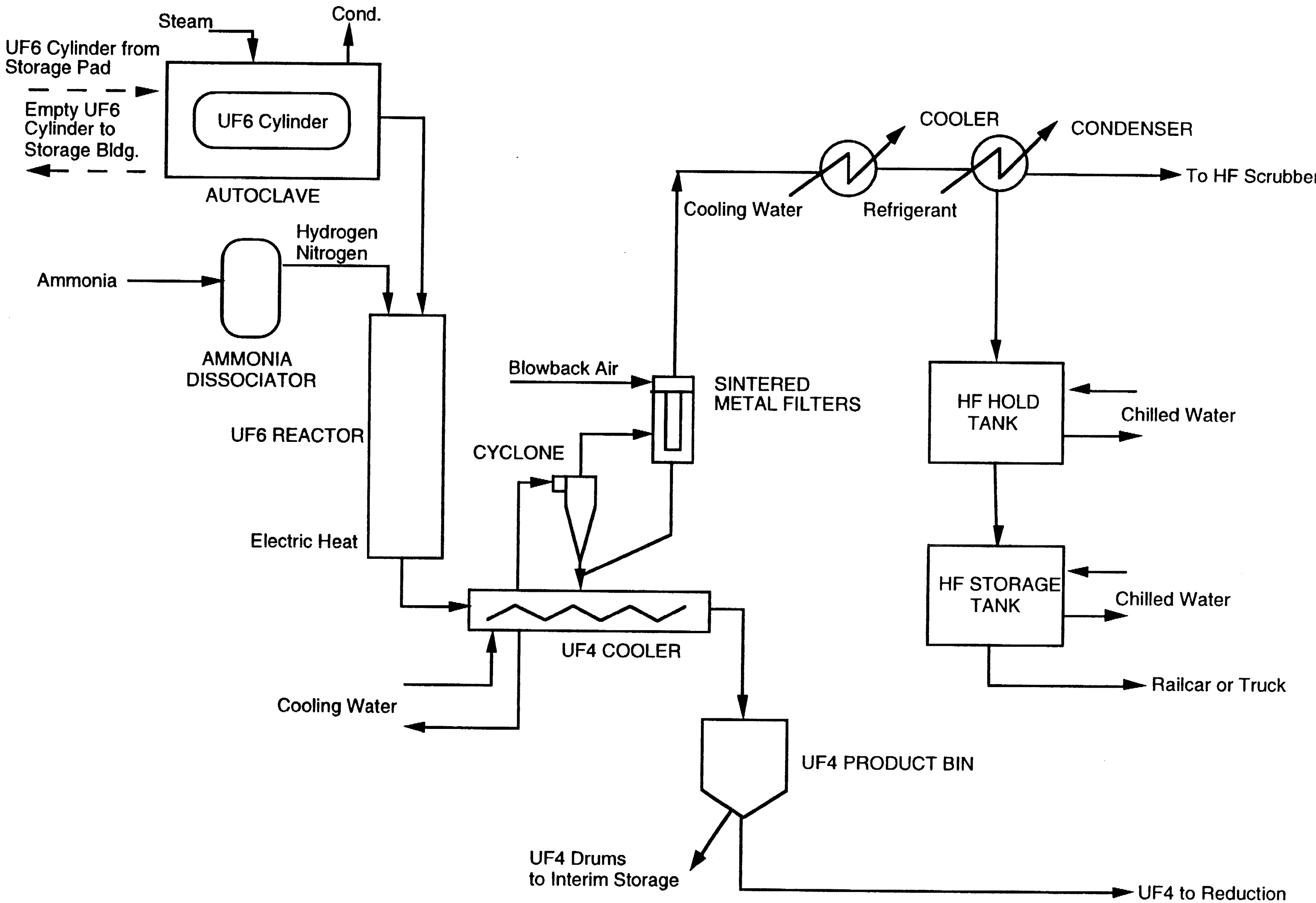


Figure 4-3 UF6 Reduction and HF Recovery Process Flow Diagram

Preliminary major equipment includes 14 autoclaves and UF_6 compressors, two 21 in. top dia by 35 in. bottom dia by 27 ft high Monel tower reactors, a 1 ft 6 in. dia by 6 ft long 200 ft^2 Monel off-gas cooler, a 2 ft dia by 6 ft long 250 ft^2 Monel off-gas condenser, two 5 ft dia by 8 ft long 1,100 gal steel HF hold tanks, four 8 ft dia by 48 ft long 18,000 gal steel HF storage tanks, three 8 ft dia by 40 ft long 15,000 gal steel ammonia storage tanks, and three 83 kW ammonia dissociators.

4.2 CONTINUOUS UF_4 REDUCTION TO METAL

UF_4 is reduced to uranium metal using magnesium metal. The chemical reaction is $UF_4 + 2Mg \text{ ---> } U + 2MgF_2$. Iron is added to produce a uranium alloy with 3% iron. The system is shown in Figure 4-4.

UF_4, magnesium, iron, and sodium chloride solids are fed into one of two weigh bins for feed makeup. Iron is added to lower the melting point of the uranium metal. Sodium chloride is added to lower the melting point of the MgF_2. The batched solids are discharged into a continuous-ribbon mixer for blending and conveyed to the reactor area.

A weigh belt feeder meters the solids feed into a reduction reactor operating at 1000°C to produce uranium metal product and MgF_2 by an exothermic reaction. The reactor is an insulated, graphite-lined vessel with electrical heating elements that supply heat for startup of the reactor and supplemental heat during normal operation. During operation, the reactor contains three layers of material: a molten magnesium layer floating on top, a molten salt zone with dispersed uranium metal, and a molten uranium metal layer at the bottom. Underflow baffles and overflow weirs allow for drainage of the molten uranium metal stream and the molten salt stream from the reactor. Off-gas from the reactor, which is primarily water vapor, argon purge, and particulates, is filtered and discharged to the Process Stack. The molten salt drains to the NaCl dissolution system.

The molten uranium metal drains into a continuous casting machine that consists of water-cooled iron molds linked together on a moving chain. The uranium is cast in an argon atmosphere to produce 2 in. by 3 in. by 20 in. long billets that weigh about 75 lb. The argon is recirculated through a cooling and cleanup unit. Billets are ejected from the mold by tipping, and are transferred to a conveyor for additional cooling. The billets are packaged in boxes, each containing 19 billets, and sent to storage and shipping.

The service life of a continuous reduction reactor is limited by erosion/corrosion of the graphite liner. It is assumed that the reactors have an 8 month service life, after which they are drained and disposed of as low level waste.

Preliminary major equipment includes an 8 ft dia by 23 ft high 1,000 ft^3 steel UF4 bin, a 7 ft dia by 23 ft high 800 ft^3 steel NaCl bin, a 6 ft dia by 22 ft high 550 ft^3 steel Mg bin, a 4 ft dia by 6 ft high 60 ft^3 steel Fe bin, two 6 ft dia by

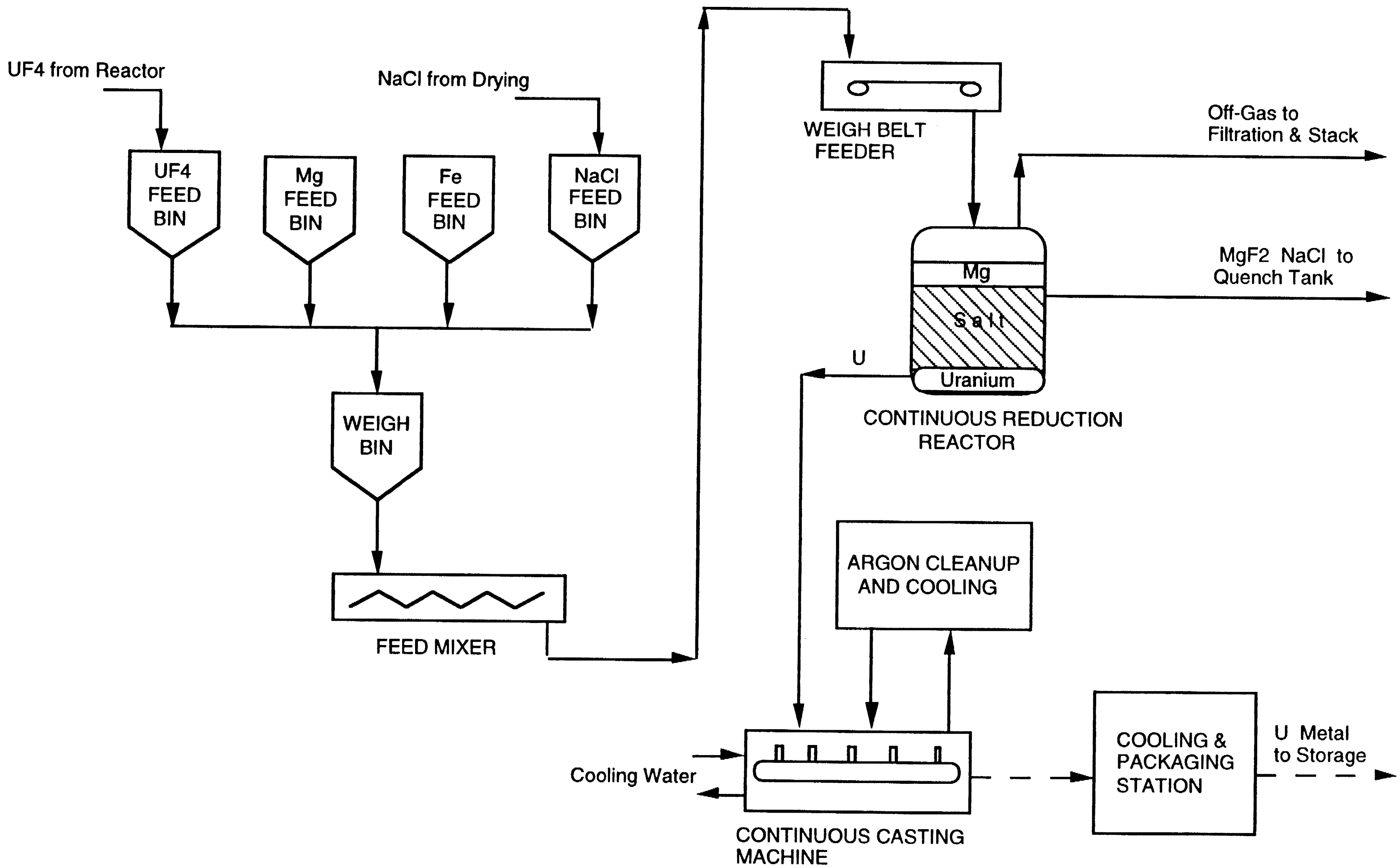


Figure 4-4 Continuous UF4 Reduction to Metal Process Flow Diagram

8 ft high 150 ft^3 steel weigh bins, a continuous-ribbon solids mixer, three 6 ft dia by 8 ft high reduction reactors, off-gas filtration equipment, three 4 ft by 10 ft by 4 ft high uranium casting machines, and a uranium billet packaging station.

4.3 NACL DISSOLUTION AND MGF_2 DRYING

The molten MgF_2-NaCl salt from the reactor is cooled and processed to separate the MgF_2 from the NaCl. The system is shown in Figure 4-5.

The molten MgF_2-NaCl salt drains from the reactor into a quench tank, where it mixes with a salt water slurry and fresh water. The molten salt cools, solidifies, and shatters into small pieces. The slurry recirculates through a heat exchanger for cooling. The slurry flows to a vertical stirred mill containing ceramic or metal balls that grind the salt into small particles to expose the NaCl for dissolution.

The ground slurry flows to a dissolution tank, where additional water is added and the slurry is agitated to dissolve the NaCl. The MgF_2 does not dissolve because it is not soluble in water. The MgF_2 is separated from the NaCl solution and washed with water in a rotary drum vacuum filter, then dried in a steam-heated rotary tube dryer. After cooling, the MgF_2 is packaged in drums and sent to the storage building. The NaCl solution from the drum filter is sent to the NaCl crystallization system.

Preliminary major equipment includes three 4 ft dia by 6 ft high 350 gal Monel quench tanks, three 2 ft dia by 6 ft long 350 ft^2 Monel quench coolers, a 6 ft by 17 ft by 25 ft high 50 hp vertical stirred grinding mill, a 11 ft dia by 13 ft high 9,000 gal Monel NaCl dissolution tank, two 8 ft dia by 12 ft long Monel rotary drum filters, a 4 ft 6 in. dia by 30 ft long 955 ft^2 MgF_2 rotary steam tube dryer, and a MgF_2 drum loading station.

4.4 NaCl CRYSTALLIZATION AND DRYING

Solid NaCl is recovered from solution by crystallization and recycled to the reduction reactor. The system is shown in Figure 4-6.

The dissolved NaCl solution from MgF_2 filtration is fed to a forced-circulation, mechanical recompression crystallizer for NaCl recovery. The crystallizer, operating at about 228°F and atmospheric pressure, evaporates water from the feed solution to form a slurry containing about 30% NaCl solids. A pump recirculates the crystallizer slurry through an external heat exchanger to supply heat for vaporizing the water. The NaCl product slurry flows from the crystallizer to a centrifuge for dewatering. The liquid is recycled to the crystallizer. The NaCl cake is dried in a rotary steam-heated dryer, cooled, and sent to the reduction reactor for feed makeup.

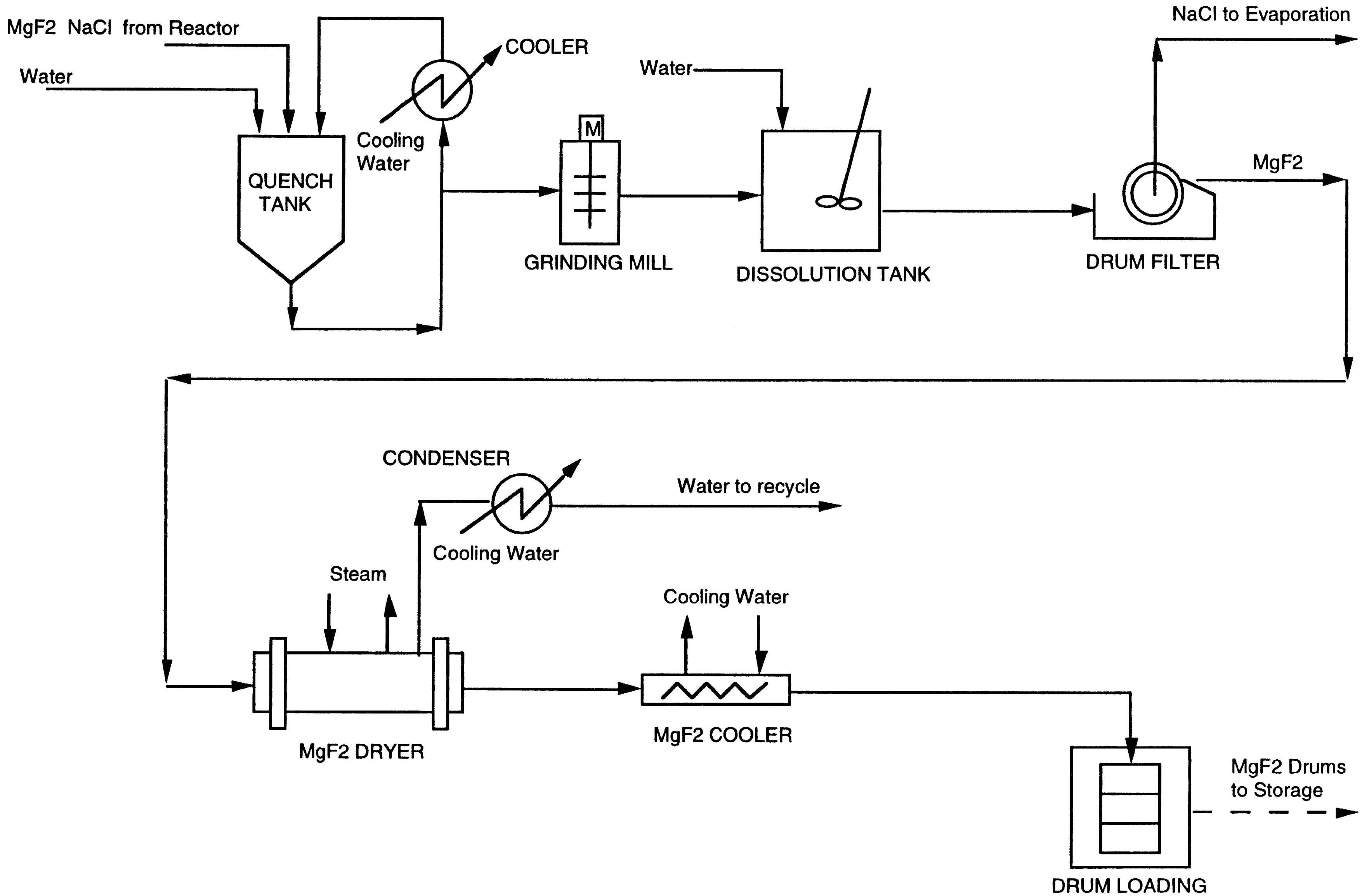


Figure 4-5 NaCl Dissolution & MgF2 Drying Process Flow Diagram

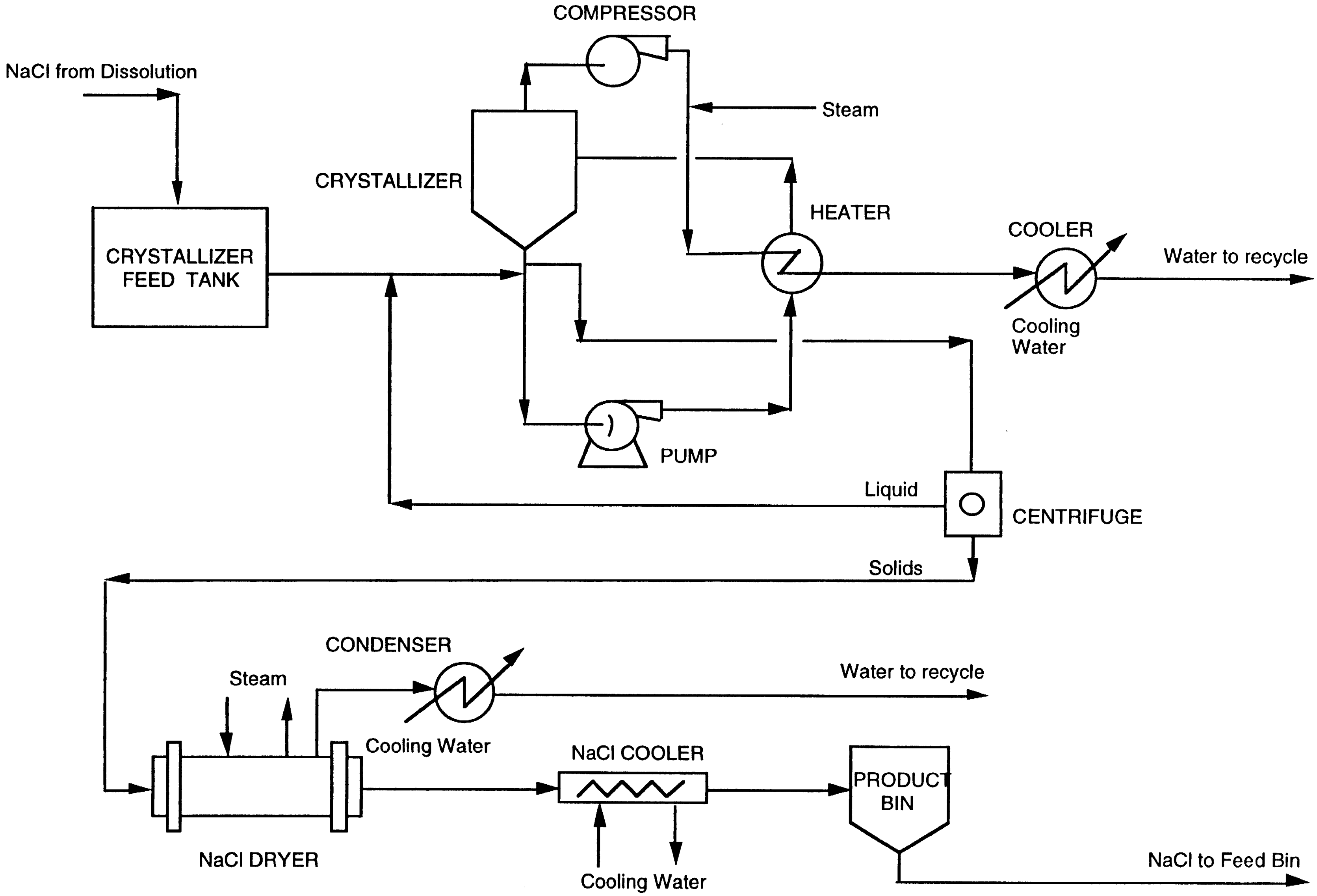


Figure 4-6 NaCl Crystallization and Drying Process Flow Diagram

The vapor from the crystallizer is compressed in a motor-driven, centrifugal compressor to about 25 psia. The vapor is condensed in the heat exchanger to provide heat to the crystallizer. The majority of the heat (>95%) is provided by the compressed vapor, with the remainder provided by boiler steam. The condensate is flashed, cooled, and reused in the NaCl dissolution system.

It is assumed that the NaCl solution does not contain significant impurities that could build up in the crystallizer or in the NaCl being recycled. To remove impurities, a purge stream would be periodically drawn from the crystallizer, evaporated, and dried or grouted for disposal.

The NaCl crystallization operation is energy-intensive. Depending on the cost of electrical power, steam, and other factors at the actual plant site, other types of crystallizers, such as a steam-heated, triple-effect crystallizer, may be more economical.

Preliminary major equipment includes an 18 ft dia by 17 ft high 32,000 gal Monel crystallizer feed tank, a 15 ft dia by 30 ft high Monel crystallizer, a 6 ft dia by 20 ft high 10,000 ft^2 titanium tube crystallizer heat exchanger, a 30,000 gpm 500 hp Monel crystallizer circulation pump, a 1,500 hp crystallizer vapor compressor, a 100 hp Monel NaCl centrifuge, an 11 ft dia by 11 ft high 7,500 gal steel condensate tank, a 16 ft dia by 20 ft high 30,000 gal steel recycle water tank, and a 4 ft 6 in. dia by 35 ft long 1,120 ft^2 Monel rotary steam tube dryer.

4.5 HF Scrubbing System

Off-gas from HF condensation is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The system is shown in Figure 4-7.

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction $HF + KOH \text{--->} KF + H_2O$. The treated off-gas is filtered, mixed with ventilation exhaust air to dilute the hydrogen to a safe concentration, and discharged to atmosphere. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction $2KF + Ca(OH)_2 \text{--->} CaF_2 + 2KOH$. A minimum level of KF is maintained in the scrub solution by adding less than the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out of the CaF_2 product and the packed bed scrubber.

The scrub solution slurry is filtered in a rotary drum vacuum filter or a pressure filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities and dried in a steam-heated rotary tube dryer. After cooling, the CaF_2 is packaged in drums and sent to the storage building.

The KOH and wash water filtrate are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and the water added for CaF_2 washing. The filtrate is then cooled and pumped back to the scrubber as scrub solution.

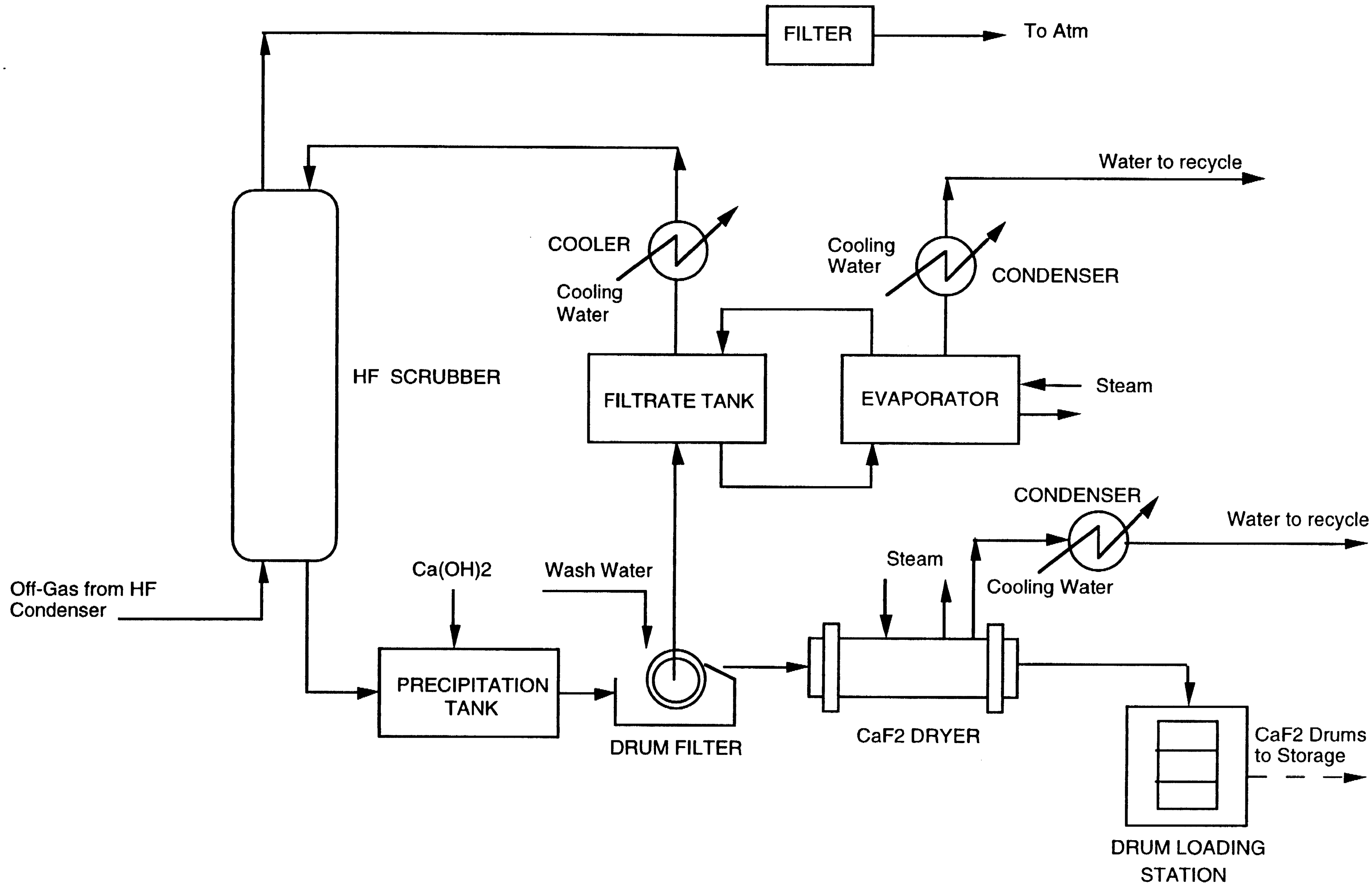


Figure 4-7 HF Scrubbing Process Flow Diagram

Preliminary major equipment includes a 1 ft dia by 15 ft high Monel HF scrubber with plastic packing, 4 ft dia by 5 ft high 500 gallon Monel precipitation and filtrate tanks, a 3 ft dia by 3 ft 6 in. long Monel rotary drum filter, a 1 ft 6 in. dia by 4 ft Monel evaporator/condenser unit, a 2 ft dia by 6 ft long steel rotary dryer, and associated tanks and pumps.

4.6 UF_6 Cylinder Handling Systems

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4.7 Waste Management

The primary wastes produced by the process are empty UF_6 cylinders, failed continuous metal reduction reactors, and nonhazardous MgF_2. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, and paints. Other radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing, packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low-level radioactive waste will be shipped to an off-site disposal facility. Hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

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

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	44 GWh	6.0 MW
Liquid Fuel	6,500 gals	NA
Natural Gas[2]	100×10^6 scf	NA
Raw Water	55×10^6 gals	NA

1 Peak demand is the maximum rate expected during any hour.
2 Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual water balance for the facility. This balance is based on the greenfield generic midwestern U.S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5-2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

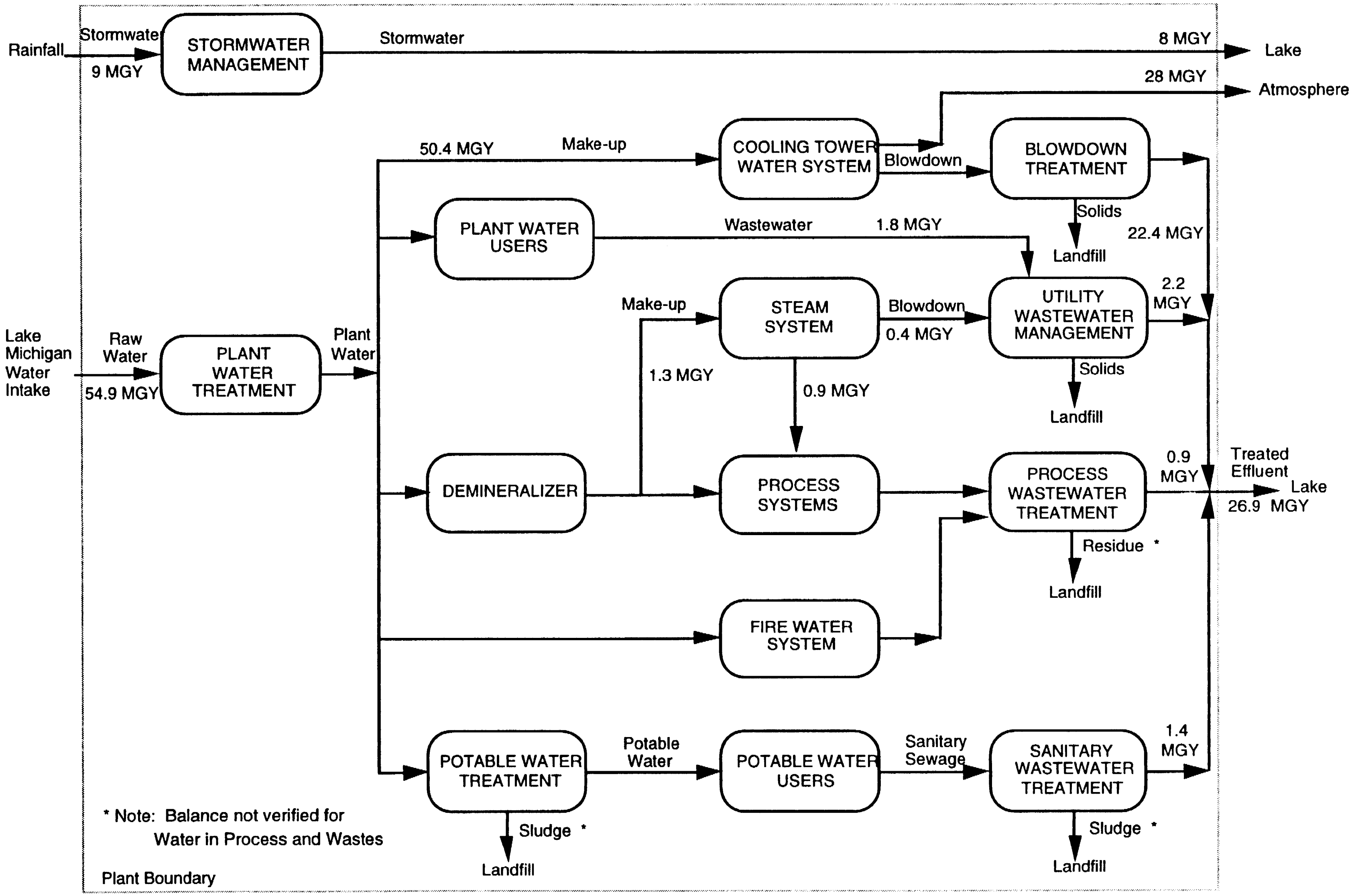


Figure 5-1 Preliminary Water Balance Continuous Reduction to Uranium Metal

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Magnesium (99.8% min., -10/+60 mesh)	8,400,000
Iron	1,300,000
Sodium Chloride	514,000
Calcium Hydroxide (Hydrated Lime)	250,000
Detergent	600
Liquid	
Ammonia (99.95% min. NH_3)	2,400,000
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	9,500
Sodium Hydroxide (50% NaOH)	7,500
Sodium Hypochlorite	5,300
Copolymers	9,300
Phosphates	930
Phosphonates	930
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (low-level radioactive and hazardous) Waste Containers (55 gallon drums & 56 ft^3 and 288 ft^3 boxes - see also Table 9-1)	549 drums 35 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6). The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14-ton DOT approved carbon steel containers.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

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

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	35,000 MWh	1.5 MW
Water	10×10^6 gal	700 gal
Solids		NA
Concrete	20,000 yd^3	
Steel (carbon or mild)	9,000 tons	
Electrical raceway	25,000 yd	
Electrical wire and cable	60,000 yd	
Piping	40,000 yd	
Steel decking	25,000 yd^2	
Steel siding	13,000 yd^2	
Built-up roof	22,000 yd^2	
Interior partitions	1,500 yd^2	
Lumber	5,400 yd^3	
HVAC ductwork	180 tons	
Special coatings	2,000 yd^2	
Asphalt paving	280 tons	
Liquids		
Fuel[2]	1.6×10^6 gals	
Gases		
Industrial Gases (propane)	4,400 gal	

1 Peak demand is the maximum rate expected during any hour.
2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used construction material (e.g., steel,) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for equipment fabrication is approximately 110 tons of Monel and 10 tons of titanium.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 EMPLOYMENT NEEDS DURING OPERATION

Table 6-1, On-Site Employment During Operation, provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	8
Professionals	8
Technicians	29
Office and Clerical	20
Craft Workers (Maintenance)	11
Operators / Line Supervision	91/15
Security	27
TOTAL EMPLOYEES (for all on-site facilities)	209

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 EMPLOYEES AT RISK OF RADIOLOGICAL EXPOSURE

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF (e.g., connecting the tank car loading hose), the operator will wear acid-resistant protective gear including a respirator.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4[1]
Process Building	38	22	22	22
HF Storage Building	2	1	1	1
Mg Metal Storage Building	1	1	1	1
Uranium Product Storage Building	3	1	1	1
MgF2 Storage Building	1	1	1	1
Cylinder Storage Pad and Building	7	3	3	3
Utilities/Services/Admin Areas	40	10	10	10
TOTAL EMPLOYEES	92	39	39	39

[1] The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170	290	510	250
Construction Management and Support Staff	30	60	90	50
TOTAL EMPLOYEES	200	350	600	300

[1] Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

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

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

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

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility work force.

7.1.2.1 Low-Level Wastes

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

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	60/54
Nitrogen Dioxide	Boiler Stack / Grade	8,100/440
Hydrocarbons	Boiler Stack / Grade	170/400
Carbon Monoxide	Boiler Stack / Grade	4,000/2,500
Particulate Matter PM-10	Boiler Stack / Grade	300/86
OTHER POLLUTANTS		
HF	Process Bldg. Stack	300
UF_4	Process Bldg. Stack	3.8
U_3O_8	Process Stack	1.2
Copolymers	Cooling Tower	1,900
Phosphonates	Cooling Tower	190
Phosphates	Cooling Tower	190
Calcium	Cooling Tower	3,300
Magnesium	Cooling Tower	840
Sodium and Potassium	Cooling Tower	340
Chloride	Cooling Tower	600
Dissolved Solids	Cooling Tower	18,000

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	7.0×10^{-4}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	1.0×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	216,000	100	26 lb U_3O_8	370 55-gal drums
Metal, surface contaminated	Failed equipment	57,000	35	67 lb U_3O_8	129 55-gal drums
Noncombustible, compactible solid	HEPA filters	12,000	62	750 lb UF_4 220 lb U_3O_8	30 4x2x7 ft boxes (3/4" plywood)
Other	Failed uranium reduction reactors (graphite, metal, insulation)	120,000	48	981 lb U	4.5 6x6x8 ft boxes (1/4" steel)
Other	LabPack (chemicals plus absorbent)	3,500	2.2	4 lb U_3O_8	8 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint	4,500	3 (600 gal)	See description	11 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	8,100	5	8 lb HF 8 lb NaOH	19 55-gal drums
Combustible debris	Wipes, etc.	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb U_3O_8 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb U_3O_8 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	270	0.5	0.1 lb U_3O_8 0.1 lb Acetone	2 55-gal drums

[1] All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.4×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	8,515 (1)	25.5×10^6
Recyclable Wastes	215	-

1 Includes 7,990 yd^3 of solid MgF_2

7.1.2.3 Hazardous Wastes

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

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

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

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, and other items generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 WASTES AND EMISSIONS GENERATED DURING CONSTRUCTION

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	2
Nitrogen Dioxide	30
Hydrocarbons	8
Carbon Monoxide	200
Particulate Matter PM-10	50

7.2.2 Solid and Liquid Wastes

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

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil and lubricants for construction vehicles, will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	60 yd^3
Hazardous Liquids	25,000 gals
Nonhazardous Solids	
Concrete	130 yd^3
Steel	40 tons
Other	1,000 yd^3
Nonhazardous Liquids	
Sanitary	3.5×10^6 gals
Other	1.5×10^6 gals

7.2.2.3 Nonhazardous Wastes

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

8.0 Accident Analysis

8.1 BOUNDING ACCIDENTS

The DUF_6 Continuous Conversion Facility buildings include areas with hazard categories of chemically high hazard (HH) for buildings containing HF and radiologically moderate hazard (HC2) for buildings containing DUF_6 and uranium metal product. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgment and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario
- An estimate of the frequency of the scenario (as defined in table 8-2) based on engineering judgment (because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques)
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere, taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following structures, systems, and components (SSCs) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant quantities of HF or NH_3, because a rupture could release some contents with unacceptable consequences
- Vessels containing significant inventories of UF_6 at elevated temperatures, because their rupture could release HF and/or uranium with unacceptable consequences
- The Process Building, HF Storage Building, and Uranium Product Storage Building structures, because they house large inventories of HF and uranium, and building collapse could result in significant damage with consequential releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Airborne Material Released to Environment
Earthquake	Extremely Unlikely	5.8×10^{-2} lb U_3O_8
Tornado	Extremely Unlikely	No Release
Flood	Incredible	No Release
HF System Leak	Anticipated	3.6 lb HF
UF_4 Drum Spill	Anticipated	1.5×10^{-4} lb UF_4
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	17 lb HF
Hydrogen Explosion	Extremely Unlikely	5×10^{-2} lb UF_4 2 lb HF
Ammonia Release	Unlikely	255 lb NH_3
Uranium Metal Fire	Unlikely	5.8×10^{-2} lb U_3O_8
HF Pipeline Rupture	Unlikely	500 lb HF
HF Storage Tank Overflow	Unlikely	45 lb HF
Reactor Rupture	Extremely Unlikely	2.6×10^{-3} lb U_3O_8

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/\text{yr} > \text{frequency} \geq 10^{-2}/\text{yr}$
Unlikely Accidents	$10^{-2}/\text{yr} > \text{frequency} \geq 10^{-4}/\text{yr}$
Extremely Unlikely Accidents	$10^{-4}/\text{yr} > \text{frequency} \geq 10^{-6}/\text{yr}$
Incredible Events	$10^{-6}/\text{yr} > \text{frequency}$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	49,000 lb U (58,000 lb U_3O_8)	1×10^{-3} (a)	1×10^{-3}	30 min
Tornado	No Release	NA	NA	NA
Flood	No Release	NA	NA	NA
HF System Leak	9 lb HF	1	.4 (b)	15 min
UF_4 Drum Spill	735 lb UF_4	2×10^{-4} (c)	1×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	17 lb HF	1	1	2 min
Hydrogen Explosion	1,000 lb UF_4 2 lb HF	.05 (d) 1	1×10^{-3} 1	30 min
Ammonia Release	255 lb NH_3	1	1	1 min
Uranium Metal Fire	49,000 lb U (58,000 lb U_3O_8)	1×10^{-3} (a)	1×10^{-3}	30 min
HF Pipeline Rupture	500 lb HF	(e)	(e)	10 min
HF Storage Tank Overflow	830 lb HF	.22 (f)	.25 (g)	15 min
Reactor Rupture	2,200 lb U (2,600 lb U_3O_8)	1×10^{-3} (a)	1×10^{-3}	15 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).

2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).

3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on thermal stress (oxidation) of uranium in DOE-HDBK-0013-93, p. 4-2.

b. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

c. Based on powder spill in NUREG-1320, *Nuclear Fuel Cycle Accident Analysis Handbook*, May 1988, p. 4.71. Also consistent with free-fall spill of powders in DOE-HDBK-0013-93, *Recommended Values and Technical Bases for Airborne Release Fractions, Airborne Release Rates and Respirable Fractions at DOE Non-Reactor Nuclear Facilities*, July 1993, p. 4-5.

d. Based on deflagration of large volume of flammable mixture above powder in DOE-HDBK-0013-93, p. 4-5. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

e. Assume 100% of the HF drains into the ground at a point 3 ft below grade during a 10 minute period. The contaminated soil is removed after 48 hrs.

f. Airborne release fraction is .22 based on 0.06 lb/min-sq ft evaporation rate, 200 sq ft spill area and 15 minute duration, using method in D. G. Gray, *Solvent Evaporation Rates*, American Industrial Hygiene Association Journal, November 1974. Fraction in respirable range is 1.

g. Based on 3 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234 and Pa-234m) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium, hydrofluoric acid, and ammonia are the primary hazardous chemical materials handled in this facility. Uranium is toxic, and hydrofluoric acid is both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Structures, systems, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Structures in high hazard areas of the Process Building and HF Storage Building (i.e., in areas with high inventories of HF or UF_6 at elevated temperatures) are designed for the performance category PC-4 DBE. Therefore, failure of these structures in the event of the DBE is incredible. In the extremely unlikely event that an earthquake exceeding the PC-3 DBE or failure of PC-3 SSCs in the Process Building occurs, it is postulated that a fire occurs in the metal storage area. The resulting consequences would be bounded by the fire scenario described in Section 8.1.3.8.

The Uranium Product Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. In the extremely unlikely event that an earthquake exceeding the PC-3 DBE or failure of PC-3 SSCs in the Storage Building occurs, the building might collapse and damage the boxes containing the uranium metal product billets. Because the billets are heavy, dense, metallic objects, an insignificant fraction of uranium would be broken into airborne respirable particles.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Structures, systems, and components are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Structures in high hazard areas of the Process Building and HF Storage Building (i.e., in areas with high inventories of HF or UF_6 at elevated temperatures) are designed for the performance category PC-4 DBT. Therefore, failure of these structures in the event of the DBT is incredible.

The Uranium Product Storage Building is designed for the performance category PC-3 DBT for radiologically moderate hazard structures. The DBT defined for this facility would not cause sufficient damage to compromise the building confinement of hazardous materials. However, in the extremely unlikely event of a DBT exceeding the PC-3 level or failure of PC-3 SSCs, a tornado wind-driven missile could impact and damage a uranium product storage box. The uranium metal billets in the box could be crushed, ejected from the box and scattered. Because the billets are heavy, dense, metallic objects, an insignificant fraction of uranium would be broken into airborne respirable particles. Therefore the tornado would result in no release.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Structures, systems, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility will be located at a site that precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF System Leak

Gaseous HF is produced from the reactions in the UF_6 reduction process. The HF is condensed and collected. Possible accidents include leakage from a vessel, pump, or pipe.

It is postulated that the off-gas line from a reactor to the condenser leaks 5% of its flowing contents for 10 minutes, thus releasing 9 lb of HF into the process building. After the leak is detected by air monitoring instruments, the reactor feed is halted to stop the leak. It is assumed that about 40% of the HF vapor (3.6 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 UF_4 Drum Spill

Solid UF_4 is produced in the Process Building. It is stored in a large bin for feeding to the metal reduction process. There is also a drum loading station to provide the capability to store additional quantities of UF_4 in drums. The drums are located in the Process Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the floor. A drum contains 1,470 lb UF_4. It is assumed that 50% of the UF_4 is released from the drum and 0.02% becomes respirable airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne UF_4. Thus 1.5×10^{-4} lb of UF_4 is discharged through the Process Building HVAC exhaust stack to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.4 Loss of Off-Site Electrical Power

An uninterruptible power supply and diesel generator provide backup electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a release to the environment.

8.1.3.5 Loss of Cooling Water

Pressure relief valves are provided to protect the reactors, vessels, and equipment. Loss of cooling water to the UF_6 reactor HF cooler or condenser would cause the reactor pressure to rise and the relief valve to open.

It is postulated that cooling water is lost and all of the hot off-gas flows through the relief valve for one minute, releasing 17 lb of HF. High temperature and pressure alarms and interlocks would shut down the feed input to the reactor to stop the release. The HF scrubber would also condense some of the HF to prevent overpressure. About 17 lb of HF would be discharged through the relief valve and released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.6 Hydrogen Explosion

Hydrogen is fed to the reduction reactors as a reagent to react with UF_6. There are two reactors in parallel, and each reactor receives about 30 lb/hr of hydrogen.

Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. The reactor vapor space normally contains excess unreacted hydrogen, HF, and nitrogen. There is normally no air in the reactor.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the reactor, air to leak into the reactor, and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

Assuming the reactor normally contains a 15 minute holdup of material, the reactor contains about 2,000 lb of UF_4. It is assumed that 50% of the uranium is released into the room, and that 100% of that material becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the uranium. Thus, 5×10^{-2} lb of UF_4 would be discharged through the Process Building exhaust stack. Also, assuming the reactor contains 2 lb of HF, this would also be released in this accident. This accident is judged to be extremely unlikely.

8.1.3.7 Ammonia Release

Ammonia is stored as a liquid in three 15,000 gallon pressure vessels located outdoors in the yard. The ammonia pressure increases as the ambient temperature increases. Tank pressure would be 93 psig if the tank contents are at 60°F, and 166 psig at 90°F. Ammonia is toxic but is not considered flammable.

A leak in an ammonia system can be readily detected by odor. Ammonia vapor or gas is lighter than air, so it will tend to rise and dissipate. Ammonia is highly soluble in water and water sprays are effective in absorbing ammonia vapor. The ammonia tank outlets are equipped with an excess flow valve, which would close and stop the ammonia flow in the event the outlet piping was cleanly broken off.

It is postulated that the ammonia supply truck fill line for an ammonia storage tank is momentarily disconnected during fill operations. The release is detected by an operator who is required to be present to monitor the unloading operations per ANSI Standard K61.1, "Safety Requirements for the Storage and Handling of Anhydrous Ammonia", Section 5.10.

Assuming a flow of 50 gpm for one minute, 255 lb of ammonia is released to atmosphere at grade. This accident is judged to be unlikely.

Catastrophic failure of an ammonia tank is considered incredible since the fabrication and installation of the tank will follow ANSI Standard K61.1, which requires ASME Code fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and contain leakage. Also, vegetation and other flammable materials will be excluded from the immediate storage tank area.

8.1.3.8 Uranium Metal Fire

Most of the areas where uranium and other hazardous materials are handled do not contain combustible materials that would support a fire of any significant magnitude. In the uranium product loading area; however, the uranium billets are packaged in wooden boxes. In the unlikely event that a fire occurs in this area, it is postulated that up to one shift's production of uranium billets may accumulate in the area (654 billets each weighing 75 lb). A fraction of 0.1% is assumed to be released as respirable airborne particles in this event, with 99.9% filtration efficiency in the building HVAC system, resulting in about 4.9×10^{-2} lb of uranium (5.8×10^{-2} lb U_3O_8) being released to the atmosphere through the Process Building exhaust stack.

8.1.3.9 HF Pipeline Rupture

Anhydrous HF is pumped from the Process Building to the HF Storage Building through an underground pipeline. The pipe is double-walled to contain possible leakage and has a leak detection alarm. It is postulated that an earthquake ruptures the pipeline and its outer pipe. Assuming it takes 5 minutes to stop the HF pump, the pipeline is 1 inch diameter and 200 ft long, and the pump runs at 10 gpm, it is estimated that approximately 60 gallons (500 lb) of anhydrous HF is released into the ground in a 10 minute period. The contaminated soil is removed after 48 hours. This accident is judged to be unlikely.

8.1.3.10 HF Storage Tank Overflow

Anhydrous HF is stored in four 18,000 gallon tanks in the HF Storage Building. Each tank contains about 143,000 lb of HF. The tanks and building are cooled to about 50°F to reduce the amount of HF that would vaporize if a spill should occur. The tanks are performance category PC-4, have high-level alarms and interlocks that stop the transfer pump, and are surrounded by dikes to contain any spillage. The building has HF air monitoring instruments and a water spray system that can be activated to absorb HF.

It is postulated that during filling, a storage tank overflows at 10 gpm for 10 minutes and releases 100 gallons (830 lb) of HF. The HF spills onto the floor and drains to a covered sump. The HF evaporates at a rate of 12 lb/min for 15 minutes, based on an evaporation rate of 0.06 lb/min-sq ft and a spill area of 200 sq ft. The building HVAC system discharges 25% of the HF vapor (45 lb) to atmosphere in a 15 minute period, based on 3 air changes/hr and a mixing factor of 0.33. The building HVAC system is then shut down to stop further releases and the building water spray system is activated to absorb HF vapor remaining in the building. The release point is the Process Building exhaust stack. This accident has been judged to be unlikely.

8.1.3.11 Reactor Rupture

There are three UF_4 continuous reduction reactors, each with a 3 ft diameter molten pool. Assuming a 3 ft deep pool and the bottom 10% of the pool is molten uranium (corresponding to a 1 hour uranium holdup time), there is about 2,200 lb of molten uranium in each reactor. In the extremely unlikely event of a reactor rupture, the molten metal could become exposed to air, oxidize, and be released as airborne particles. A fraction of 0.1% is assumed to be released as respirable airborne particles in this event, with 99.9% filtration efficiency in the building HVAC system, resulting in about 2.2 x 10^{-3} lb of uranium (2.6 x 10^{-3} lb U_3O_8) being released to the atmosphere through the Process Building exhaust stack.

9.0 Transportation

9.1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, uranium metal product in wooden boxes (crates) from the Process Building to the Uranium Product Storage Building, and low-level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car or truck transport of uranium product to the plant boundary. Hazardous waste materials, such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, and laboratory wastes, requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary (for further transport to off-site hazardous waste treatment, storage, and disposal facilities).

9.2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product, and waste materials are shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH), hydrochloric acid (HCl), and ammonia (NH_3). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium metal (uranium product), hydrofluoric acid (HF), low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Output Material #1
Transported Materials					
Type	UF_6	HCl	NaOH	NH_3	Uranium Metal
Physical Form	Solid	Liquid	Liquid	Liquid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	NH_3 / 100°F, 197 psig (max.)	Uranium / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	Rail Car 11,000 gal	Box 2' x 2' x 1'
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	105S-300-W	TBD
Container Weight (lb)	2,600	50	50	TBD	50
Material Weight (lb)	27,000	540	660	52,000	1,425
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	100% NH_3	97% U 3% Fe
Shipments					
Average Volume (ft^3)/Year	323,000	132	81	67,600	120,000
Packages/Year	2,322	18	11	46	30,100
Packages/Life of Project	46,440	360	220	920	602,000
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	9	6	1	28 (truck) or 80 (railcar), 4 cars/train
Shipments/Year	2,322 (truck) or 49 (rail)	2	2	46	1,075 (truck) or 94 (rail)
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	40	920	21,500 (truck) or 1,880 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Rail	Truck/Rail
Destination - Facility Type	NA	NA	NA	NA	TBD

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #2	Output Material #3	Output Material #4	Output Material #5	Output Material #6
Transported Materials					
Type	Hydrofluoric Acid	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Liquid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	HF / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	Rail Tankcar 11,000 gal	55 Gallon Drum/Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	105A-300-W	Varies	Varies	Varies	48G
Container Weight (lb)	TBD	50/300	50	50	2,600
Material Weight (lb)	84,000	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% HF	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	120,600	6,700	265	44	323,000
Packages/Year	82	507/35	36	6	2,322
Packages/Life of Project	1,640	10,140/700	720	120	46,440
Packages/Shipment	6 railcars / train	40/7	18	6	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	14	13/5	2	1	387 (truck) or 49 (rail)
Shipments/Life of Project	280	260/100	40	20	7,740 (truck) or 980 (rail)
Form of Transport/Routing					
Form of Transportation	Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	Customer	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

10.0 References

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
CaF_2	calcium fluoride
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt hour(s) (1×10^9 watt-hour)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MgF_2	magnesium fluoride
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

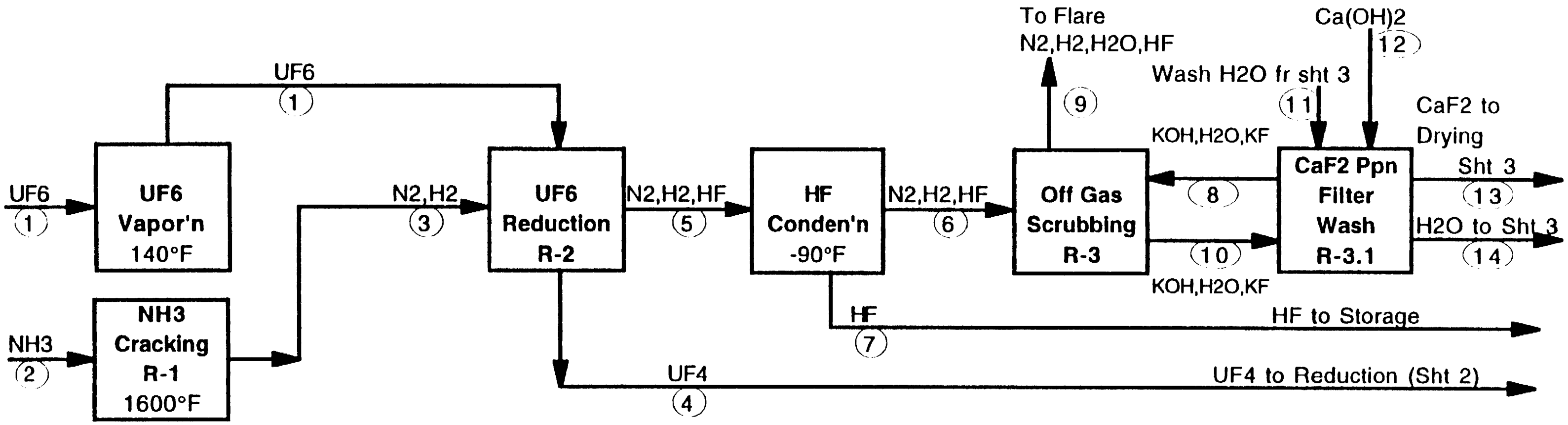
ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

CONTINUOUS REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
UF6 Reduction with Hydrogen

	116	74	78	112
R-3.1:	2 KF +	Ca(OH)2 ->	CaF2 +	2 KOH
	176	112	118	170



	34	28	6
R-1:	2 NH3 -->	N2 +	3 H2
	1,082	891	191

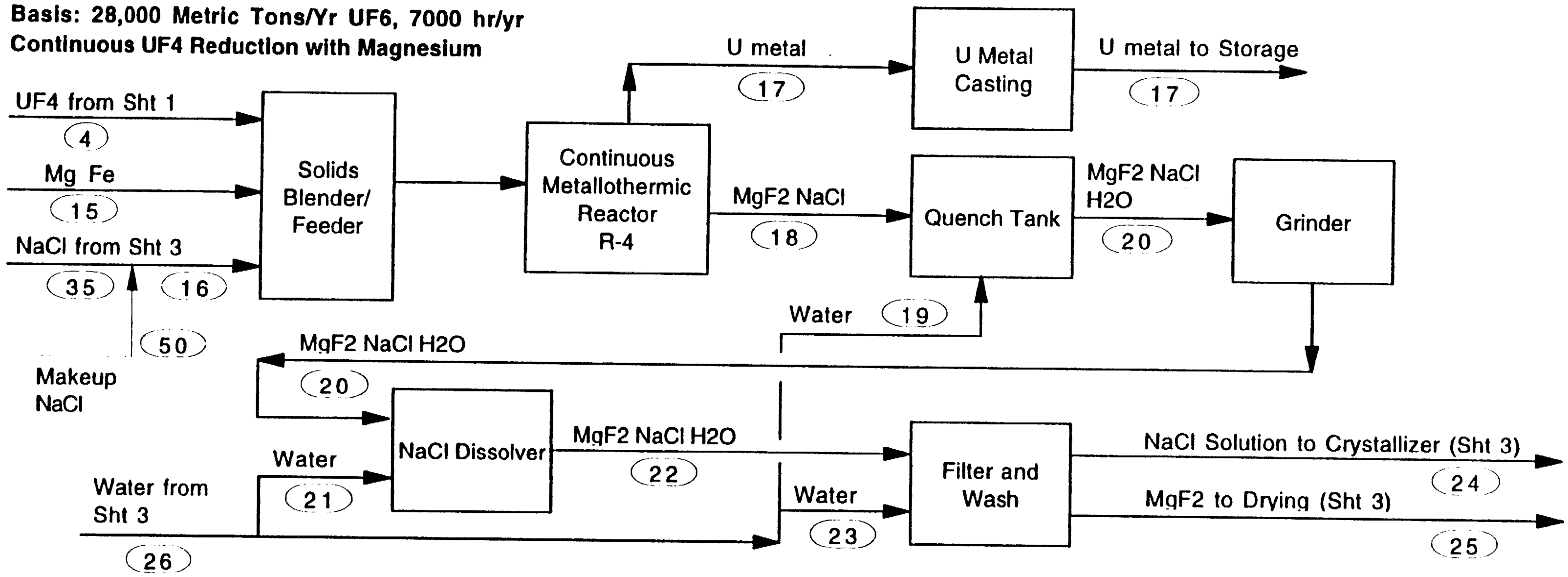
	40	112	36	116
R-3:	2 HF+	2 KOH--->	2 H2O +	2 KF
	61	170	55	176

	352	2	314	40
R-2:	UF6 +	H2 -->	UF4 +	2 HF
	28,000	159	24,977	3,182

	(11)	(12)	(13)	(14)
Ca(OH)2		112		
CaF2			118	
H2O	118		59	114
Total MT/yr	118	112	177	114
kg/kg U	0.0062	0.0059	0.0094	0.0060

	MW	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
UF6	352	28,000									
UF4	314				24,977						
HF	20					3,182	61	3,121		0.061	
NH3	17		1,082								
N2	28			891		891	891			891	
H2	2			191		32	32			32	
KOH	56								204		34
KF	58								10		186
H2O	18								9,227	43	9,282
Total MT/yr		28,000	1,082	1,082	24,977	4,105	983	3,121	9,441	966	9,502
kg/kg U		1.48	0.057	0.057	1.32	0.22	0.052	0.16	0.50	0.051	0.50

CONTINUOUS REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Continuous UF4 Reduction with Magnesium

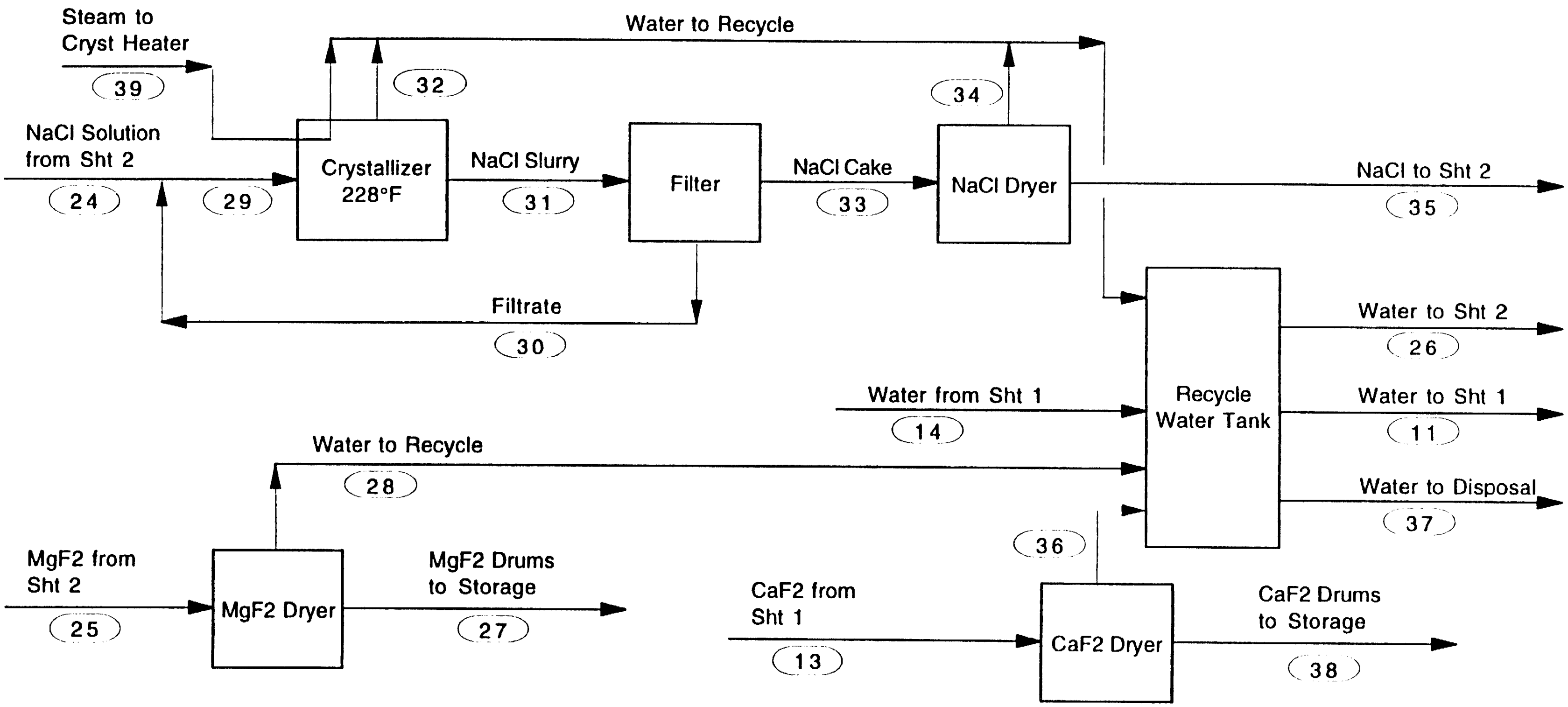


	314	48	124	238
R-4:	UF4 +	2 Mg -->	2 MgF2 +	U
	24,977	3,818	9,864	18,932

	24	25	26	50
U		0.99		
MgF2		9,864		
NaCl	46,301	233		233
H2O	176,057	4,932	180,989	
Total MT/yr	222,358	15,029	180,989	233

	MW		15	16	17	18	19	20	21	22	23
U	238				18,931	0.99		0.99		0.99	
Fe	56		585		585						
UF4	314										
Mg	24		3,818								
MgF2	62					9,864		9,864		9,864	
NaCl	58.5			46,534		46,534		46,534		46,534	
H2O	18						56,398	56,398	109,795	166,193	14,795
Total MT/yr		0	4,404	46,534	19,516	56,399	56,398	112,796	109,795	222,592	14,795
kg/kg U		0.000	0.23	2.46	1.03	2.98	2.98	5.96	5.80	11.76	0.78

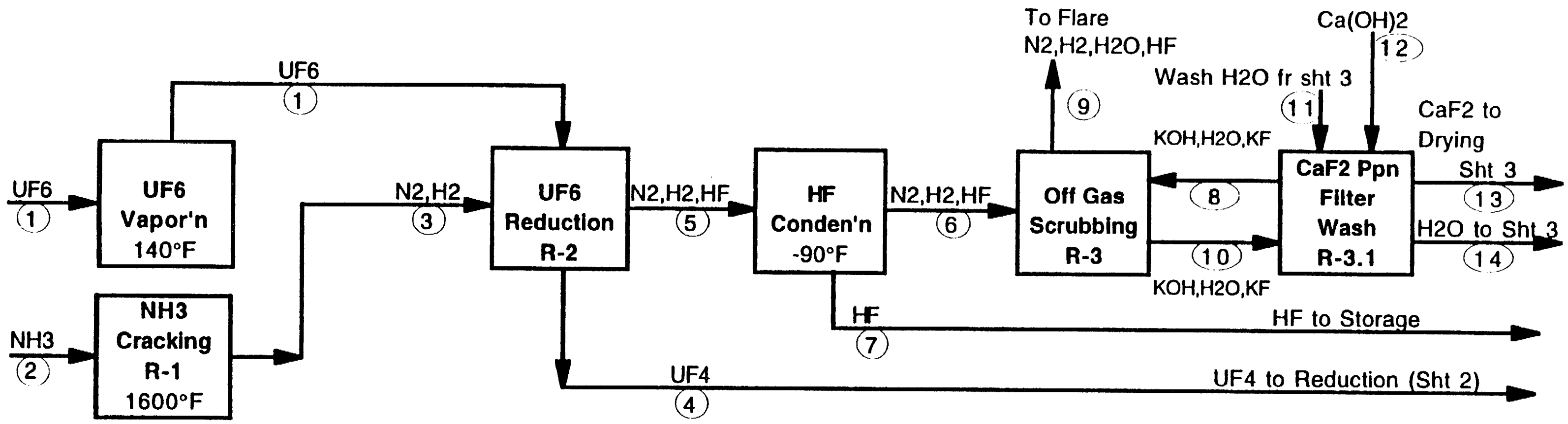
CONTINUOUS REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
NaCl Recovery and Byproduct Treatment



	MW	27	28	29	30	31	32	33	34	35	36	37	38	39
NaCl	58.5	233		71,767	25,466	71,767		46,301		46,301				
H2O	18		4,932	243,194	67,137	71,767	171,427	4,630	4,630		59	3,483		3,429
MgF2	62	9,864												
U	238	0.99												
CaF2	78												118	
Cement														
Total MT/yr		10,097	4,932	314,961	92,603	143,534	171,427	50,932	4,630	46,301	59	3,483	118	3,429
kg/kg U		0.53	0.26	16.64	4.89	7.58	9.05	2.69	0.24	2.45	0.0031	0.18	0.0062	0.18

CONTINUOUS REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
UF6 Reduction with Hydrogen

	116	74	78	112
R-3.1:	2 KF +	Ca(OH)2 ->	CaF2 +	2 KOH
	55	35	37	53



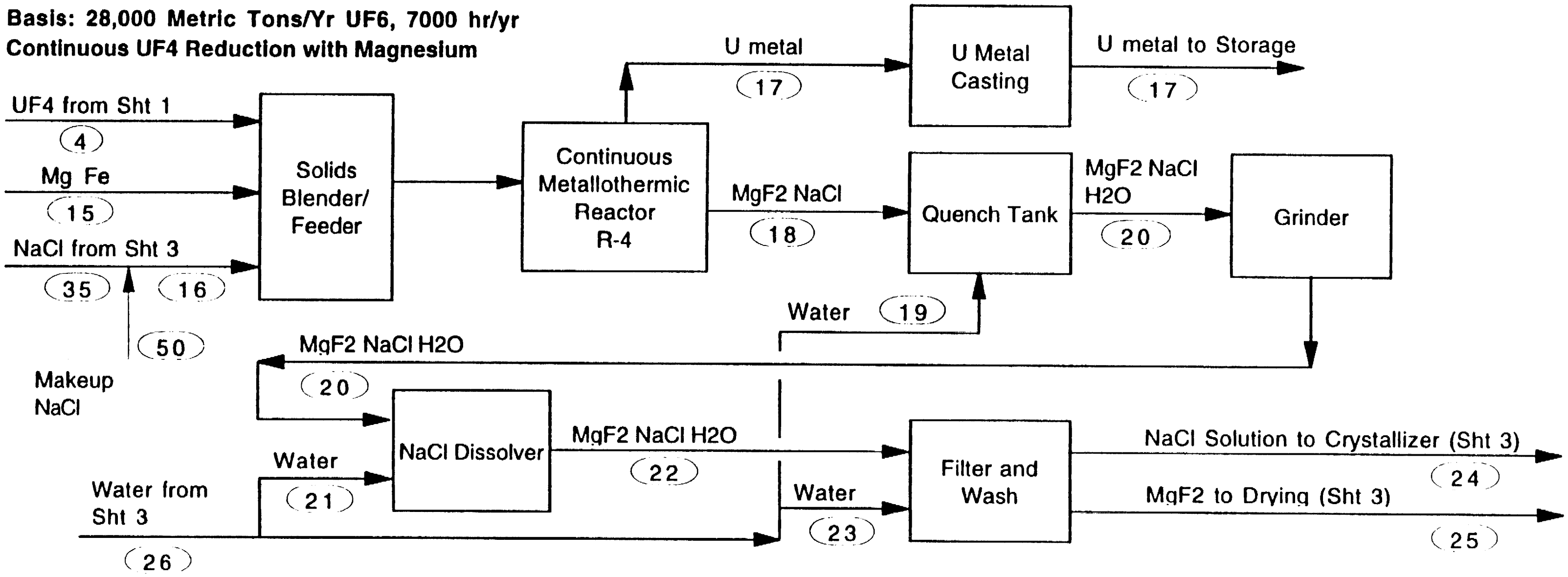
	34	28	6	
R-1:	2 NH3 -->	N2 +	3 H2	
	340	280	60	
	352	2	314	40
R-2:	UF6 +	H2 -->	UF4 +	2 HF
	8,800	50	7,850	1,000

	40	112	36	116
R-3:	2 HF+	2 KOH--->	2 H2O +	2 KF
	19	53	17	55

	(11)	(12)	(13)	(14)
Ca(OH)2		35		
CaF2			37	
H2O	37		19	36
Total lb/hr	37	35	56	36
kg/kg U	0.0062	0.0059	0.0094	0.0060

	MW	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
UF6	352	8,800									
UF4	314				7,850						
HF	20					1,000	19	981		0.019	
NH3	17		340								
N2	28			280		280	280			280	
H2	2			60		10	10			10	
KOH	56								64		11
KF	58								3		59
H2O	18								2,900	14	2,917
Total lb/hr		8,800	340	340	7,850	1,290	309	981	2,967	304	2,986
kg/kg U		1.48	0.057	0.057	1.32	0.22	0.052	0.16	0.50	0.051	0.50

CONTINUOUS REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Continuous UF4 Reduction with Magnesium

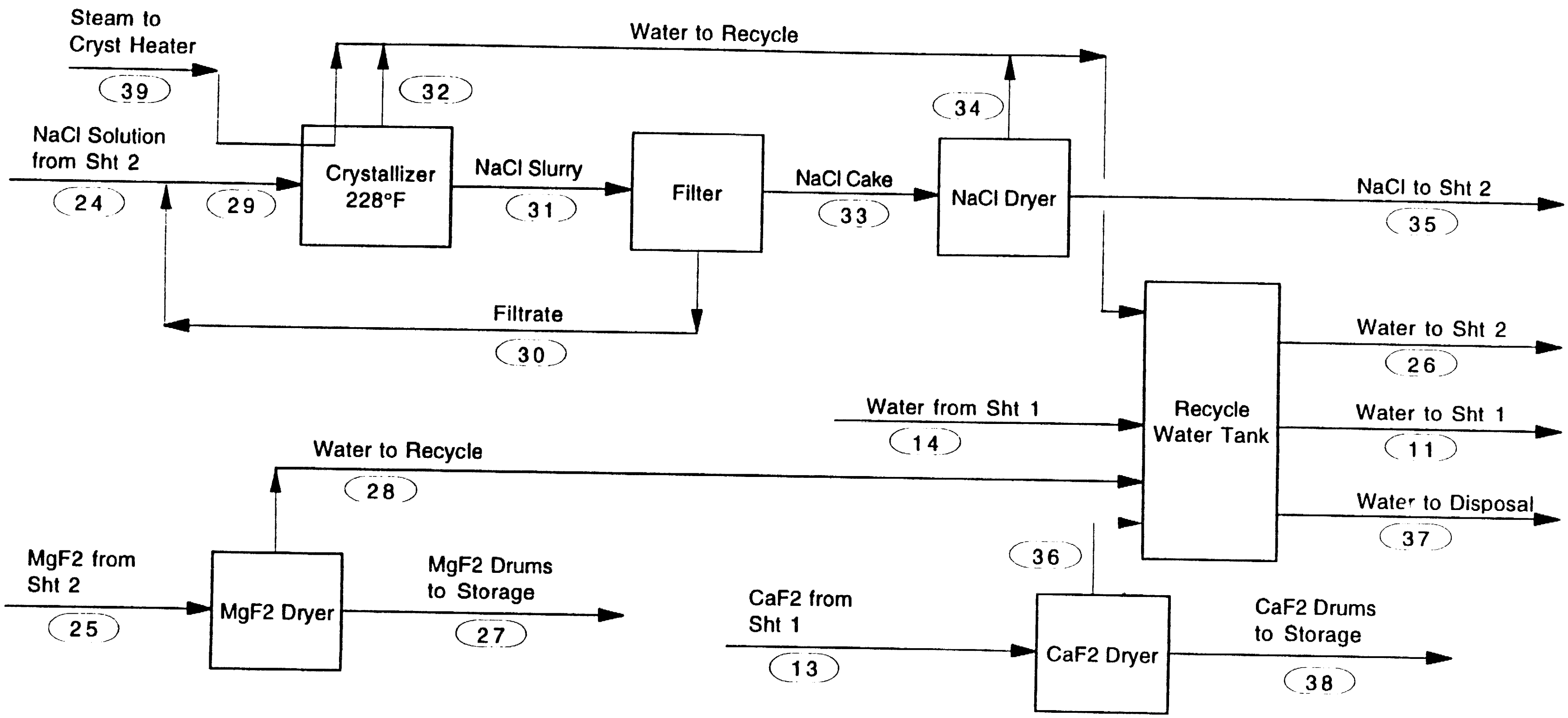


	314	48	124	238
R-4:	UF4 +	2 Mg -->	2 MgF2 +	U
	7,850	1,200	3,100	5,950

	(24)	(25)	(26)	(50)
U		0.31		
MgF2		3,100		
NaCl	14,552	73		73
H2O	55,332	1,550	56,882	
Total lb/hr	69,884	4,723	56,882	73

	MW		(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
U	238				5,950	0.31		0.31		0.31	
Fe	56		184		184						
UF4	314										
Mg	24		1,200								
MgF2	62					3,100		3,100		3,100	
NaCl	58.5			14,625		14,625		14,625		14,625	
H2O	18						17,725	17,725	34,507	52,232	4,650
Total lb/hr		0	1,384	14,625	6,134	17,725	17,725	35,450	34,507	69,957	4,650
kg/kg U		0.000	0.23	2.46	1.03	2.98	2.98	5.96	5.80	11.76	0.78

CONTINUOUS REDUCTION TO URANIUM METAL
Basis: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
NaCl Recovery and Byproduct Treatment



	MW	27	28	29	30	31	32	33	34	35	36	37	38	39
NaCl	58.5	73		22,555	8,004	22,555		14,552		14,552				
H2O	18		1,550	76,432	21,100	22,555	53,877	1,455	1,455		19	1,095		1,078
MgF2	62	3,100												
U	238	0.31												
CaF2	78													
Cement													37	
Total lb/hr		3,173	1,550	98,988	29,104	45,111	53,877	16,007	1,455	14,552	19	1,095	37	1,078
kg/kg U		0.53	0.26	16.64	4.89	7.58	9.05	2.69	0.24	2.45	0.0031	0.18	0.0062	0.18

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Appendix B

Equipment List

MAJOR EQUIPMENT LIST
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (14)	6'Dx18'L, carbon steel, steam-heated	Proc. Bldg
UF6 Compressor (14)	800 lb/hr UF6, 15 psig discharge	Proc. Bldg
UF6 Reduction Reactor (2)	21"Dx35"Dx27'H, 60 kw, Monel	Proc. Bldg
UF4 Product Cooler (2)	12"Dx10'L, screw conveyor with cooling water, Monel, 20 cfh	Proc. Bldg
Reactor Off-Gas Equipment	Cyclone, sintered metal filters, Monel	Proc. Bldg
UF4 Product Bin (2)	5'Dx7'H, 100 cf, steel	Proc. Bldg
UF4 Drum Filling Station	5.4 drums/hr, glovebox	Proc. Bldg
UF4 Dust Collector	baghouse	Proc. Bldg
UF4 Conveyor	40 cfh	Proc. Bldg
HF Cooler	1'6"Dx6'L, 200 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Condenser	2'Dx6'L, 250 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Hold Tanks (2)	5'Dx8'L, 1100 gal, steel	Proc. Bldg
HF Storage Tanks (4)	8'Dx48'L, 18,000 gal, steel	Proc. Bldg
Off-Gas Scrubber	1'Dx15'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	1 kw electric heater	Proc. Bldg
Off-Gas HEPA Filter (2)	24"x24"x12"	Proc. Bldg
Off-Gas Exhauster (2)	150 scfm	Proc. Bldg
Lime Feed Bin	3'Dx7'H, 40 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 0.5 cfh, steel	Proc. Bldg
Precipitation Tank	4'Dx5'H, 500 gal, Monel	Proc. Bldg
Rotary Drum Filter	3'Dx3.5'L, 30 sq ft, Monel	Proc. Bldg
Vacuum Pump	100 cfm	Proc. Bldg
Filtrate Tank	4'Dx5'H, 500 gal, Monel	Proc. Bldg
Scrub Solution Cooler	1'6"Dx4'L, 50 sq ft, Monel tubes steel shell	Proc. Bldg
Scrub Solution Pump	6 gpm, Monel	Proc. Bldg
Evaporator	1'6"Dx4'L, 50 sq ft, Monel	Proc. Bldg
Condenser	1'6"Dx4'L, 50 sq ft, Monel tubes	Proc. Bldg
	steel shell	Proc. Bldg
Evaporator Condensate Tanks (2)	3'Dx3'H, 100 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg
UF4 Feed Bin	8'Dx23'H, 1000 cf, steel	Proc. Bldg
Mg Feed Bin	6'Dx22'H, 550 cf, steel	Proc. Bldg
NaCl Feed Bin	7'Dx23'H, 800 cf, steel	Proc. Bldg
Iron Feed Bin	4'Dx6'H, 60 cf, steel	Proc. Bldg
Reactor Feed Weigh Bin (2)	6'Dx8'H, 150 cf, steel, with load cells	Proc. Bldg
Reactor Feed Mixer	65 cf working capacity	Proc. Bldg
Reactor Feed Hopper	small	Proc. Bldg
Reactor Weigh Belt Feeder (3)	85 cfh, 8000 pph	Proc. Bldg
Continuous Reduction Reactor (3)	6'D	
Uranium Casting Machine (3)	28 billets/hr, 4'x4'x10'L	Proc. Bldg
Uranium Billet Cooling Station (3)	28 billets/hr	Proc. Bldg
Billet Packaging Station	4.4 boxes/hr	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
Salt Quench Tank (3)	4'Dx6'H, 350 gal, cone-bottom, Monel	Proc. Bldg
Salt Quench Cooler (3)	2'Dx6'L, 350 sq ft, Monel tubes, steel shell	Proc. Bldg
Salt Quench Circulation Pump (3)	100 gpm	Proc. Bldg
Salt Grinding Mill	Vertical stirred ball mill, 6'Wx17'Lx25'H 50 hp	Proc. Bldg
NaCl Dissolution Tank	11'Dx13'H, 9000 gal, Monel	Proc. Bldg
Rotary Drum Filter (2)	8'Dx12'L, 300 sf, Monel	Proc. Bldg
Vacuum Pump (2)	100 cfm	Proc. Bldg
Filtrate Transfer Pump (2)	65 gpm, Monel	Proc. Bldg
MgF2 Rotary Dryer	4'6"Dx30'L, 955 sq ft steam tubes, 7.5 hp, steel	Proc. Bldg
MgF2 Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg
MgF2 Dryer Condensate Tank	5'Dx6'H, 900 gal, steel	Proc. Bldg
MgF2 Solids Cooler	12"Dx8'L screw conveyor with cooling water,	Proc. Bldg
	steel, 32 cfh	Proc. Bldg
MgF2 Bucket Elevator	20'H, 32 cfh, steel	Proc. Bldg
MgF2 Product Bin	4'Dx7'H, 70 cf, steel	Proc. Bldg
MgF2 Drum Filling Station	4.2 drums/hr, glovebox	Proc. Bldg
MgF2 Dust Collector	baghouse	Proc. Bldg
Crystallizer Feed Tank	18'Dx17'H, 32,000 gal, Monel	Proc. Bldg
Crystallizer Body	15'Dx30'H, Monel	Proc. Bldg
Crystallizer Heat Exchanger	6'Dx20'H, 10,000 sqft, titanium tubes, steel shell	Proc. Bldg
Crystallizer Circulation Pump	30,000 gpm, 500 hp, Monel	Proc. Bldg
Crystallizer Compressor	1500 hp	Proc. Bldg
Crystallizer Condensate Tank	11'Dx11'H, 7500 gal, steel	Proc. Bldg
Condensate Cooler	2'Dx8'L, 500 sq ft, steel	Proc. Bldg
Centrifuge	100 hp	Proc. Bldg
Recycle Water Tank	16'Dx20'H, 30,000 gal, steel	Proc. Bldg
NaCl Rotary Dryer	4'6"Dx35'L, 1120 sq ft steam tubes 7.5 hp, steel	Proc. Bldg
NaCl Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg
NaCl Dryer Condensate Tank	5'Dx6'H, 800 gal, steel	Proc. Bldg
NaCl Solids Cooler	12"Dx8'L screw conveyor with cooling water, steel, a cfh	Proc. Bldg
NaCl Product Bin	6'Dx9'H, 200 cf, steel	Proc. Bldg
NaCl Dust Collector	baghouse	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
CaF2 Rotary Dryer	1'6"Dx6'L, steel	Proc. Bldg
CaF2 Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg
CaF2 Dryer Condensate Tank	4'Dx4'H, 250 gal, steel	Proc. Bldg
CaF2 Solids Cooler	12"Dx8'L screw conveyor with cooling water	Proc. Bldg
CaF2 Product Bin	4'Dx6'H, 60 cf, steel	Proc. Bldg
CaF2 Drum Loading Station	1.1 drum/day avg.	Proc. Bldg
CaF2 Dust Collector	baghouse	Proc. Bldg
Ammonia Storage Tank (3)	8'Dx40'L, 15,000 gal, steel, 250 psig	Yard
Ammonia Dissociator (3)	5000 cfh H2+N2, 83 kw	Yard
SUPPORT SYSTEMS		
Process Material Handling Systems	DUF_6 cylinder handling:	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated carbon steel storage racks for 400 14-ton DUF_6 cylinders	Proc. Bldg
	Two (2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195 storage racks each for cylinders	Proc. Bldg/ Storage Areas
	UF_4 interim drum handling:	
	-1 55 gal drum automated conveyor, 30 ft. length ea.	Proc. Bldg/
	-2 forklift trucks (for 55 gal drum pallets)	
	U Prod handling:	
	-3 flatbed trucks	Yard
	-3 overhead bridge cranes, 5 ton ea,	Proc. Bldg
	-3 automated conveyors, 30 ft. length ea.	Proc. Bldg/ U Prod Bldg
	-3 forklift trucks (for ingot pallets)	Proc. Bldg/ U Prod Bldg
	CaF_2 handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ Warehouse
	Mg handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ MgF_2 Bldg

MAJOR EQUIPMENT LIST (Continued)
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF_2 traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg
Process Control / Monitoring System	-Computer based liquid processing distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, U Prod handling, waste grouting / LLW packaging and CaF drum handling areas	Proc. Bldg
HF Storage Building Water Spray System	-Building water spray system complete with pumps, piping, vessels, alarms and controls installed in the HF storage tank area to monitor, alarm and actuate a water spray designed to mitigate the effects of an unplanned HF release	HF Bldg & Proc Bldg (HF Areas only)
Sampling / Analytical Systems	-4 local sampling glove boxes equipped with laboratory liquid / powder sampling hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF_2 traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg
Process Control / Monitoring System	-Computer based liquid processing distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, U Prod handling, waste grouting / LLW packaging and CaF drum handling areas	Proc. Bldg
HF Storage Building Water Spray System	-Building water spray system complete with pumps, piping, vessels, alarms and controls installed in the HF storage tank area to monitor, alarm and actuate a water spray designed to mitigate the effects of an unplanned HF release	HF Bldg & Proc Bldg (HF Areas only)
Sampling / Analytical Systems	-4 local sampling glove boxes equipped with laboratory liquid / powder sampling hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and U Prod pallets	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and U Prod tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect	
	Fire water pump - 3000 gpm diesel	
	Fire water tanks 2 - 270,000 gal	
	Fire system piping	
	Sprinkler System	
	Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 20,000 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2@ 300 cfm 150 psig	Util. Bldg
	Breathing air compressors- 2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, minus 40°F dew point	Util. Bldg
	Demineralized water system - 4000 gpd	Util. Bldg
	Sanitary water treatment system - 3700 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 74,000 gpd	Wastewater Treatment area
	Electrical substation - 6000 kW	Substation
	Emergency generators - 2 @ 500kW	Substation
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 32 MM Btu/hr, 3200 gpm	Yard

MAJOR EQUIPMENT LIST (Continued)
Continuous Reduction to Uranium Metal

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2,& fume hoods 2-2000 cfm, 5 HP exhaust fans	Proc. Bldg gloveboxes
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-80,000 cfm, 200 HP exhaust fans, 2-80,000 cfm 100 HP supply air units	U Areas DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, 2-10,000 cfm, 10 HP exhaust fans, Process'g 2-10,000 cfm, 15 HP supply air units	CaF_2, MgF_2 Areas Waste Control Room Support Areas
HF Area HVAC	2-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, Emergency shutdown on HF leak	HF Areas
HVAC Chillers	3-360 ton chillers	
Circulating Pumps	3-600 gpm, 20 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

CONTINUOUS REDUCTION TO URANIUM METAL - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 17)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 18)	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4"+1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	20	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25"	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	20	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	20	6	Steel	1/4"	3483.0
UF6 reduction / HF recovery surveillance	1	0.50	1752	6,7	3	Monel,Steel	3/4",1/4"	876.0
Transfer UF4 drums to interim storage	2	0.50	360	8,9	3	Steel	0.06"	360.0
UF4 drum interim storage surveillance	1	0.50	2190	9	3	Steel	0.06"	1095.0
Transfer UF4 drums to UF4 reduction	2	0.50	360	8	3	Steel	0.06"	360.0
Mixing and Weighing surveillance	1	0.50	1752	10	3	Steel	1/4"	876.0
Reduction, Casting, & Reactor offgas treat. surveillance	1	0.50	1752	11	3	Steel	1/4"	876.0
Transfer billets to interim storage	2	0.25	7500	12	3	Wood	3/4"	3750.0
Transfer billets to storage building.	2	0.50	7500	15	3	Wood	3/4"	7500.0
Load billets for shipment offsite	1	1.00	1072	16	3	Wood	3/4"	1072.0
Billet interim storage surveillance	1	0.50	2190	13	3	Wood	3/4"	1095.0
Billet storage building surveillance	1	0.50	2190	14	3	Wood	3/4"	1095.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 17)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 18)	PERSON HOURS
NaCl Dissolution & Crystallization surveillance	1	0.50	1752	11,13	35	Steel	1/4"	876.0
MgF2 Drying & Packaging surveillance	1	0.50	1752	13	50	Steel	1/4"	876.0
Transfer MgF2 drums to interim storage	2	0.50	4192	13	35	Wood	3/4"	4192.0
Load MgF2 drums for shipment offsite	1	1.00	734	14	100	Wood	3/4"	734.0
MgF2 drum interim storage surveillance	1	0.50	2190	13	35	Wood	3/4"	1095.0
MgF2 drum storage building surveillance	1	0.50	2190	14	100	Wood	3/4"	1095.0
NaCl Drying surveillance	1	0.50	1752	10	35	Steel	1/4"	876.0
Decon Waste Treatment surveillance	1	0.50	1752	6	35	Monel	3/4"	876.0
HF scrubbing / CaF2 Processing surveillance	1	1.00	1752	6	35	Monel	3/4"	1752.0
Transfer CaF2 drums to interim storage	2	0.50	47	1,2,3	35	Steel	1/4"	47.0
Load CaF2 drums for shipment offsite	1	1.00	8	1,2,3	35	Steel	1/4"	8.0
HF Storage Building surveillance	1	0.50	2190	13	250	Wood	3/4"	1095.0
HF loading for shipment offsite	2	10.00	82	13	250	Wood	3/4"	1640.0
Mg metal storage building surveillance	1	0.50	2190	4	200	Steel	1/4"	1095.0
CaF2 interim storage surveillance	1	0.50	2190	1,2,3	35	Steel	1/4"	1095.0
LLW processing, packaging, and shipping	2	8.00	1100	19	3	Steel	0.06"	17600.0
Process control room operations	8	8.00	1100	1,2,3	35	Steel	1/4"	70400.0
Laboratory operations	4	8.00	1100	7,9	35	Steel	1/4",0.06"	35200.0
HP	2	8.00	1100	1,2,3	35	Steel	1/4"	17600.0
Management / Professionals	16	8.00	250	11	3	Steel	1/4"	32000.0
Accountability	2	2.00	1100	3,4,14	3	Steel	1/4",0.06"	4400.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 17)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 18)	PERSON HOURS
Industrial and sanitary waste treatment	4	8.00	1100	5	75	Steel	1/4"	35200.0
Utilities operations	4	8.00	1100	13	150	Wood	3/4"	35200.0
Administration	20	8.00	250	7,9,10	125	Steel	1/4"	40000.0
Guardhouse	5	8.00	1100	5	150	Steel	1/4"	44000.0
Maintenance								15576.0
								413576.6

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 17)	SOURCE	DISTANCE (ft)	MATERIAL	THICKNESS (Note 18)	PERSON HOURS

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UF6 reactor; there are 2 reactors.
7) UF4 product bin; there are 2 bins.
8) A single drum of UF4.
9) There is up to 1 weeks supply of UF4 in the Interim Storage Area = 345 drums.
10) Inventory of UF4 in the Mixing/Weighing Area,
11) Inventory of uranium in Production/Casting/Packaging area.
12) A box of uranium billets.
13) There are up to 33 boxes of uranium billets in interim storage.
14) There are up to 2500 boxes of uranium billets in the storage building.
15) Each transfer consists of 4 boxes of billets.
16) There are 28 boxes of billets per shipment.
17) 2322 UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    30000 boxes of billets/yr / 4 boxes per transfer = 7500 per year.
    30000 boxes of billets/yr / 28 boxes per transfer = 1072 per year.
    82 railcars/yr of HF
    29340 MgF2 drums/yr / 7 drums per transfer = 4192 transfers per year
    29340 MgF2 drums/yr / 40 drums per shipment = 734 transfers per year
    324 CaF2 drums/yr / 7 drums per transfer = 47 transfers per year
    324 CaF2 drums/yr / 40 drums per shipment = 8 transfers per year
    Assume 2% of UF4 is sent to interim storage in drums = 360 drums
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
18) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
19) Batch of LLW
20) A single 3 mo. old empty UF6 cylinder

CONTINUOUS REDUCTION TO URANIUM METAL - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 15)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 16)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4"+1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4"+1/4"	1456
UF6 Reactor (2)	2	26	2	6	3	Monel	3/4"	104
UF4 product cooler (2)	2	104	2	6,7	7	Monel, Steel	3/4",1/4"	416
UF4 off-gas equip (cyclone, sintered metal filter) (1)	2	4	1	17	1			8
UF4 conveyor (1)	2	104	1	6,7	10	Monel, Steel	3/4",1/4"	208
UF4 dust collector (cyclone, sint. mtl filt., HEPA filt.) (1)	2	4	1	17	1			8
HF cooler (1)	2	26	1	6	55	Monel	3/4"	52
HF refrigerated condenser (1)	2	26	1	6	55	Monel	3/4"	52
Off-gas scrubber (1)	2	26	1	6	35	Monel	3/4"	52
Off-gas heater (1)	2	26	1	6	40	Monel	3/4"	52
Off-gas HEPA filters (2)	2	4	2	6	40	Monel	3/4"	16
Off-gas exhausters (2)	2	52	2	6	50	Monel	3/4"	208
Lime feeder (1)	2	104	1	1,2,3	35	Steel	1/4"+1/4"	208
Rotary drum filter (1)	2	26	1	1,2,3	45	Steel	1/4"+1/4"	52
Vacuum pump (1)	2	52	1	1,2,3	45	Steel	1/4"+1/4"	104
Scrub solution cooler (1)	2	26	1	1,2,3	30	Steel	1/4"+1/4"	52
Scrub solution pump (1)	2	52	1	1,2,3	30	Steel	1/4"+1/4"	104
Evaporator (1)	2	26	1	1,2,3	45	Steel	1/4"+1/4"	52
Condenser (1)	2	26	1	1,2,3	35	Steel	1/4"+1/4"	52
Condensate pump (1)	2	52	1	1,2,3	35	Steel	1/4"+1/4"	104
Reactor feed weigh bin (2)	2	26	2	10	3	Steel	1/4"	104
Reactor feed mixer (1)	2	52	1	10	3	Steel	1/4"	104
Reactor weigh belt feeder (3)	2	104	3	10,11	3	Steel	1/4"	624
Continuous reduction reactor (3)	2	26	3	11	3	Steel	1/4"	156
Uranium casting machine (3)	2	104	3	11	3	Steel	1/4"	624

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 15)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 16)	THICKNESS	PERSON HOURS PER YEAR
Billet packaging station (1)	2	52	1	11	3	Steel	1/4"	104
Salt quench cooler (3)	2	26	3	11	3	Steel	1/4"	156
Salt quench circulation pump (3)	2	52	3	11	3	Steel	1/4"	312
Salt grinding mill (1)	2	52	1	11	30	Steel	1/4"	104
NaCl dissolution tank (1)	2	26	1	11	40	Steel	1/4"	52
Rotary drum filter (2)	2	52	2	11	40	Steel	1/4"	208
Vacuum pump (2)	2	52	2	11	30	Steel	1/4"	208
Filtrate transfer pump (2)	2	52	2	11	30	Steel	1/4"	208
MgF2 rotary dryer (1)	2	52	1	13	40	Wood	3/4"	104
MgF2 dryer condenser (1)	2	26	1	13	55	Wood	3/4"	52
MgF2 solids cooler (screw conveyor) (1)	2	104	1	13	45	Wood	3/4"	208
MgF2 bucket elevator (1)	2	104	1	13	45	Wood	3/4"	208
MgF2 dust collector (baghouse) (1)	2	4	1	17	1			8
Crystallizer body (1)	2	26	1	13	35	Wood	3/4"	52
Crystallizer heat exchanger (1)	2	26	1	13	45	Wood	3/4"	52
Crystallizer circulation pump (1)	2	52	1	13	45	Wood	3/4"	104
Crystallizer compressor (1)	2	52	1	13	30	Wood	3/4"	104
Condensate cooler (1)	2	26	1	13	40	Wood	3/4"	52
Centrifuge (1)	2	52	1	13	50	Wood	3/4"	104
NaCl rotary dryer (1)	2	52	1	10	50	Steel	1/4"	104
NaCl dryer condenser (1)	2	26	1	10	30	Steel	1/4"	52
NaCl solids cooler (screw conveyor) (1)	2	104	1	10	25	Steel	1/4"	208
NaCl dust collector (baghouse) (1)	2	4	1					8
CaF2 rotary dryer (1)	2	52	1	1,2,3	48	Steel	1/4"+1/4"	104
CaF2 dryer condenser (1)	2	26	1	1,2,3	48	Steel	1/4"+1/4"	52
CaF2 solids cooler (screw conveyor) (1)	2	104	1	1,2,3	48	Steel	1/4"+1/4"	208
CaF2 dust collector (baghouse) (1)	2	4	1					8

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 15)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 16)	THICKNESS	PERSON HOURS PER YEAR
Ammonia dissociator (3)	2	26	3	11	100	Steel	1/4"	156
HVAC equipment	2	520	1	11	30	Steel	1/4"	1040
Boiler, Water Systems, and other Utilities	1	52	3	13	125	Wood	3/4"	156
Waste water treatment equipment	1	2190	1	5	75	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	5	75	Steel	1/4"	2190
Admin building	1	1000	1	7,9,10	125	Steel	1/4"	1000
								15576

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 15)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 16)	THICKNESS	PERSON HOURS PER YEAR

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UF6 reactor; there are 2 reactors.
7) UF4 product bin; there are 2 bins.
8) A single drum of UF4.
9) There is up to 1 weeks supply of UF4 in the Interim Storage Area = 345 drums.
10) Inventory of UF4 in the Mixing/Weighing Area,
11) Inventory of uranium in Production/Casting/Packaging area.
12) A box of uranium billets.
13) There are up to 33 boxes of uranium billets in interim storage.
14) There are up to 2500 boxes of uranium billets in the storage building.
15) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
    10 hours per week on HVAC components
    6 hours per day on waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
16) Materials do not include walls between operating areas.
17) Loaded filter/bag

Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

Section 6.11

Potential Shielding Applications of Depleted Uranium in Metal and Oxide Forms

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6.11
Potential Shielding Applications of Depleted Uranium in Metal and Oxide Forms

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LIST OF ABBREVIATIONS

A-E	architect-engineer
AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATSB	Administration and Technical Support Building
BOD	Biological Oxygen Demand
BTU	British Thermal Units
BWR	Boiling Water Reactor
C	carbon
° C	degrees Centigrade
CAA	Clean Air Act
CAR	Cost Analysis Report
CDR	Conceptual Design Report
CEC	Claiborne Enrichment Center
CFR	Code of Federal Regulations
Ci	curie (3.7 x 10^{10} disintegrations per second of radiation)
cm	centimeters
COC	Certificate of Compliance
cSv	centisieverts (measure of radiation dose)
CWA	Clean Water Act
D	average atmospheric dispersion (50-percentile)
DAW	dry active wastes
DF	decontamination factor
DI	deionized
dis/sec	disintegrations per second (radioactivity)
DOD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
DSC	dry storage container
DUCRETE™	depleted uranium concrete
EAP	Engineering Analysis Project
EAR	Engineering Analysis Report
EDRST	Equivalent Dose Rate Shielding Thickness

EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESB	Emergency Services Building
F	conservative atmospheric dispersion (95-percentile)
° F	degrees Fahrenheit
FSR	Feasibility Study Report
FRP	fiber reinforced plastic
ft	feet
FTE	full time equivalent
g	grams
gal/hr	gallons per hour
g/s	grams per second
gpd	gallons per day
gpm	gallons per minute
GWSB	General Warehouse and Storage Building
ha	hectares
HCF	heat conduction factor
HEPA	high efficiency particulate air (filter)
HP	horse power
HPRACB	Health Physics and RCA Access Control Building
hr	hour
HSM	Horizontal Storage Module
HTSMF	High Temperature Shielding Manufacturing Facility
HVAC	heat, ventilation and air conditioning
HX	heat exchanger
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
INEL	Idaho National Engineering Laboratory
ISFSI	Independent Spent Fuel Storage Installation
JMN	Justification of Mission Need
JNS	Justification of New Start
KD	Key Decisions
kg	kilograms
kPa	kilopascals (pressure)

kVA	thousand volt amps
kW	kilowatt
kW(e)	kilowatt electric
kW(t)	kilowatt thermal
L	liter
lb	pound
LLW	low level waste
LTSMF	Low Temperature Shielding Manufacture Facility
LWR	Light Water Reactor
m	meter
m^2	square meters
M	million
MBTU	million British thermal units
MkW	million kilowatts
ml	milliliters
ML	mega liters (million liters)
MPB	Main Processing Building
MPC	Multipurpose Canister
MPU	Multipurpose Unit
mrem	millirem
MSA	Major System Acquisition
MSB	multipurpose sealed basket
MSCF	million standard cubic feet
MSCM	million standard cubic meters
$MTUF_6$	metric tonnes of uranium hexafluoride
MW	megawatts
NAC	Nuclear Assurance Corporation
NCA	Noise Control Act
NEC	National Electric Code
NEPA	National Environmental Protection Act
NFPA	National Fire Protection Act
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NPH	Natural Phenomena Hazard
NPHM	Natural Phenomena Hazard Mitigation
NRC	Nuclear Regulatory Commission
NUREG/CR	Nuclear Regulatory Commission/Contractor Report

OCRWM	Office of Civilian Radioactive Waste Management
OSHA	Occupational Safety and Health Administration
PAD	Protective Action Distance
PP	Project Plan
ppm	parts per million (weight basis)
ppmv	parts per million volume (molar basis)
PSA	pressurized swing absorption
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PWR	Pressurized Water Reactor
Radwaste	radioactive waste
RCA	Radiological Control Area
RCRA	Resource Conservation and Recovery Act
RG	regulatory guides
ROD	Record of Decision
RMW	radioactive mixed waste
RSB	Radwaste Storage Building
SA	strong acid (high in exchange resin)
SB	strong base (high in exchange resin)
SAR	Safety Analysis Report
SCAB	Shielding Cask Assembly Building
SCF	standard cubic feet
SCFM	standard cubic feet per minute
S.M.	standard cubic meters
SCPSB	Shielding Cask Product Storage Building
SEER	Seasonal Energy Efficiency Ratio (BTUs/watt)
SMF	Shielding Manufacture Facility
SNC	Sierra Nuclear Corporation
SNF	spent nuclear fuel
SPS	Standby Power Source
SSC	structure, system and components
STC	storable transport cask
STP	standard temperature and pressure
t	time
TAR	Technology Assessment Report
te	metric tonne(s)
TSCA	Toxic Substances Control Act
TRI	Toxic Release Inventory

TSC	transportable storage cask
TSS	total suspended solids
TSVS	transportable storage vessel system
U	uranium metal
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide
UBC	Universal Building Code
UBS	Uninterruptible Battery Supply
UC	uranium carbide
UC-C	85% UC - 15% C
UCRL	University of California Research Laboratory
UF_6	uranium hexafluoride
UPHF	Uranium Processing and Handling Facilities
UPMP	Uranium Process Management Project
UPS	Uninterruptible Power Supply
USB	Utility Supply Building
VSV	Ventilated Storage Vessel
WBS	work breakdown structure
WMB	Waste Management Building
wt%	weight percent
yr	year
yd	yard
$\mu g/m^3$	micrograms per cubic meter
$\mu g/s$	micrograms per second

PREFACE

This report presents and evaluates potential radiation shielding applications of depleted uranium. Depleted uranium has been proposed for many shielding applications, including medical isotopes, ion exchange resins, spent nuclear fuel (SNF), and high-level waste (HLW). Commercial SNF has by far the largest potential use in the near term, and, if depleted uranium is used, it would easily use the entire DOE inventory. Therefore, this report uses existing and proposed shielding designs and source terms from the commercial SNF industry. These designs envelope expected conditions for DOE applications, including HLW canisters. The report subsequently proposes a preconceptual design for a plant producing shielding containing depleted uranium and estimates the parameters and impacts of its construction and operation.

Effective shielding of commercial SNF mandates the use of materials capable of attenuating both gamma and neutron radiation; the latter accounts for the majority of the external dose with most SNF source terms. Effective gamma shielding requires a high atomic weight material, while effective neutron shielding needs a low atomic weight material. Commercial designs overcome this dilemma by either using discrete, heterogeneous gamma and neutron shields, or by using large thicknesses of relatively low-density materials as homogeneous shields. Consequently, uranium metal requires two-to-three times the thickness of other uranium compounds (the dioxide and carbides) for the same external dose rate when used as homogeneous shielding for commercial SNF. However, as a heterogeneous shield material with a separate neutron shield [e.g., 3 inches (in.) of polyethylene], the uranium metal and compound thicknesses are roughly comparable. Thus, this report uses as its basis a heterogeneous shield approach for uranium metal and a homogenous approach for the other uranium compounds.

The report considers two principal forms of depleted uranium and their shielding manufacturing approaches. The first is depleted uranium as the sintered dioxide, mixed in concrete. This is termed DUCRETE™, and the manufacturing plant is designated the Low-Temperature Shielding Manufacturing Facility (LTSMF). DUCRETE™ has been studied and proposed for use in SNF storage applications at commercial nuclear power plant sites, with potential size and weight advantages. In use, it would be enclosed within a stainless steel shell or annulus. Over 80 percent of the current SNF storage installations use horizontal designs with homogeneous concrete shields. Calculations using standard horizontal designs and SNF source terms indicate over a 65 percent reduction in the wall thickness with DUCRETE™. Vertical storage designs use considerably less (< 50 percent) DUCRETE™ than horizontal designs, but could still consume the entire DOE inventory of depleted uranium. DUCRETE™ may also be an appropriate material for overpacks in SNF disposal, although this has not been as actively pursued as the storage applications. This DUCRETE™ design uses pellets of uranium dioxide, although variations have been proposed. LTSMF variations include the use of different sized pellets, microspheres, uranium carbides, resins, and carbon, all of which result in minimal changes to the basic, DUCRETE™ facility parameters.

The second approach uses direct casting of molten uranium metal, and is designated the High-Temperature Shielding Manufacturing Facility (HTSMF). Uranium metal shielding has been proposed for SNF disposal packages, primarily as part of a Multi-Purpose Unit (MPU). This would be a shielded container licensed for storage, transportation, and disposal. Additional shielding would be provided by overpacks. Variations include alloys of the uranium with 4-6 percent of other metals. In particular, a uranium/4 percent iron alloy offers somewhat lower melting temperatures and is the direct product of a metal conversion process (the CMR - Continuous Metallothermic Reduction - process).

No current licensed or detailed shielding designs use depleted uranium in significant quantities. No license applications or implementation programs currently exist that would consume the DOE inventory of depleted uranium. However, both concrete and metal based conceptual designs have been proposed for SNF shielding applications. Significantly, use of depleted uranium for annular shielding in SNF containers would consume the entire DOE inventory. Cost issues may ultimately decide if depleted uranium shielding is deployed in significant quantities. The use of depleted uranium for shielding requires a centralized manufacturing plant, with specialized equipment, dedicated labor, and shipment of essentially completed casks to the user sites. The central facility receives steel and parts from suppliers, and assembles the initial shielding cask or assembly. The plant casts the uranium shielding directly into the annular space of the cask or assembly. Final assembly and quality control operations also occur at the central plant. This route represents a significant departure from the current industry's approach, where most of the manufacturing is considered to be a small construction project at the user's site using standard contractors. Currently, only the inner basket containing the SNF is assembled at the supplier's site. This difference occurs because depleted uranium is still a radioactive material, and its use requires a licensed facility, a qualified workforce, and contamination control.

LTSMF and HTSMF throughput is based upon the equivalent of 28,000 metric tons per year (te/yr) as UF_6, which corresponds to a 20 year operating period to consume the DOE inventory of depleted uranium. The uranium dioxide equivalent throughput is 21,477 te/yr, while the metal throughput becomes 19,516 te/yr. The dioxide and the metal are assumed to arrive at the shielding plant from the conversion facility. The LTSMF uses high-shear mixing to produce the DUCRETE™, which is sequentially cast into the annular cavity of the shielding assembly. After a 30-day curing period, the cask undergoes final assembly, including permanent sealing of the DUCRETE™ shielding space. After an interim storage period, the finished DUCRETE™ cask would be shipped to the user site and used for SNF storage for up to 40 years. Subsequently, the inner container with the SNF would be removed and shipped elsewhere, and the (now empty) cask would be sent to disposal as low-level waste. The HTSMF directly casts the uranium metal into the annulus as a liquid at elevated temperatures. After cooling, heat treatments, and cleaning, the shielding assembly is completed, and shipped to the user's site. Once loaded with SNF, the metal shielding remains sealed, and, ultimately, goes with the SNF to repository disposal.

1.0 DESCRIPTION OF POTENTIAL SHIELDING APPLICATIONS USING DEPLETED URANIUM AND SHIELDING MANUFACTURING PROCESSES

Depleted uranium has use in several potential radiation shielding applications, including storage, transportation, or disposal containers for spent nuclear fuel (SNF). There are two basic cases examined in this report:

1. A low-temperature route using depleted uranium concrete, known as DUCRETE™, made from dense uranium dioxide (UO_2). The dense UO_2 would be substituted as the aggregate in standard concrete, which would give the DUCRETE™ a higher density than its non-uranium-containing standard concrete counterpart. The UO_2 would be mixed with cement at low temperatures. This also bounds the route using different shapes of the UO_2, uranium carbides, and other matrix materials. This route assumes storage applications, and thus, DUCRETE™ ultimately is sent to low-level waste (LLW) disposal.

2. A high-temperature route using depleted uranium metal, which would be cast into a shield at high temperature. This also bounds the use of uranium alloys. This route assumes that the depleted uranium metal ultimately resides with SNF in a repository.

These two categories accommodate all uranium shielding forms and variations. Basic process information is provided for both routes.

Historically, uranium has been used for shielding applications on a small scale. Two events have occurred that merit consideration of uranium-based shielding on a large scale. First, recent events have focused on the relatively large accumulation of depleted uranium hexafluoride (UF_6) currently stored by the Department of Energy (DOE), and potential avenues for its disposition. Second, SNF inventories from commercial power reactors have necessitated an onsite storage technology that requires adequate shielding. Therefore, both a large source and a potentially large application exist for depleted uranium.

This section discusses the shielding properties of depleted uranium and their incorporation into existing SNF shielding designs. No existing, licensed, or proposed designs use depleted uranium in quantities exceeding 10 percent of the DOE inventory. Consequently, a brief analysis is conducted of the shielding effectiveness of depleted uranium in different forms, using the predominant industry- and regulator-accepted horizontal SNF storage design. Based upon the literature, the analyses use depleted uranium as the metal (alloyed and unalloyed); the dioxide would be fixed by cement, resins, or other materials. These analyses indicate comparable usage for the uranium compounds when used as the radial shielding, but a higher usage for uranium metal. However, if the uranium metal is used with a separate neutron shield (e.g., polyethylene), all of the designs use comparable quantities of uranium, and if implemented, the potential SNF storage market could consume the entire DOE inventory of depleted uranium. Finally, this section provides shielding manufacturing information on both the low-temperature and high-temperature routes, with process flow diagrams and mass and energy balances.

1.1 Radiation Shielding Using Depleted Uranium

Depleted uranium has been suggested for several radiation shielding applications, potentially including:

- medical isotopes
- specialized utility applications, including spent ion exchange resins and activated metals ("core internals")
- axial plug for SNF handling
- high-level waste (HLW) containers
- radial shield for SNF handling

The first three applications constitute relatively small uses of depleted uranium, perhaps a maximum of 10 percent of the DOE inventory. The HLW container applications currently are not well defined. However, depleted uranium as radial shielding for SNF handling represents a near-term application that would require significant quantities of uranium materials. As a first approximation, 10,000 to 12,000 containers are required. At over 40 te of uranium per container, essentially the entire DOE inventory would be consumed.

Effective shielding of commercial SNF mandates the use of materials capable of attenuating both gamma and neutron radiation; the latter accounts for the majority of the external dose with most SNF source terms. Effective gamma shielding requires a high atomic weight material, while effective neutron shielding needs a low atomic weight material. Commercial designs overcome this dilemma by either using discrete, heterogeneous gamma and neutron shields, or by using large thicknesses of relatively low-density materials as homogeneous shielding for commercial SNF. However, as a heterogeneous shield material with a separate neutron shield (e.g., 3 inches of polyethylene), the uranium metal and compound thicknesses are roughly comparable. Thus this report uses as its basis a heterogeneous shield approach for uranium metal and a homogeneous approach for the other uranium compounds.

Appendix A provides a detailed analysis of radiation shielding using depleted uranium forms. Analyses include use of a horizontal storage module (HSM), the Multi-Purpose Canister (MPC) approach, the Multi-Purpose Unit (MPU) system, and analyses by the Idaho National Engineering Laboratory (INEL) to use vertical concrete casks using DUCRETE™ as the primary shielding material in place of concrete. Appendix A also summarizes shielding designs and consumption of depleted uranium. No design has been chosen as a preference to analyze (for the use of DUCRETE™). The HSM is provided as an example because it constitutes over 80 percent of the current installations at nuclear power plant sites. Only one site is currently using vertical concrete casks. Neither design, horizontal or vertical, is determined to impact the manufacturing plant (size or configuration).

1.2 Summary Description of Shielding Manufacturing and Potential Applications

Potential shielding applications of depleted uranium follow two principal routes. The first route uses uranium dioxide encapsulated in a cement/concrete matrix. This is frequently referred to as "DUCRETE™" for depleted uranium concrete (Haelsig, 1994; Lessing, 1995; Hopf, 1995). This route relies upon relatively simple, low-temperature mixing techniques, and it is principally associated with onsite storage applications for SNF, either at a utility plant or a centralized facility [the Modular Retrievable Storage (MRS) facility]. The second route uses depleted uranium metal, cast or rolled into an annular shield geometry, and enclosed by stainless steel walls (Hertzler, 1994; Derrington, 1994). The metal route requires high temperature operations, and is principally associated with SNF disposal programs and the planned repository.

Currently, the low-temperature route using concrete without uranium is used almost exclusively for dry onsite storage of commercial SNF. Most of the concrete work occurs at the utility site using local contractors. However, the use of a radioactive material like depleted uranium would require a facility for manufacturing the DUCRETE™. Presently, no shielding manufacturers use significant quantities of depleted uranium, but potential future applications like the MPC envision essentially complete manufacture at a facility, with subsequent shipment to the user's site. Therefore, analyses in this report assume a central manufacturing facility for either the DUCRETE™ or the metal route and subsequent shipment of the essentially completed shielded cask to a site for use. The two basic approaches and their principal variations are discussed in the sections that follow.

1.2.1 Depleted Uranium in Concrete (DUCRETE™)

1.2.1.1 Summary

Depleted uranium concrete, or DUCRETE™, involves mixing a uranium oxide with cement and other constituents of ordinary concrete (Haelsig, 1994; Lessing, 1995; Hopf, 1995). Initially, triuranium octaoxide (U_3O_8) was used due to its relative ease of manufacture. However, the dense, ceramic form of UO_2 results in better shielding and is the preferred form for DUCRETE™. In use, the UO_2 comprises 75 to 85 percent of the DUCRETE™ on a mass basis.

1.2.1.2 Assumptions and Bases

The following assumptions and bases were made regarding DUCRETE™ Manufacture:

(a) Use of a central manufacturing facility for DUCRETE™ preparation and casting.

(b) Railroad shipment of fabricated shields/casks from the manufacturing facility to the user sites.

(c) Either road or railroad shipments of depleted uranium to the manufacturing facility. Adequate supply is not an issue.

(d) DUCRETE™ mixture uses colemanite sand that contains (bound) water and boron.

(e) DUCRETE™ has a density of 8 g/cm^3 (500 lb/ft^3).

(f) Inside storage capacity equivalent to 1 year's output of product.

(g) SNF storage application.

(h) After use, SNF is removed from the casks, and the casks are sent to a LLW disposal facility.

(i) No structural credit is assigned to the DUCRETE™.

(j) Use the vertical SNF container as the basic design (figures 1.1 and 1.2).

(k) The overall calculations neglect losses of the uranium to waste streams. These losses are calculated separately (see section 6).

The manufacture of the shielding occurs at a central shielding manufacturing plant. Essentially, complete casks or shielding assemblies are shipped to the user sites after the manufacture has been completed. This requires railroad transport due to the heavy loads involved (typically 100 te or more). The operations at the user site include limited construction, including the construction of supports using regular concrete (i.e., without depleted uranium), which would occur regardless of the use of regular concrete or DUCRETE™ for the shielding. These impacts are not included because the main focus is on the change in the shielding impacts due to the use of DUCRETE™.

The shielding manufacturing plant assumes that the depleted UO_2 is received in 30-gallon drums, containing approximately 667 kg of the dioxide per drum. Approximately 21,500 te of UO_2 would be received per year, corresponding to around 32,150 of these drums. The dioxide would be in either pelletized or microsphere forms, with bulk density of ~ 5.9g/cm^3 and ~ 9 g/cm^3, respectively. The DUCRETE™ would use the material in its received state. The DUCRETE™

mix includes colemanite sand that contains boron, which improves the neutron shielding effectiveness of the DUCRETE™ mixture. This sand amounts to 11 percent of the total weight. A high-shear mixer is used for combining the materials and preparing the DUCRETE™. The sand, cement, and additives arrive in 100 kg containers, which are returned when empty to the vendors for reuse.

The SNF storage container for the DUCRETE™ application uses a design similar to figures 1.1 and 1.2. Each container consumes approximately 45.3 te UO_2 (40 te as uranium), 7 te colemanite sand, 6 te of cement, 0.06 te of cement additives, and 3 te of water, for a total weight of 61.3 te of DUCRETE™. Thus, at full capacity and neglecting losses, the plant produces around 480 finished, SNF storage containers per year. Production of components for an HSM would have comparable fabrication requirements, although fewer modules (about 160) would be manufactured due to the greater consumption of depleted uranium per module. From the perspective of the manufacturing plant, there are essentially no differences. A storage period of 1 year is assumed prior to shipment to a user site. Inside storage is assumed because the casks are not sealed. After conclusion of the SNF storage phase, the SNF is removed, and the DUCRETE™ container is moved and sent to disposal as LLW, perhaps as an overpack containing other LLW.

1.2.1.3 Overall Process Flow Diagrams and Material and Energy Balances for DUCRETE™ Manufacture

Figure 1.3 shows the overall process flow diagram and material and energy balances, while table 1.1 summarizes the results. The overall process consists of cask/steel assembly, DUCRETE™ mixing, casting, DUCRETE™ curing, and final assembly. Section 4 provides additional information on material and energy usage.

1.2.1.4 Specific Flow Diagrams and Material and Energy Balances

1.2.1.4.1 Shielding Cask Assembly Building (cask/steel assembly)

This building receives and assembles the nonradioactive shielding components into an assembly ready for casting of the DUCRETE™. Figure 1.4 presents the flow sheet, and table 1.2 provides the mass and energy balances and treatability categories of any secondary waste streams. This station performs numerous machining and welding operations, many of which are design-specific. Thus, only general parameters are included. The cask body comprises most of the steel. At most, another metric ton of parts are added (e.g., flanges, drain parts, lifting trunnions, ribs). The design incorporates stainless steel, and the flow sheet assumes tungsten-inert gas (TIG) welding using an argon cover gas. The welded shielding assembly is transported by rail to the DUCRETE™ mixing station. The annulus is filled with DUCRETE™, and it is cured prior to welding of the top cover. Facility waste consists primarily of weld splatter, abrasives, and broken equipment, and is handled as sanitary waste.

1.2.1.4.2 DUCRETE™ Manufacture Station (DUCRETE™ mixing, casting, and curing)

The DUCRETE™ manufacturing station uses a high shear mixer for combining and homogenizing the DUCRETE™ constituents, and subsequently directly casting the materials into the annulus of the cask. The approach assumes three mixers operating, with one in cleaning or as backup. The complete shield requires multiple pours over several hours, therefore, vibrators would be used to minimize differentiation at pour joints and eliminate potential voids. Around 17,300 mixer pours are required annually. Figure 1.5 provides the flow diagram, and table 1.3 presents the material and energy balances and treatability categories of any secondary waste streams. The mixers account for most of the energy consumption. The mixers are also responsible for the facility waste. Facility waste is assumed to be comprised of six failed mixer units annually, due to seizing, premature setting, DUCRETE™ coating/tolerances, or breakage. This amounts to about 0.035 percent of the materials processed by the mixers annually.

1.2.1.4.3 DUCRETE™ Water Recycle Station

The DUCRETE™ mixers require periodic rinsing, flushing, and removal of materials adhering to the internal surfaces. The approach accomplishes this by rinsing the mixer with water, which includes low speed mixer operation with water. The water is subsequently removed and treated with flocculants, and the sludge removed as a 50 percent slurry in water. The rinse water is recycled. Figure 1.6 shows the flow sheet, and table 1.4 presents the material and energy balances and treatability categories of any secondary waste streams.

1.2.1.4.4 Final Shielding Assembly Station (final assembly)

This station completes the assembly of the shielding cask. Operations include welding the seal on the annulus, welding the fittings and drains, and final quality control. Figure 1.7 depicts the flow sheet, and table 1.5 provides the material and energy balances and treatability categories of any secondary waste streams.

1.2.1.4.5 Waste Management Station

Figure 1.8 presents the flow sheet, and table 1.6 summarizes the material and energy balances and treatability categories of any secondary waste streams. The failed mixers are assumed to be sent directly to disposal. Other facility wastes are grouted. There are no process water effluent streams requiring treatment. High-efficiency particulate air (HEPA) filters treat all air exhaust from radiological areas. As a first approximation, 50 percent of the HEPA filters are changed each year (due to the inherently dusty process), packaged in drums, and sent to LLW disposal without any additional treatment. Annual LLW generation totals approximately 500 drums. Section 6 provides additional information on waste management and waste composition.

1.2.2 Depleted Uranium Metal

1.2.2.1 Summary

Depleted uranium metal is a dense material, with a density around 19 g/ml. This provides it with excellent properties for gamma shielding. Neutron shielding using a separate polyethylene layer is provided, as shown in figures A.15, A.16, and A.21 in appendix A.

1.2.2.2 Assumptions and Bases

The following assumptions and bases were made regarding shielding manufacture using uranium metal and treatability categories of any secondary waste streams:

(a) Use of a central manufacturing facility for casting and fabrication of the uranium metal shielding assembly.

(b) Railroad shipment of fabricated shields/casks from the manufacturing facility to the user sites.

(c) Either road or railroad shipments of depleted uranium supply to the manufacturing facility. Adequate supply of the uranium metal is not an issue.

(d) The metal arrives as 34-kg billets, loaded in boxes on pallets.

(e) The metal ingots are melted (in a vacuum or under nitrogen) and directly cast into a shield (i.e., the annulus of figures A.21 and A.22 in appendix A).

(f) High stainless steel or titanium alloys constitute the annular walls; these have adequate strength and do not deform or react during the casting of molten uranium.

(g) 43 te of metal are used per shielding cask; 19,516 te of metal are processed by the facility each year. This corresponds to approximately 453 casks annually. A polyethylene shield compensates for the poor neutron shielding properties of uranium.

(h) The "Depleted Uranium MPU" is the representative uranium metal cask (figures A.21 and A.22 in appendix A).

(i) The depleted uranium metal cask assembly containing SNF is subsequently sent to the repository for disposal.

(j) The overall calculations neglect losses of the uranium to waste streams. These losses are calculated separately (see section 6).

The facility assumes that uranium metal is received from the conversion plant in a suitable shipping container. The metal is melted in furnaces under a vacuum or nitrogen inerting, and directly cast into the annular space of the shielding container. The shielding container consists of high stainless, nickel, or titanium alloys with sufficient strength and melting point margins to accommodate the molten uranium metal without deformation. Figures A.21 and A.22 in appendix A show the annular shield design.

1.2.2.3 Overall Process Flow Diagrams and Material and Energy Balances

Figure 1.9 displays the overall process flow diagram, and table 1.7 presents the overall material and energy balances and treatability categories of any secondary waste streams. The uranium metal is received at the facility, melted, and directly cast into an annular shield. Section 4 provides additional details on material and energy consumption.

1.2.2.4 Specific Flow Diagrams and Material and Energy Balances

1.2.2.4.1 Initial Shielding Assembly Station for Uranium Metal (cask/steel assembly)

This station is the same as that for DUCRETE™ shielding (section 1.2.1.4.1) and figure 1.4 shows the flow sheet. There are slight differences in the flow rates, therefore, table 1.8 gives the revised material and energy balances for uranium metal and treatability categories of any secondary waste streams.

1.2.2.4.2 Uranium Metal Shielding Manufacturing Station (direct cast)

The uranium metal shielding manufacturer assumes direct casting of the molten uranium into the annulus formed within the assembled cask. This requires multiple furnaces for melting the uranium and preheating of the cask assembly. Figure 1.10 provides the flow sheet, and table 1.9 presents the material and energy balances and treatability categories of any secondary waste streams. Preheating of the cask assembly occurs in a soaking pit, fired by natural gas. The preheated cask is moved under the furnaces, and a graphite-lined, high-alloy manifold is attached between the bottom of the furnaces and the top of the annulus. Uranium metal billets are charged to the furnaces (about 3 te per furnace), and air is purged from the furnace-manifold-cask system with nitrogen. The system is brought up to temperature. The furnaces melt the uranium, which flows into the cask annulus via the heated manifold. Between 13 and 14 furnace charges are required to completely fill the annulus. The approach assumes that the cask metals have sufficient strength and lack of reactivity to contain the molten uranium. After casting, a temporary cap/seal combination is inserted, and the cask is removed. Air flowing along the outside of the cask slowly cools and solidifies the uranium. After cooling, the cask is cleaned for scale removal, and final assembly occurs. The final assembly material and energy balances are similar to those of DUCRETE™ (table 1.5).

1.2.2.4.3 Waste Management Station for Uranium Metal Shielding

Figure 1.11 presents the flow sheet, and table 1.10 summarizes the material and energy balances and treatability categories of any secondary waste streams. Facility wastes include compactible and noncompactible materials; the latter are grouted. There are no process water effluent streams requiring treatment. HEPA filters treat all air exhaust from radiological areas. As a first approximation, 50 percent of these HEPA filters are changed each year, packaged in drums, and sent to LLW disposal without any other treatment. Annual LLW generation totals approximately 3,300 drums. The uranium metal ultimately resides with the SNF in the repository. Section 6 provides additional information on waste management and waste composition.

Table 1.1 Overall Material and Energy Balances for DUCRETE™ Manufacture

Material/Item	Input, te/yr	Output, te/yr
UO_2	21,477	0
Cement	2,909	0
Colemanite Sand	3,350	0
Cement Additives	29	0
Shielding Forms (rough)	480 *	0
Finished Shielding Casks	0	480 *
Argon	245	0

Process Electricity Usage: 670 kW(e) average.
* Number of casks

Table 1.2: Material and Energy Balances for the Initial Shielding Assembly Station and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, te/yr							Treatability Category
	1	2	3	4	5	6	7	
Stainless Steel	9,610	720	0	0	0	0	0	N/A
Weld Metal	0	0	0	240	0	0	0	N/A
Argon	0	0	155	0	155	0	0	N/A
Assembled Casks	0	0	0	0	0	480 (#)	0	N/A
Facility Waste*	0	0	0	0	0	0	< 10,000 L	Other Hazardous Waste
Total	9,610	720	155	240	155	0	< 10,000 L	N/A
Temperature, °C	25	25	25	25	25	25	25	N/A
Volume, L/hr	157	10	9,918	6	9,918	0	1.1	N/A

Enthalpies: Welding: 5 kW/stand x 21 stands x 50% = 53 kW(e)

Note: Includes steel weight of 22 te per cask.

Refer to Figure 1.4 (Initial Shielding Assembly Station) for corresponding stream numbers.

*Conventional waste (not LLW)

Table 1.3: Material and Energy Balances for the DUCRETE™ Manufacture Station and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, te/yr											Treatability Category
	1	2	3	4	5	6	7	8	9	10	11	
UO_2	21,477	0	0	0	0	0	0	(trace)	0	21,477	8	N/A
Cement	0	2,870	0	0	0	0	0	1	0	2,870	1	N/A
Cement Additives	0	0	29	0	0	0	0	0	0	29	0.01	N/A
Colemanite Sand	0	0	0	3,350	0	0	0	0	0	3,350	1.2	N/A
Water	0	0	0	0	(trace)	1,435	0	(trace)	1,435	1,435	0.5	N/A
Assembled Casks	0	0	0	0	0	0	480(#)	0	0	480(#)	0	N/A
Air/Nitrogen	0	0	0	0	0	0	0	5	0	0	0	N/A
Facility Waste	0	0	0	0	0	0	0	0	0	0	26,000 L	Metal, Surface Contaminated
Total	21,477	2,870	29	3,350	(trace)	1,435	10,560	6	1,435	39,744 (L)	26,000 L	N/A
Temperature, °C	25	25	25	25	25	25	25	25	25	25	25	N/A
Volume, L/hr	416	110	1.1	128	(trace)	164	72,500	542	164	12,400	3	N/A

1. Includes steel weight of 22 te per cask.
2. Enthalpies: High shear mixers: (4) x 60A x 440 V x (0.7071) x (2)/1000 = 150 kW.

Table 1.4: Material and Energy Balances for the DUCRETE™ Water Recycle Station and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, te/yr						Treatability Category
	1	2	3	4	5	6	
DUCRETE™	0	29.3	0	(trace)	0	29.3	Contaminated Dry Active Waste (LLW)
Flocculants	0	0	3.7	0	0	3.7	Aqueous Liquids (LLW)
Water	33	3,678	0	0	3,645	33	N/A
Air/Nitrogen	0	0	0	5	0	0	N/A
Total	33	3,707	3.7	5	3,645	66	N/A
Temperature, °C	25	25	25	25	25	25	N/A
Volume, L/hr	3.8	423	0.4	452	416	6.3	N/A

Facility waste and enthalpies are included in the table 1.10 values.

Note: Refer to Figure 1.6 (Process Flow Diagram for DUCRETE™ Water Recycle Station) for corresponding stream numbers.

Table 1.5: Material and Energy Balances for the Final Shielding Assembly Station and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, te/yr							Treatability Category
	1	2	3	4	5	6	7	
Stainless Steel	48	0	0	0	0	0	0	N/A
Weld Metal	0	24	0	0	0	0	0	N/A
Argon	0	0	90	0	90	0	0	N/A
Assembled Cask	0	0	0	39,869 480(#)	0	39,941 480(#)	0	N/A
Facility Waste	0	0	0	0	0	0	0*	Other Hazardous Waste
Total	48	24	90	39,869 480(#)	90	39,941 480(#)	0	N/A
Temperature, °C	25	25	25	25	25	25	25	N/A
Volume, L/hr	0.7	0.4	769	1,030	769	1,030	0	N/A

Enthalpies: Welding: 5 kW/stand x 12 stands x 50% = 30 kW(e).
Note: Refer to Figure 1.7 (Final Shielding Assembly Station) for corresponding stream numbers.
*Included in table 1.6 values.

Table 1.6: Material and Energy Balances for the Waste Management Station at the Low Temperature Shielding Manufacturing Facility (LTSMF) and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, L/yr								Treatability Category
	1	2	3	4	5	6	7	8	
Facility Waste/ Compactible	13,000	0	0	0	0	3,904	0	0	Metal, surface contaminated
All other facility waste	0	13,000	0	0	39,000	0	0	0	Non-combustible, non-compactible solid (LLW)
Cement	0	0	39 te	0	0	0	0	0	N/A
Water	0	0	0	20,000	0	0	0	0	N/A
HEPAs	0	0	0	0	0	0	0	0	Non-combustible contaminated solid (LLW)
DAW	0	0	0	0	0	0	0	0	Combustible solid (LLW)
Argon/Air/N_2	0	0	0	0	0	0	90 SCFM	350,000 SCFM	N/A
DUCRETE™ Casks	0	0	0	0	0	0	0	0	Metal, activated (LLW)
IX/Carbon	0	0	0	0	0	0	0	0	Sludge/Resin (LLW)
Total	13,000	13,000	39 te	20,000	39,000	3,904	90 SCFM	350,000 SCFM	N/A
Temperature, °C	25	25	25	25	25	25	25	25	N/A
Volume, L/hr	1.5	1.5	3.0	2.2	4.5	0.4	5,759	5.9×10^8	N/A

Note: Refer to Figure 1.8 (Waste Management Station) for corresponding stream numbers.

Table 1.6: Material and Energy Balances for the Waste Management Station at the Low Temperature Shielding Manufacturing Facility (LTSMF) and Treatability Categories of Secondary Waste Streams (continued)

Item/ Component	Stream Number, L/yr								Treatability Category
	9	10	11	12	13	14	15	16	
Facility Waste/ Compactible	0	0	0	0	0	0	0	0	Metal, surface contaminated (LLW)
All other facility waste	0	0	0	0	0	0	0	0	Non-combustible, non-compactible solid (LLW)
Cement	0	0	0	0	0	0	0	0	N/A
Water	0	0	0	0	0	0	0	0	N/A
HEPAs	0	25,000	0	0	0	0	0	0	Non-combustible contaminated solid (LLW)
DAW	0	0	0	532,766	0	53,277	0	0	Combustible solid (LLW)
Argon/Air/N_2	350,090 SCFM	0	350,090 SCFM	0	0	0	10,320 SCFM	0	N/A
DUCRETE™ Casks	0	0	0	0	0	0	0	3.7×10^6	N/A
IX/Carbon	0	0	0	0	4,800	0	0	0	Sludge/Resin (LLW)
Total	350,090 SCFM	25,000	350,090 SCFM	532,766	4,800	53,277	10,320 SCFM	3.7×10^6	N/A
Temperature, °C	25	25	25	25	25	25	25	25	N/A
Volume, L/hr	5.9×10^8	2.8	5.9×10^8	60.8	0.5	6.1	1.7×10^7	420.5	N/A

Note: Refer to Figure 1.8 (Waste Management Station) for corresponding stream numbers.

Table 1.7: Overall Material and Energy Balances for Depleted Uranium Metal Shielding Manufacture

Material/Item	Input, te/yr	Output, te/yr
Uranium Metal	19,516	0
Shielding Forms, rough*	12,400 [453(#)]	0
Finished Shielding Casks	0	453(#)
Argon	245	0

*Principally stainless steel.
Process Electricity Usage: 1,520 kW(e) average.
Process Natural Gas Usage: 351 kW(t) average.

Table 1.8: Material and Energy Balances for the Initial Shielding Assembly Station for Uranium Metal and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, te/yr							Treatability Category
	1	2	3	4	5	6	7	
Stainless Steel	11,400	900	0	0	0	0	0	N/A
Weld Metal	0	0	0	400	0	0	0	N/A
Argon	0	0	155	0	155	0	0	N/A
Assembled Casks	0	0	0	0	0	453(#)	0	N/A
Facility Waste*	0	0	0	0	0	0	< 10,000 L	Other Hazardous Waste
Total	11,400	900	155	400	155	453(#)	< 10,000 L	N/A
Temperature, °C	25	25	25	25	25	25	25	N/A
Volume, L/hr	157	13	9,918	6	9,918	738	1.1	N/A

Enthalpies: Welding: 5 kW/stand x 21 stands x 50% = 53 kW(e)

Note: Includes steel weigh of 28 te per cask.

Refer to Figure 1.4 (Initial Shielding Assembly Station) for corresponding stream numbers.

*Conventional waste (not LLW)

Table 1.9: Material and Energy Balances for the Uranium Metal Shielding Manufacturing Station and Treatability Categories of Secondary Waste Streams

Item/ Component	Stream Number, te/yr								Treatability Category
	1	2	3	4	5	6	7	8	
Uranium Metal	19,516	0	0	19,516	0	(trace)	19,516	(trace)	N/A
Assembled Casks	0	12,700 453(#)	12,700 453(#)	12,700 453(#)	0	0	0	0	N/A
Air/Nitrogen	0	0	0	0	1,400 SCFM	1,400 SCFM	0	0	N/A
Facility Waste	0	0	0	0	0	0	0	26,000 L	Other Hazardous Waste
Total	19,516	12,700	12,700	32,216	1,400 SCFM	1,400 SCFM	19,516	26,000 L	N/A
Temperature, °C	25	25	1,100	25	25	25	1,200	25	N/A
Volume, L/hr	114	944	944	944	2.4×10^6	2.4×10^6	~125	3	N/A

Note: Refer to Figure 1.10 (Uranium Metal Shielding Manufacturing Station) for corresponding stream numbers.

Table 1.10: Material and Energy Balances for the Waste Management Station at the High Temperature Shielding Manufacturing Facility (HTSMF) and Treatability Categories of Secondary Waste Streams

Item/Component	Stream Number, L/yr								Treatability Category
	1	2	3	4	5	6	7	8	
Facility Waste/ Compactible	13,000	0	0	0	0	3,900	0	0	Metal, surface contaminated (LLW)
All other facility waste	0	13,000	0	0	39,000	0	0	0	Combustible solid (LLW)
Cement	0	0	39 te	0	0	0	0	0	N/A
Water	0	0	0	20 te	0	0	0	0	N/A
HEPAs	0	0	0	0	0	0	0	0	Non-combustible, non-compactible solid (LLW)
DAW	0	0	0	0	0	0	0	0	Combustible solid (LLW)
Argon/Air/N_2	0	0	0	0	0	0	1,400 SCFM	370,000 SCFM	N/A
IX/Carbon	0	0	0	0	0	0	0	0	Sludge/Resin (LLW)
Total	13,000	13,000	39 te	20 te	39,000	39,000	1,400 SCFM	370,000 SCFM	N/A
Temperature, °C	25	25	25	25	25	25	25	25	N/A
Volume, L/hr	1.5	1.5	3.0	22	4.5	0.4	89,584	6.2×10^8	N/A

Note: Refer to Figure 1.11 (Waste Management Station for the HTSMF) for corresponding stream numbers.

Table 1.10: Material and Energy Balances for the Waste Management Station at the High Temperature Shielding Manufacturing Facility (HTSMF) and Treatability Categories of Secondary Waste Streams (continued)

Item/ Component	Stream Number, L/yr							Treatability Category
	9	10	11	12	13	14	15	
Facility Waste/Compactible	0	0	0	0	0	0	0	Metal, surface contaminated (LLW)
All other facility waste	0	0	0	0	0	0	0	Combustible solid (LLW)
Cement	0	0	0	0	0	0	0	N/A
Water	0	0	0	0	0	0	0	N/A
HEPAs	0	25,000	0	0	0	0	0	Non-combustible, non-compactible solid (LLW)
DAW	0	0	0	1.1×10^6	0	5.8×10^5	0	Combustible solid (LLW)
Argon/Air/N_2	371,400 SCFM	0	371,400 SCFM	0	0	0	10,320 SCFM	N/A
IX/Carbon	0	0	0	0	4,800	0	0	Sludge/Resin (LLW)
Total	371,400 SCFM	25,000	371,400 SCFM	1.1×10^6	4,800	5.8×10^5	10,320 SCFM	N/A
Temperature, °C	25	25	25	25	25	25	25	N/A
Volume, L/hr	6.3×10^8	2.8	6.3×10^8	120.3	0.5	66.1	1.7×10^7	N/A

Note: Refer to Figure 1.8 [Waste Management Station for the LTSMF (DUCRETE™)] for corresponding stream numbers.

Figure 1.1: Typical Vertical Design for SNF Storage (Hertzler, 1994)

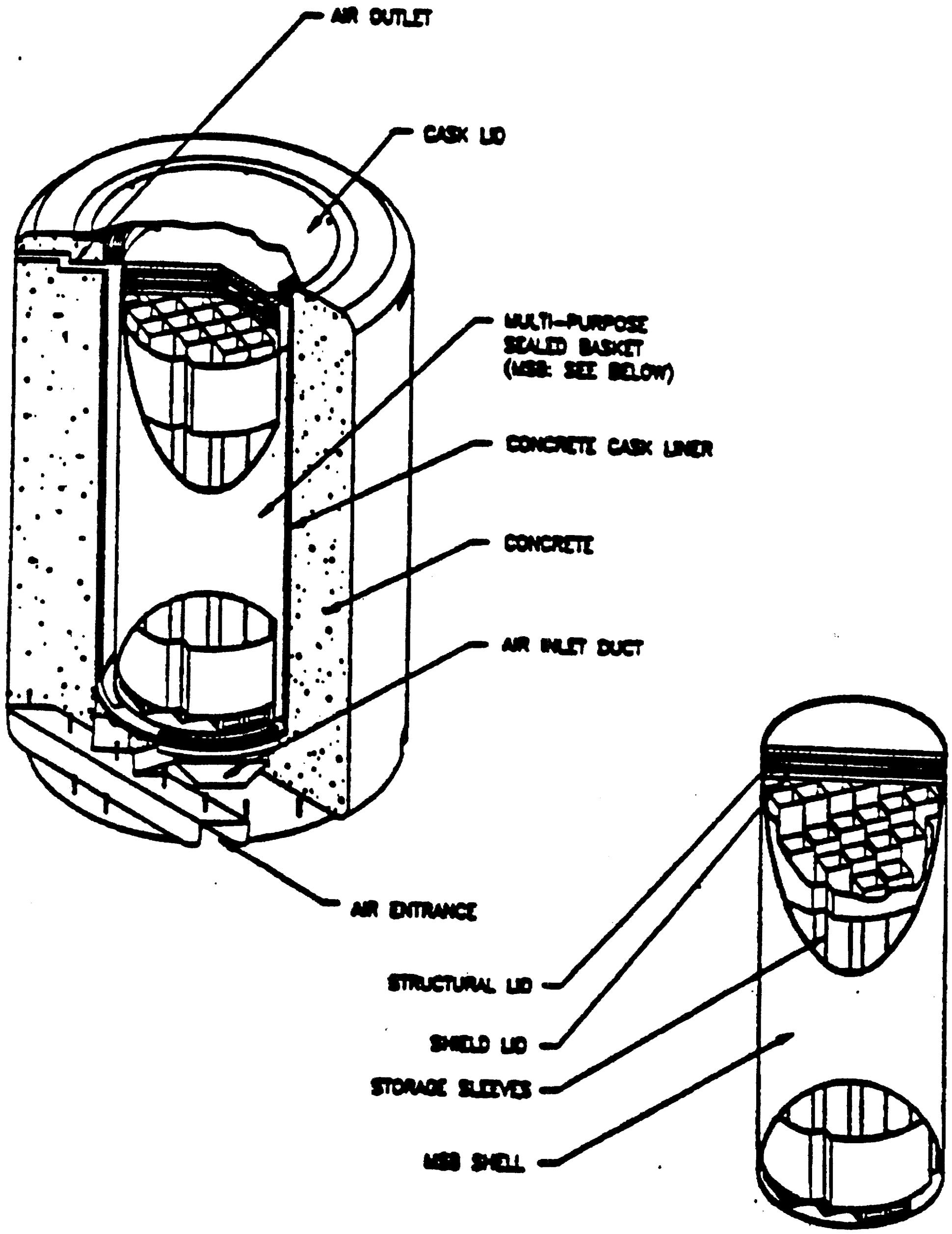


Figure 1.2: Comparison of Cross-Sections Between Regular Concrete and DUCRETE™ for Vertical SNF Storage (Lessing, 1995)

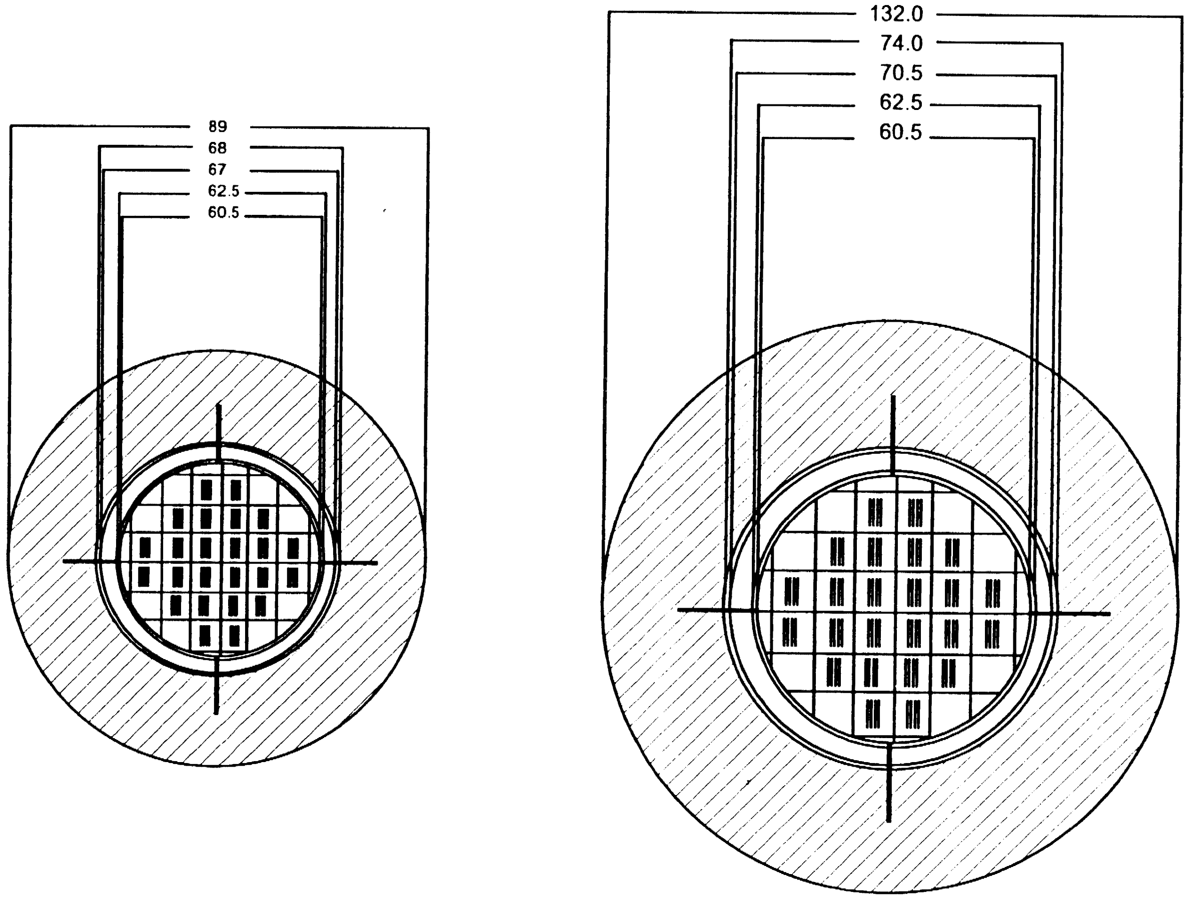


Figure 1.3: Overall Material and Energy Balances for DUCRETE™ Shielding Manufacture (Annual Basis)

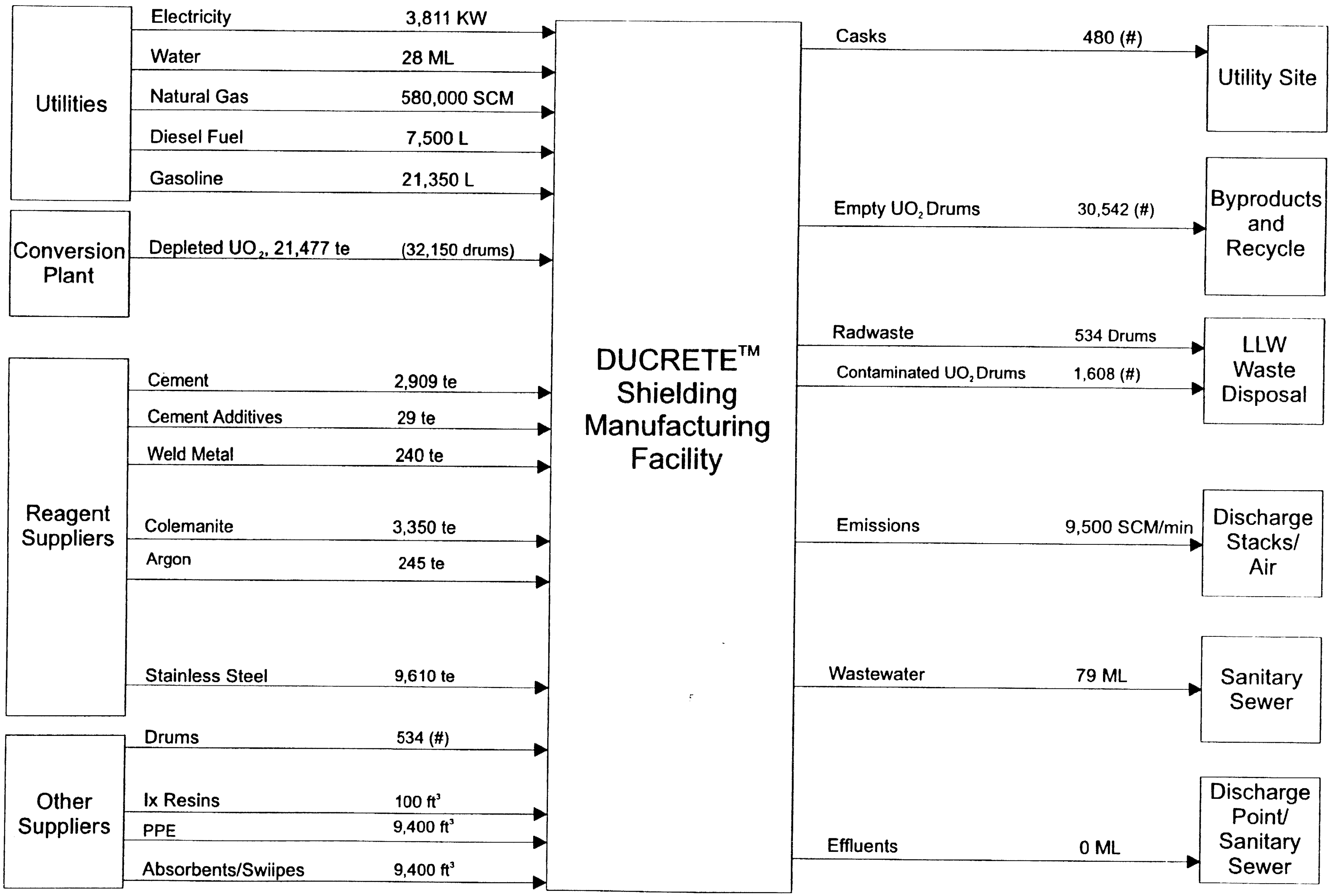
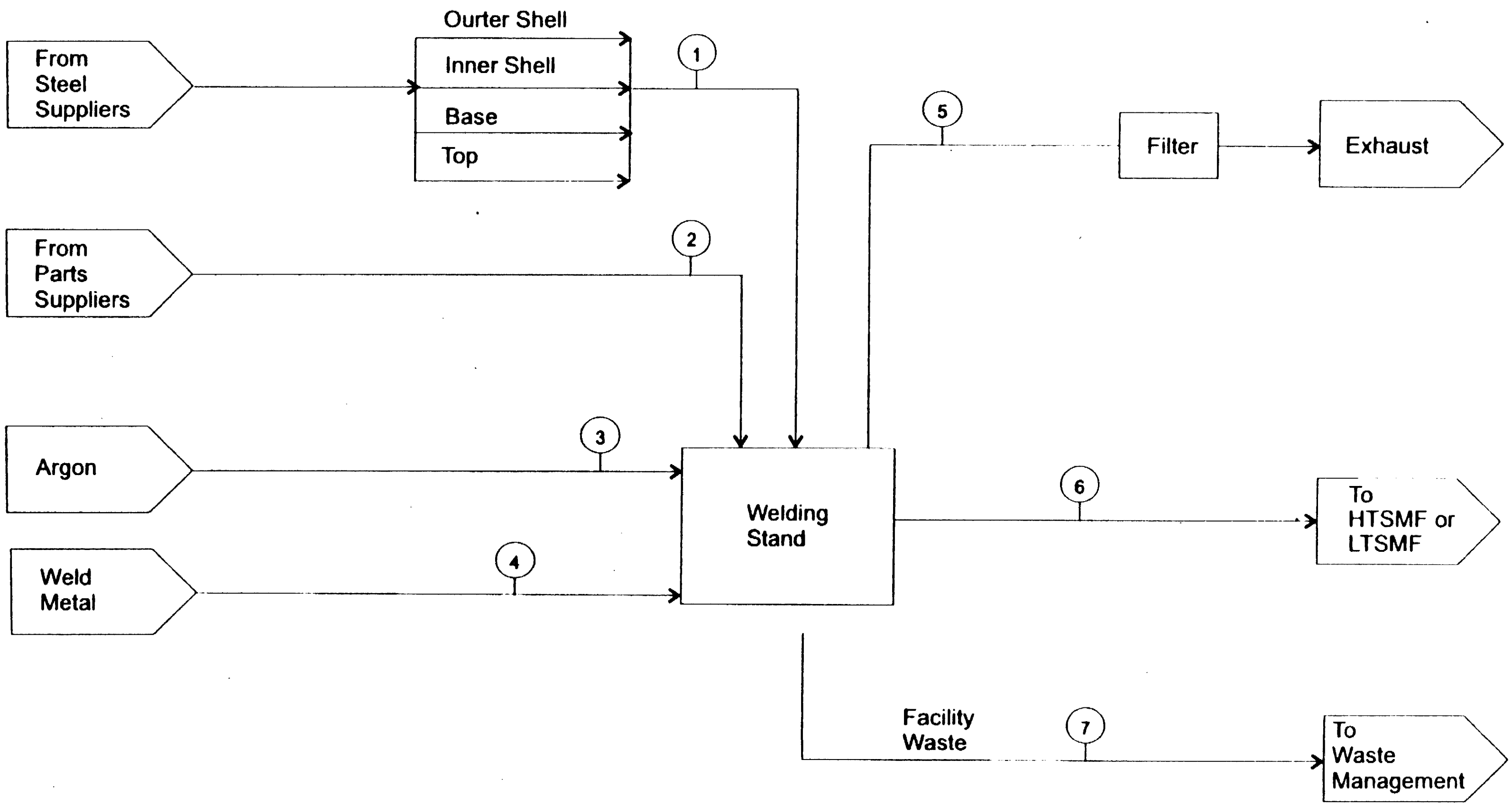


Figure 1.4: Initial Shielding Assembly Station



* Particulate Filter for Welding Operations
**Assembled Casks to DUCRETE™ Mixing

Figure 1.5: Process Flow Diagram for DUCRETE™ Preparation

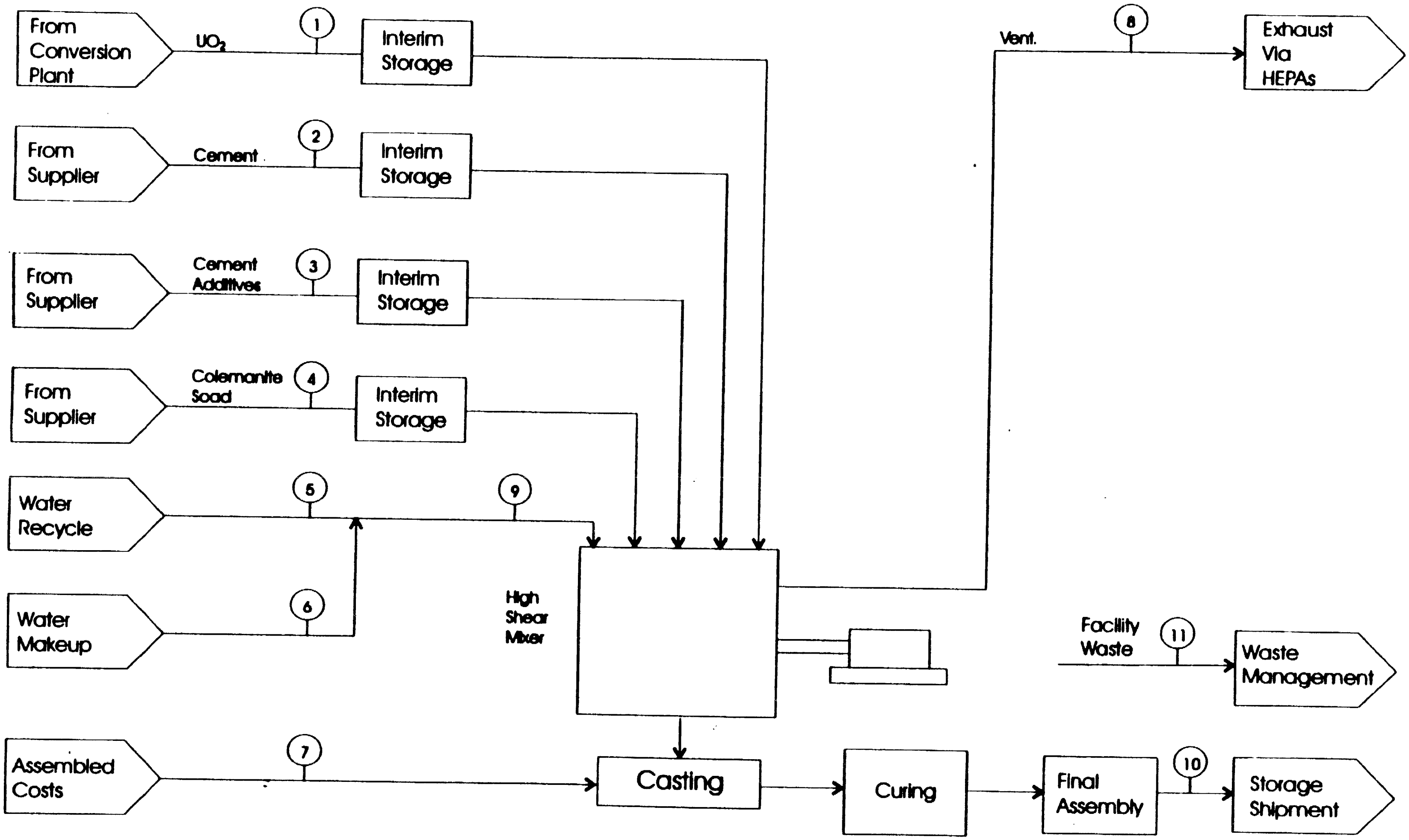


Figure 1.6: Process Flow Diagram for DUCRETE™ Water Recycle Station

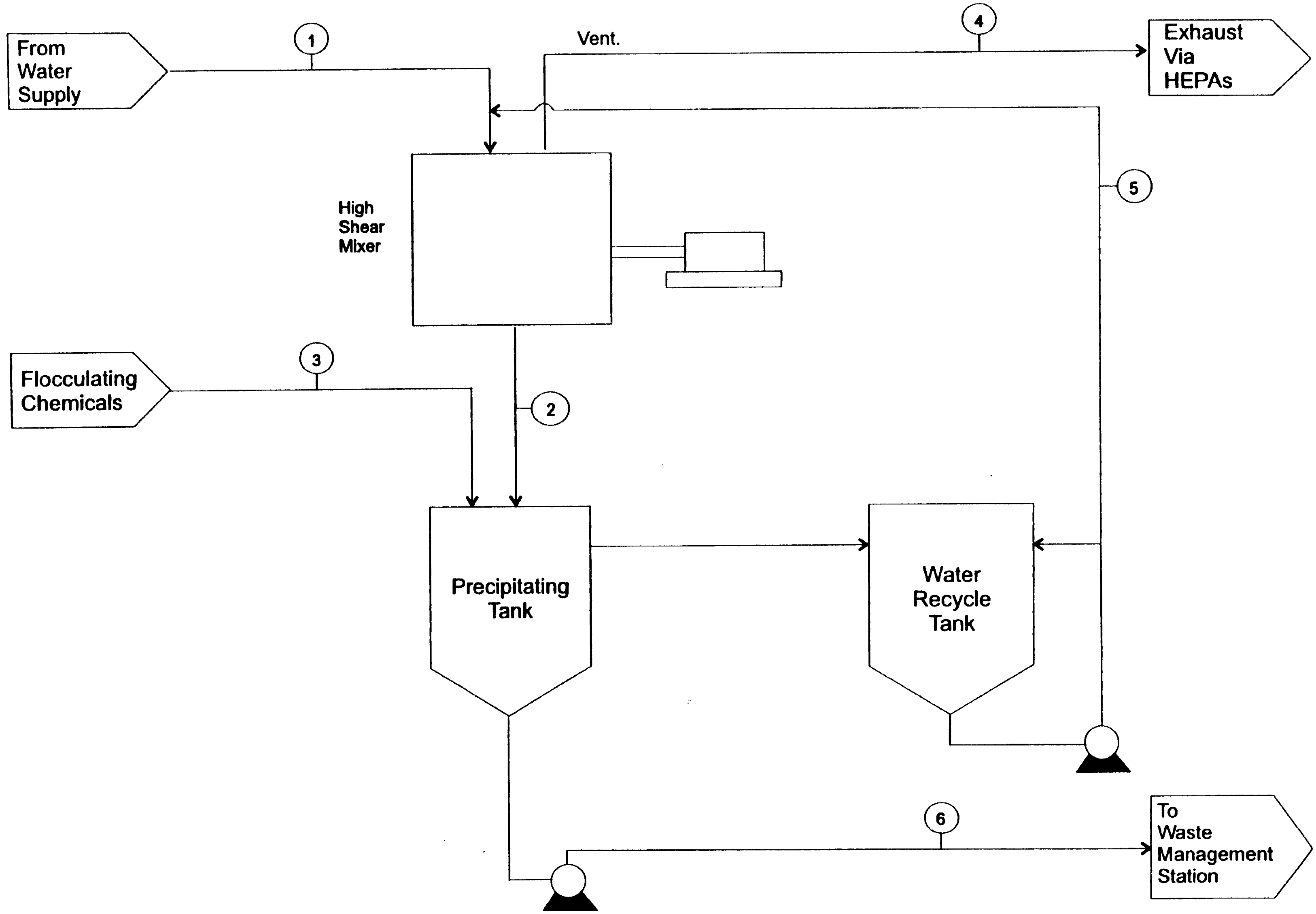


Figure 1.7: Final Shielding Assembly Station

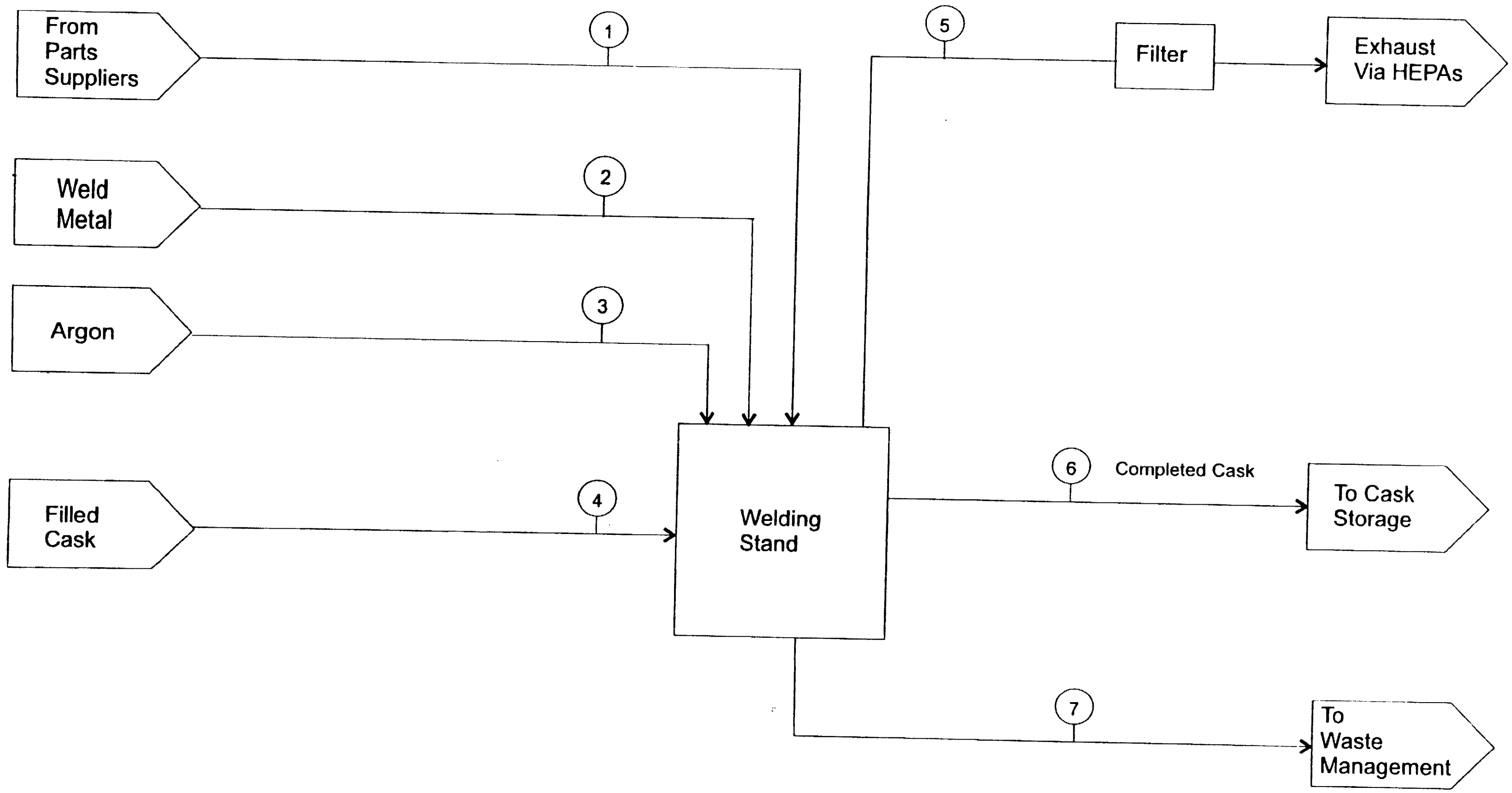


Figure 1.8: Waste Management Station for the LTSMF (DUCRETE™)

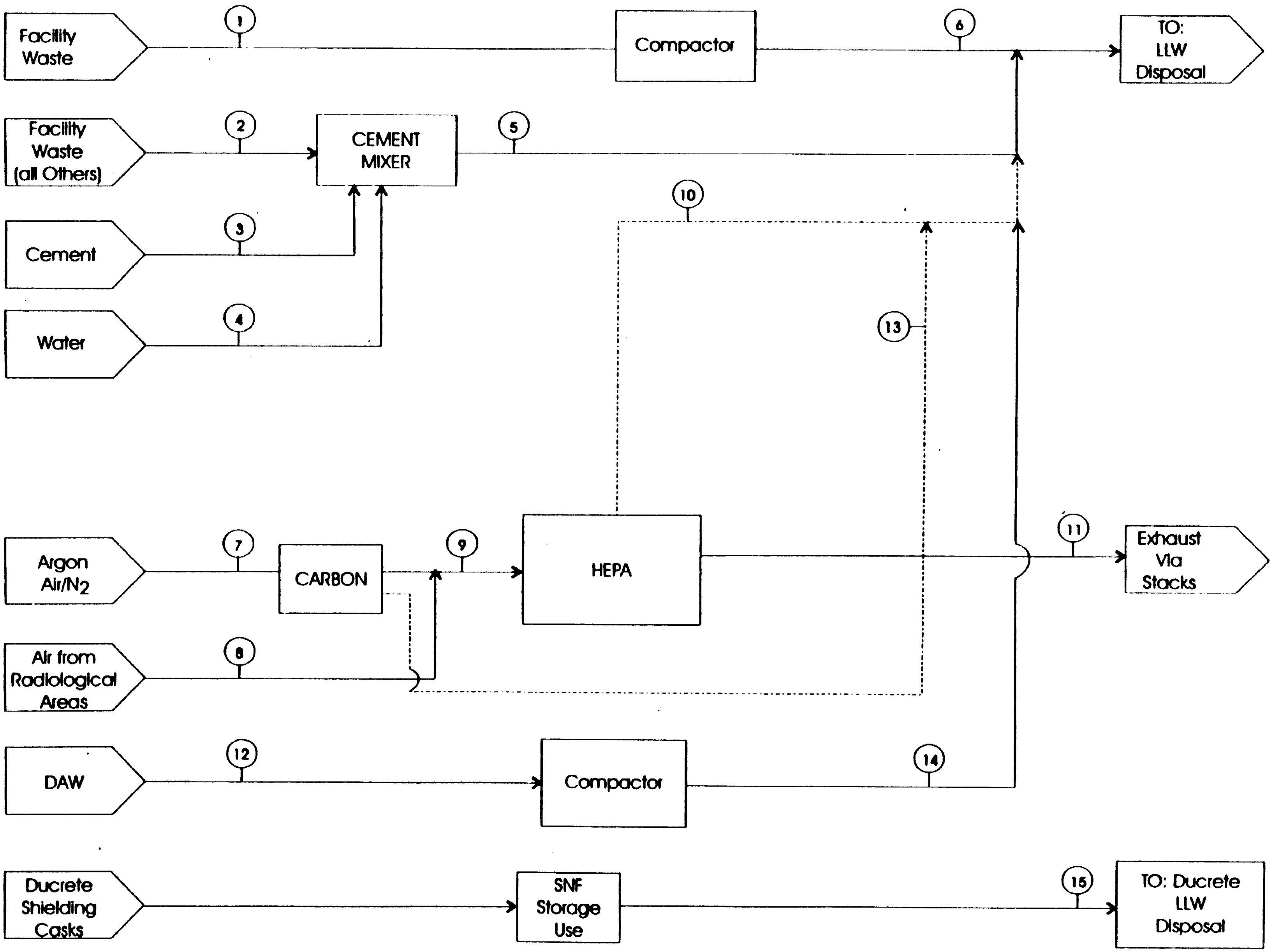


Figure 1.9: Overall Material and Energy Balances for the Depleted Uranium Metal Shielding Manufacture

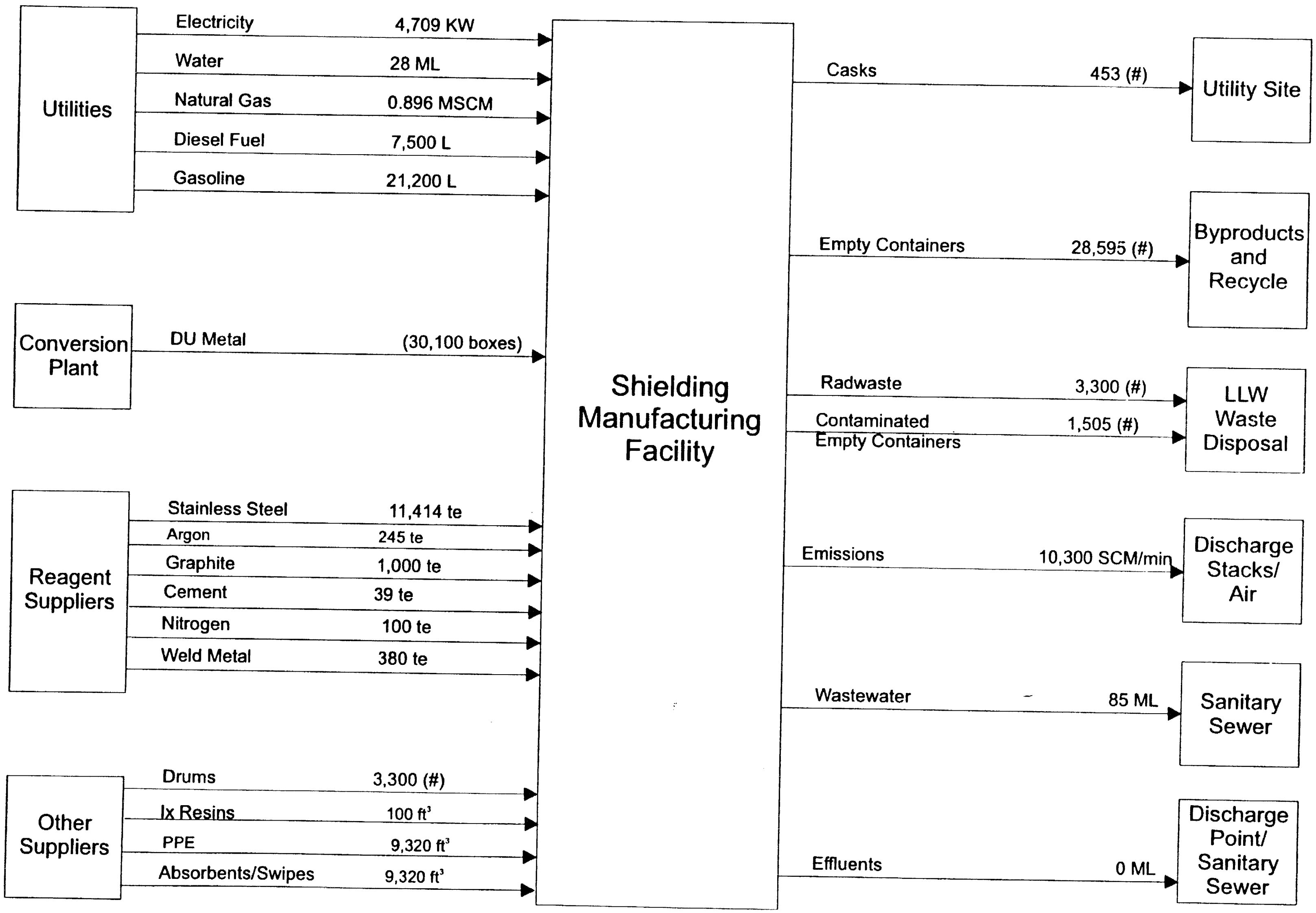


Figure 1.10: Uranium Metal Shielding Manufacturing Station

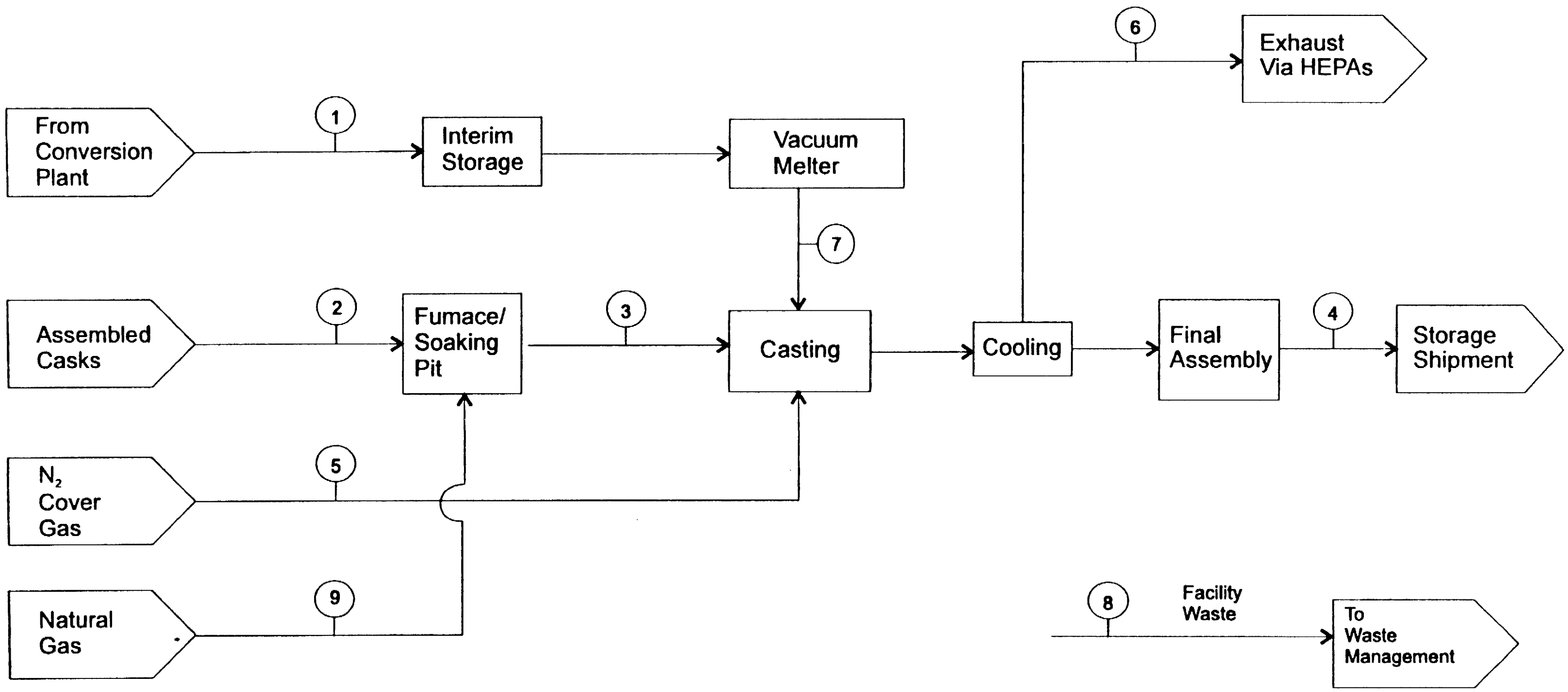
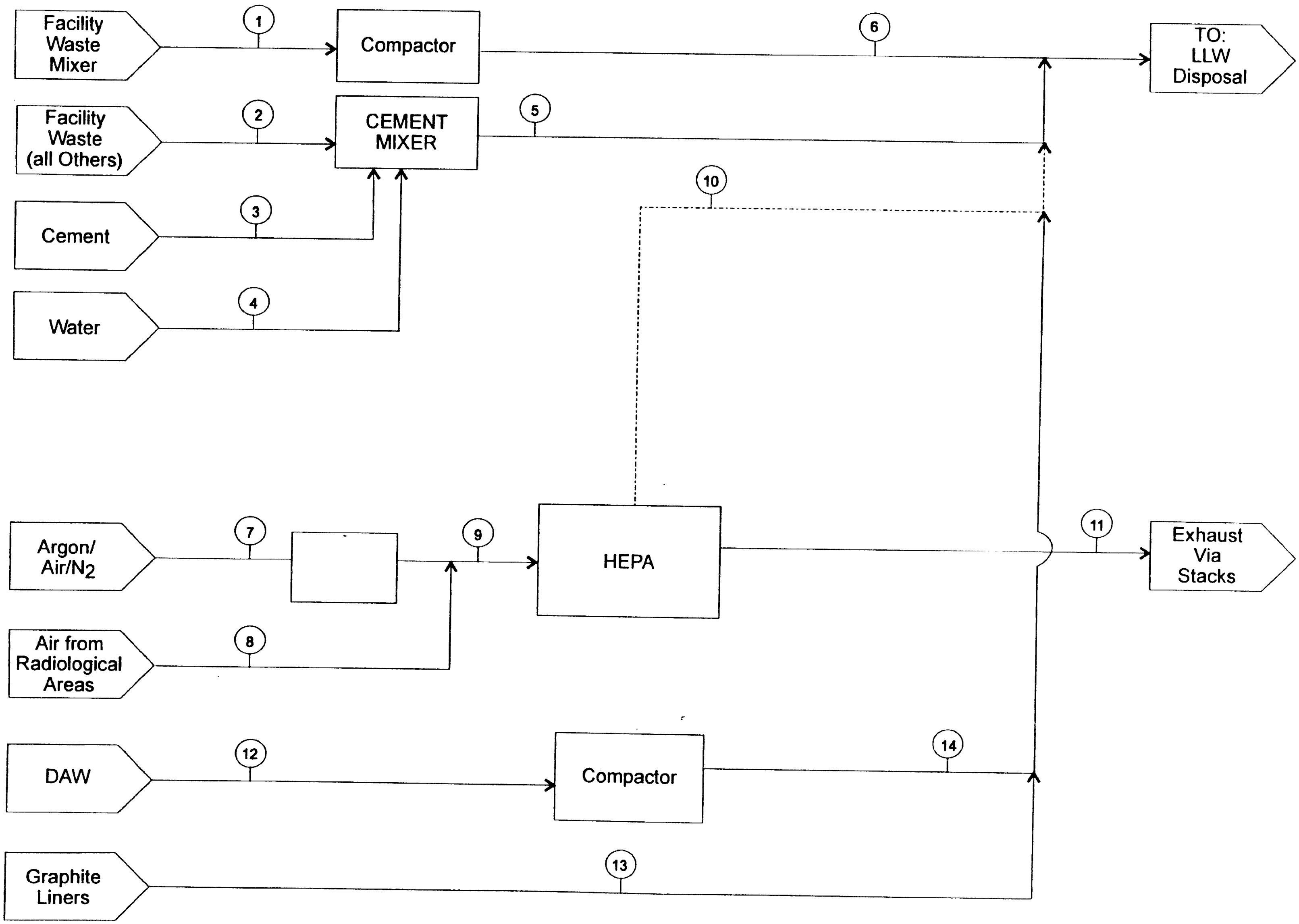


Figure 1.11: Waste Management Station for the HTSMF



2.0 DESCRIPTION OF THE SHIELDING MANUFACTURING FACILITY

In the Shielding Manufacturing Facility (SMF), the following major operations are carried out:

- Receipt and assembly of nonradioactive shielding components
- Generation of the depleted uranium shielding and its incorporation into the assembly
- Final assembly and inspection of the shielding assembly
- Storage of the shielding assembly prior to shipment
- Support functions, including waste management, Health Physics (HP), emergency services, analysis, and administration

Ten major buildings are required to perform these functions. A low-temperature process produces DUCRETE™-based shielding, and this facility is designated as the Low Temperature Shielding Manufacturing Facility (LTSMF). A high-temperature route generates uranium metal-based shielding, and this is designated the High Temperature Shielding Manufacturing Facility (HTSMF). Section 2.1 discusses the LTSMF, while section 2.2 discusses the HTSMF. Section 2.3 presents general design and safety criteria applicable to either the LTSMF or the HTSMF. Appendix B provides equipment lists for the LTSMF, and appendix C provides equipment lists for the HTSMF.

The buildings of the LTSMF and the HTSMF follow generally accepted designs and would not require unusual construction or unique construction equipment. No unusual contractor or supplier requirements appear necessary. The buildings use standard metal, concrete, and/or concrete block construction on spread footings, with at-grade construction. Evaluation of site-specific conditions, local suppliers, and economics during a detailed design phase may favor one building approach over another. However, this preconceptual design assumes predominantly concrete block construction due to its inertial properties, the likely existence of local suppliers, the large usage of concrete during the plant's construction (which should result in favorable economics), wide acceptability in building codes, and the probable incorporation of crane rails and supports into the building's structure. The LTSMF does not contain any buildings or areas with moderate- or high-hazard rankings, and therefore, the LTSMF does not require special construction. In contrast, the uranium metal handling and casting areas of the HTSMF would have steel-reinforced concrete walls and roof materials, each approximately 20-cm-thick (8 in.), commensurate with construction requirements for a moderate hazard facility. Thicker concrete flooring and subflooring are anticipated for several of the buildings handling the shielding due to the expected weights and potentially high floor loadings [approaching 25,000 kg/m^2 (5,200 lb/ft^2) or more]. Carbon steel, for rebar, beams, trestles, and other support functions, represents the principal metal used in construction. Some alloy usage for furnaces is anticipated in the HTSMF; this usage would be small, on the order of 100 te, and would be fully ascertained in a more detailed design. Metal usage is expected to be well within established market supply, and, thus significant impacts or shortages are not anticipated.

Potential hazards and accident analyses dictate the specific design and construction requirements of DOE and Nuclear Regulatory Commission (NRC) facilities via established protocols (these are discussed in section 2.3). At the pre-conceptual level of this report and without the identification of a specific site, qualitative assessments and hazard rankings are possible and have been made. Table 2.1 summarizes these assessments for the LTSMF and table 2.2 summarizes these assessments for the HTSMF. For the LTSMF, most of the buildings would be assigned low-hazard rankings. LTSMF buildings and areas that contain and handle radioactive materials do so with minimal energy for dispersion and contamination, and with radioactive materials in forms that resist dispersion (i.e., uranium dioxide sand, pellets, and DUCRETE™). Hence, there are no offsite consequences and only minimal onsite consequences. Certain buildings would be required to continue operations after a seismic event or an accident, and these buildings would be categorized as low hazard/essential. The cask storage building could potentially contain around 20,000 te of depleted uranium. However, the uranium exists in a solidified form in qualified casks, and hence, the release fractions are effectively zero. Thus, this building would not have a hazard ranking, and a general design would be acceptable. The HTSMF building hazard rankings are the same as the LTSMF except for those areas of the Main Processing Building (MPB) that handle large quantities of uranium metal and are involved in casting operations. These areas of the HTSMF MPB would have a moderate ranking due to the quantities of uranium metals, the presence of molten uranium metal, dispersive energy, and the potential for respirable particle production during an event.

2.1 Depleted Uranium in Concrete (DUCRETE™) - LTSMF

The LTSMF consists of the following 10 main buildings:

- Shielding Cask Assembly Building (SCAB)
- Main Processing Building (MPB)
- Shielding Cask Product Storage Building (SCPSB)
- General Warehouse and Storage Building (GWSB)
- Waste Management Building (WMB)
- Radwaste Storage Building (RSB)
- Utility Supply Building (USB)

- Health Physics and RCA Access Control Building (HPRACB)
- Emergency Services Building (ESB)
- Administration and Technical Services Building (ATSB)

These are discussed in the sections that follow.

2.1.1 General Description

2.1.1.1 Shielding Cask Assembly Building (SCAB)

Figure 2.1 provides the layout of the SCAB. The SCAB does not handle radioactive materials and is located outside the Radiological Control Area (RCA). The SCAB receives, inspects, and accepts the partially fabricated, raw steel forms. These include the stainless steel shells for the shielding itself. The steel forms arrive by both truck and rail, and the SCAB includes receiving bays for both transportation modes. SCAB operations weld, assemble, and machine the steel forms into the final shapes for the shielding container. For casks, this is a cylindrical container with an annulus, open at the top but closed at the bottom. Various connections, plugs, ports, etc. are also added. The SCAB includes a 7-day, interim storage area for 15 assembled shielding forms. Assuming a cask manufacturing rate of 475 per year and a 3-m-square footprint per assembly station, the SCAB allows for the assembly of up to 21 cask forms at a time. Assembled shielding cask forms are transported via the rail line to the MPB for casting of the depleted uranium shielding material into the annulus.

The SCAB consists of standard concrete block and metal construction over spread footings. The SCAB incorporates three, overhead 150-te cranes for movement of the shielding forms. These cranes include the standard limit and safety switches, and maintain position in the event of a loss of power. Crane rails are supported by additional steel pillars and footings. The concrete floor and subfloor are each 0.6-m-thick (2 ft) to accommodate the heavy weight of the shielding forms and their equipment. Individual hoods and exhausts are used for the removal of welding fumes. Two 12.6-kW Uninterruptible Power Supply/Uninterruptible Battery Supply (UPS/UBS) systems provide clean, uninterruptible power for computers, controls, and emergency equipment (Bowden, 1995). A diesel-electric Standby Power Supply (SPS) is located at the USB and provides backup power for electric equipment and actuators in the SCAB.

2.1.1.2 Main Processing Building (MPB)

Figure 2.2 provides the layout of the MPB. This building houses the radioactive material processing. It consists of standard construction based upon concrete block and spread footers. Several interior walls are included for isolating areas and units within the building. The MPB incorporates four, overhead 150-te cranes for movement of the shielding forms. These cranes include the standard limit and safety switches, and maintain position in the event of a loss of power. Crane rails are supported by additional steel pillars and footings. The concrete floor and subfloor are each 0.6-m-thick (2 ft) to accommodate the heavy weight of the shielding forms and their equipment. Individual hoods and exhausts are used for the removal of welding fumes. Two 12.6-kW UPS/UBS systems provide clean, uninterruptible power for computers, controls, and emergency equipment. A diesel-electric SPS is located at the USB and provides backup power for electric equipment and actuators in the MPB. The MPB consists of the following six areas:

- Depleted Uranium Dioxide Receiving Area
- Depleted Uranium Dioxide Storage Area
- DUCRETE™ Mixing and Casting Area
- DUCRETE™ Curing Area
- Final Assembly and Quality Control Area
- Finished Cask Interim Storage and Shipping Area

Section 2.1.2 discusses these areas in more detail.

2.1.1.3 Shielding Cask Product Storage Building (SCPSB)

Figure 2.3 provides the layout of the SCPSB. The shielding casks require storage prior to shipment to a user site. Ostensibly, the casks could be stored on an outside pad. However, the weatherproof tops cannot be attached until the casks are actually loaded with fuel. Also, outside storage necessitates a subsequent cleaning and inspection step (e.g., for dirt and birds). Furthermore, rectangular shield wall assemblies might not be amenable to outside storage. Thus, the design assumes inside storage in a building with normal ventilation (no HEPA filtration). The building is a standard design of concrete block construction upon spread footings, and the concrete floor consists of a 60-cm concrete slab on a 60-cm base of compacted gravel. Optimization and site-specific studies during a more detailed design phase may allow the use of other approaches, such as metal buildings, and analyze trade-offs between layouts and crane requirements (e.g., spans). A 150-te bridge crane is used to transfer the casks from the railroad transfer car to the storage area with an approximate span of 200 ft. The design includes a 12.6 kW UPS/UBS for continuous power to instrumentation and computers. Four buildings are required for a 12-month storage capacity.

2.1.1.4 General Warehouse and Storage Building (GWSB, for Nonradioactive Materials)

Figure 2.4 provides the layout of the GWSB. The GWSB provides space for most of the items received on the site. The building consists of standard construction with concrete block walls upon spread footings. The GWSB is near the main entrance to the site and, thus, avoids heavy traffic within the site due to routine deliveries. The GWSB includes six loading/unloading bays, an office area, and several storage bays. The design incorporates a computer system for logging, accounting, and communication, and a 12.5 kW UPS/UBS.

2.1.1.5 Waste Management Building (WMB)

Figure 2.5 provides the layout of the WMB. The WMB includes a waste sorting area, a compactor area, two solidification areas (based upon cement or similar solidifying agents), two counting/assay areas, and a packaging area. The building also includes wet and dry decontamination areas. The design includes computer systems and a 12.5 kW UPS/UBS.

2.1.1.6 Radwaste Storage Building (RSB)

Figure 2.6 provides the layout of the RSB. The RSB follows standard construction criteria. The exterior uses a metal wall and frame, with interior concrete block partitions for the actual waste storage areas. This building temporarily stores packaged and/or solidified LLW until its shipment offsite. The RSB is located within the RCA.

2.1.1.7 Utility Supply Building (USB)

Figure 2.7 provides the layout of the USB. The USB provides utility functions for the shielding manufacturing site. The building is of standard construction, with concrete block walls on spread-footer foundations, and a concrete slab floor. It includes radiological work areas with HEPA exhaust. The USB provides pressurized nitrogen for inerting the mixers and casting areas, using pressurized swing absorption systems. Two parallel trains consuming approximately 362 kW(e) each provide up to a total of 1,400 SCFM of nitrogen at 80 psig and 99 percent purity. An adjacent plant also produces deionized water for the site. The USB incorporates a large maintenance shop for servicing contaminated plant equipment.

The USB has an office and a rest area. It also includes two receiving bays (truck only) and HP/change areas. The USB includes two SPS diesel-electric generators for backup power if the utility connection is disrupted. The USB is located within the RCA.

2.1.1.8 Health Physics and RCA Access Control Building (HPRACB)

Figure 2.8 provides the layout of the HPRACB. The HPRACB functions as the main portal to the shielding manufacturing and uranium handling areas in the RCA. It is a two-story building of general construction, based upon concrete block. The ground floor is divided into the inlet and outlet portals, while the second floor contains offices and a conference room.

2.1.1.9 Emergency Services Building (ESB)

Figure 2.9 provides the layout of the ESB. The ESB is a two-story building of concrete and steel construction, located immediately adjacent to the ATSB. The building provides space for the firefighters, paramedics, communications equipment, and emergency vehicles. The second floor contains the offices, while the first floor houses the vehicles. The design includes a 12.6 kW UPS/UBS combination for providing clean and continuous power during an outage.

2.1.1.10 Administration and Technical Services Building (ATSB)

Figure 2.10 provides the layout of the ATSB. The ATSB is a two-story building of standard construction. The ATSB provides the following functions:

- Office space for administration and technical staff
- Main cafeteria
- Security and visitor control
- HP center
- Analytical support and laboratory services
- Emergency/first aid

The engineering staff and computer personnel occupy the second floor. Security and first aid are located on the left side of the ATSB, adjacent to the ESB. The design includes one 5-kW UPS/UBS for computer and communications power, and one 12.6-kW UPS/UBS for analytical instrumentation power.

2.1.2 Description of Key Areas in the Main Processing Building for DUCRETE™ Shielding Manufacture (LTSMF)

2.1.2.1 Depleted Uranium Dioxide Receiving Area

Figure 2.11 displays the layout for a unit in this area. This area incorporates four truck bays and one rail bay for the receipt of UO_2. Several railcars can be within the rail bay and be unloaded at the same time. The UO_2 drums are unloaded using fork lifts and other standard equipment.

2.1.2.2 Depleted Uranium Dioxide Storage Area

Figure 2.12 displays the layout for a unit in this area. This provides storage for the UO_2 material in its original shipping container for over a month. The 30-gallon drums are stored double stacked (each drum holds approximately 667 kg). Using one square meter as the footprint for a pallet, and double stacking to allow for inter-row spacing, one day's average receipt equates to around 22 m^2. Total height would be approximately 1.5 m, including palletizing materials. A bridge crane (capacity of 15 te or so) services the area to facilitate drum movements and minimize aisle spaces. One unit corresponds to 100 percent capacity.

2.1.2.3 DUCRETE™ Mixing and Casting Area

Figure 2.13 displays the layout for a unit in this area. The LTSMF directly casts the DUCRETE™ into the annular space of the cask. Consequently, this area possesses the capabilities for shielding cask receipt and handling, mixing of the depleted UO_2 with cement and sand, casting of the DUCRETE™, and movement of the (now loaded) DUCRETE™ shielding cask. It can be assumed, however, that on the average, DUCRETE™ production uses high shear mixers, which have a good record of reliability in nuclear applications (Lessing, 1995; U.S. DOE 1991). Using 1-hour batch times, two mixers can prepare adequate quantities of DUCRETE™ for one cask in approximately two shifts, using successive pours of the material into the cask's annular space. A third mixer is included as a standby. After loading, a temporary sealed top is inserted, and the cask is moved to stands that provide a firm, level area for setting (i.e., initial solidification) of the DUCRETE™. One to 2 days may be required for adequate DUCRETE™ solidification and strength to allow movement without concern. The approach assumes crane transport, although a car/rail system could be evaluated as part of a more detailed design. Two units are required in the design for 100 percent capacity.

2.1.2.4 DUCRETE™ Curing Area

Figure 2.14 displays the layout for a unit in this area. Typically, a month-long curing period achieves at least 90 percent of the ultimate strength, and this area provides a controlled storage area environment for the curing to occur. Adequate space is included for monitoring and environmental control chambers. Periodic inspection and temperature monitoring would be conducted on the DUCRETE™ during this curing period. It is envisioned that the temporary seal is not removed from the cask annulus. Measurements are either non-contact (i.e., through the side wall) or through ports in the seal (i.e., for strength measurements). One unit is required at the 100 percent capacity condition.

2.1.2.5 Final Assembly and Quality Control Area

Figure 2.15 displays the layout for a unit in this area. Final assembly includes filling any voids within the DUCRETE™ shielding, adding a permanent seal and cover to the DUCRETE™-filled annulus, and draining fixtures. Quality control includes material certifications, weight and density measurements, weldment checks and evaluations, and dimensional tolerances.

2.1.2.6 Finished Cask Interim Storage and Shipping Area

Figure 2.16 displays the layout for a unit in this area. This area provides for a short lag storage space for the finished shielding cask prior to its shipment to the SCPSB.

2.2 Depleted Uranium Metal - HTSMF

The HTSMF consists of the following 10 major buildings:

- Shielding Cask Assembly Building (SCAB)
- Main Processing Building (MPB)
- Shielding Cask Product Storage Building (SCPSB)
- General Warehouse and Storage Building (GWSB)
- Waste Management Building (WMB)
- Radwaste Storage Building (RSB)
- Utility Supply Building (USB)
- Health Physics and RCA Access Control Building (HPRACB)
- Emergency Services Building (ESB)
- Administration and Technical Services Building (ATSB)

These are discussed in the sections that follow.

2.2.1 General Description

2.2.1.1 Shielding Cask Assembly Building (SCAB)

The SCAB for the HTSMF is the same as the one for the LTSMF due to similarities in cask size and manufacturing. Thus, figure 2.1 also represents the layout for the HTSMF SCAB.

2.2.1.2 Main Processing Building (MPB)

Figure 2.17 provides the layout for the MPB. This building houses most of the radioactive material processing. Approximately half of the building consists of standard construction, based upon concrete block construction and spread footers. However, the other half has areas containing large inventories of warm uranium metal. Consequently, these areas and the metal casting units would have construction commensurate with a moderate-hazard facility, including 8-in.-thick steel-reinforced concrete walls and roofs. Several interior walls are included for isolating areas and units within the building. The MPB incorporates four, overhead 150-te cranes for movement of the shielding forms. These cranes include the standard limit and safety switches, and maintain position in the event of a loss of power. Crane rails are supported by additional steel pillars and footings. The concrete floor and subfloor are each 0.6-m-thick (2 ft) to accommodate the heavy weight of the shielding forms and their equipment. Individual hoods and exhausts are used for the removal of welding fumes. Two 12.6 kW UPS/UBS systems provide clean, uninterruptible power for computers, controls, and emergency equipment. A diesel-electric SPS is located at the USB and provides backup power for electric equipment and actuators in the MPB. The MPB consists of the following six areas:

- Depleted Uranium Metal Receiving Area
- Depleted Uranium Metal Storage Area
- Depleted Uranium Metal Shielding Casting Area
- Depleted Uranium Metal Shielding Cooling Area
- Final Assembly and Quality Control Area
- Finished Cask Interim Storage and Shipping Area

Section 2.2.2 discusses these areas in more detail.

2.2.1.3 Shielding Cask Product Storage Building (SCPSB)

The SCPSB for the HTSMF is essentially the same as the one for the LTSMF because the cask dimensions are comparable. Thus, figure 2.3 also represents the layout of the HTSMF SCPSB.

2.2.1.4 General Warehouse and Storage Building (GWSB)

The HTSMF requires different supplies as compared to the LTSMF, but the quantities are comparable. Thus, the GWSB for the HTSMF is essentially the same as the one for the LTSMF. Thus, figure 2.4 also represents the layout of the HTSMF GWSB.

2.2.1.5 Waste Management Building (WMB)

The estimates in section 6 indicate the HTSMF generates more waste than the LTSMF. However, this is within the limits of a preconceptual design, and to a first approximation, the WMB for the HTSMF is essentially the same as the one for the LTSMF. Thus, figure 2.5 also represents the layout of the HTSMF WMB.

2.2.1.6 Radwaste Storage Building (RSB)

The RSB for the HTSMF is essentially the same as the one for the LTSMF. Thus, figure 2.6 also represents the layout of the HTSMF RSB.

2.2.1.7 Utility Supply Building (USB)

The HTSMF has similar utility requirements as the LTSMF. Thus, to a first approximation, the USB for the HTSMF is essentially the same as the one for the LTSMF. Thus, figure 2.7 also represents the layout of the HTSMF USB.

2.2.1.8 Health Physics and RCA Access Control Building (HPRACB)

The HPRACB for the HTSMF is essentially the same as the one for the LTSMF. Thus, figure 2.8 also represents the layout of the HTSMF HPRACB.

2.2.1.9 Emergency Services Building (ESB)

The ESB for the HTSMF is the same as the one for the LTSMF. Thus, figure 2.9 provides the layout of the HTSMF ESB.

2.2.1.10 HTSMF Administration and Technical Services Building (ATSB)

The ATSB for the HTSMF is the same as the one for the LTSMF. Thus, figure 2.10 provides the layout of the ATSB.

2.2.2 Description of Key Areas in the Main Processing Building for Depleted Uranium Metal Shielding Manufacture (HTSMF)

2.2.2.1 Depleted Uranium Metal Receiving Area

This area incorporates four truck bays and one rail bay for the receipt of uranium metal. The uranium metal would be received as 34-kg billets, with 19 billets loaded into a wooden box. Each pallet contains four boxes (i.e., 2.5 to 3 te per pallet). The pallets are unloaded using cranes and heavy-duty fork lifts. One unit corresponds to 100 percent capacity. This area would be similar in layout to the LTSMF receiving area (figure 2.11).

2.2.2.2 Depleted Uranium Metal Storage Area

Figure 2.18 displays the layout for a unit in this area. This provides storage for the uranium metal in its original shipping billet for up to 3 months. The containers are stored on pallets, stacked two high (each container holds approximately 2,500 to 3,000 kg). Daily receipts would average 20 pallets. Using a 1 m by 1.3 m footprint per pallet, 1 day's average receipt equates to around 13 m^2 (140 ft^2 - effectively 8 ft wide by 18 ft long). Total height would be approximately 1.5 m (4.5 ft), including palletizing materials. A bridge crane (capacity of 15 te or so) services the area to facilitate material movements and minimize aisle spaces. One unit corresponds to 100 percent capacity.

2.2.2.3 Depleted Uranium Metal Shielding Casting Area

Figure 2.19 displays the layout for a unit in this area. The approach assumes direct casting of the uranium metal into the shielding annulus. Initially, assembled casks are received from the SCAB and placed into a soaking pit or furnace for preheating, as the addition of hot molten uranium to a cold steel shell is likely to produce operational problems including cracking. The soaking pit would probably use natural gas as the fuel. Preheat temperatures of 900 to 1,000 °C (1,600 to 1,800 °F) should be adequate. Subsequently, the cask is moved under the uranium metal melting furnaces. Additional heat may be added to the metal shell to maintain its temperature. A spider-type manifold is attached to the top of the annulus, and connects it with the bottom of each furnace. Each furnace is loaded with approximately 3,000 kg of uranium metal billets. A nitrogen supply inerts the cask-manifold-furnace system. Nitrogen inerting introduces some nitriding of the uranium, but this should not be a concern for shielding applications (it may even be beneficial). Alternatively, a vacuum can be applied. The furnaces are activated and the uranium melts. The molten uranium discharges into the annulus via the manifold. The furnaces are isolated, recharged with uranium metal billets, reconnected, and the cycle repeated. Electric induction furnaces melt the uranium metal (Derrington, 1994), which is periodically discharged into the annulus. Eight standard furnaces (one backup) are required per cask. The design assumes steel and nickel alloys for the manifolds and cask annulus. The manifold has graphite linings for improved stability and performance. Molten uranium metal reacts and forms alloys with mild steels, although the assumed cask material (stainless steel) should have adequate resistance. These effects and process parameters would be determined in a demonstration program. After filling, the manifold is removed and a temporary cap/seal combination applied to the cask annulus. This isolates the molten uranium from the atmosphere and allows safe movement. The cap/seal combination includes ports for sampling and inerting. The filled cask is transferred to a cooling area for solidification of the molten uranium. Initially, the cask is placed in a cooling pit. Cooling and partial solidification of the uranium metal occur via conduction through the outer wall, using (building) air as the cooling medium. Further cooling via both walls of the annulus occurs in cooling stands, again using air against the stainless steel shells. Actual parameters would be determined in a demonstration program, including the most appropriate stainless steel alloys and linings to avoid uranium/steel reactions. Cleaning of the oxide scale on the steel shell would also be conducted in this area.

2.2.2.4 Depleted Uranium Metal Shielding Cooling Area

Figure 2.20 displays the layout for a unit in this area. This unit provides for additional cooling of the shielding casks by natural convection. Shrinkage occurs upon cooling, and uranium metal exhibits several different crystal forms. Consequently, reheating may be necessary. Heat treatments and annealing may also be necessary for structural and corrosion considerations.

2.2.2.5 Final Assembly and Quality Control Area

The layout of this unit is similar to the LTSMF Final Assembly and Quality Control Area (figure 2.15). Final assembly includes filling any voids within the uranium metal shielding, adding a seal and cover to the filled annulus, and draining fixtures. Quality control includes material certifications, weight and density measurements, weldment checks and evaluations, and dimensional tolerances.

2.2.2.6 Finished Cask Interim Storage and Shipping Area

This area provides for an interim storage space for the finished shielding cask prior to its shipment to the SCPSB. Its layout is similar to figure 2.16.

2.3 General Design and Safety Criteria

The present approach developed for the shielding manufacturing facility is at the preconceptual design level, and specific design features, safety criteria, and hazards mitigation have to be developed at a later stage. The following general design and safety criteria are applicable to either DOE or NRC-licensed facilities:

- double confinement
- nominal, low-pressure operation
- inerting of tanks and mixers
- use of high-integrity components, including welded piping
- logical integration of process operations

- full sprinkler and fire protection in the buildings
- application of the As Low As Reasonably Achievable (ALARA) concept, including automated operation

DOE and NRC regulations require <u>double confinement</u> of radioactive materials, including depleted uranium. This means that there exists at least two barriers between the uranium and the environment. The design accomplishes this primarily by placing all piping, equipment, and operations within buildings. Hence, the piping represents the first level of confinement, and the building constitutes the second level. Potential emissions and effluents are treated (at least filtration) at least twice prior to discharge. Chemicals are also stored within double confinement.

The present processes for depleted uranium use <u>low pressures</u> for all operations involving radioactive materials. Typical maximum pressures (essentially at the pump discharges) are around two atmospheres gauge (30 psig); most pressures are around a tenth of an atmosphere or so. The use of available industrial components (designed to the ANSI 150-pound rating class) provides a working pressure margin in excess of a factor of six. Steam, compressed air, and nitrogen represent the only items pressurized above two atmospheres, and these are handled using proven, qualified industrial equipment and procedures.

In the processes, the vessels and operations involving potentially flammable mixtures with radioactive materials are inerted. The LTSMF mixers and vessels are inerted with nitrogen. The HTSMF melts uranium under a vacuum, and casting operations would be carried out under a vacuum or with nitrogen inerting.

The design uses proven, <u>high-integrity components</u> and materials. Welded piping is used as much as possible; the few joints are for anticipated maintenance requirements and are primarily flanged. The design incorporates self-closing, quick-disconnects for those operations where frequent disconnections occur . The design envisions the use of seal-less and high-integrity mechanical seals for the many pumping requirements. Specific materials of construction would be identified during more detailed design efforts.

In the present design, the process operations are integrated and the design incorporates recycle streams for water and reagents, thus conserving resources and minimizing waste generation.

The buildings have full fire protection by having sprinkler systems, compartmentation, and other systems in all buildings.

The design applies the <u>ALARA</u> concept as much as possible at this preconceptual design level. Most of the operations are assumed to be automatic and operated from central control rooms. Purging and decontamination are required prior to maintenance. The site arrangement and layout (see section 3) incorporate a separate RCA for the processing of uranium, with appropriate distances between the processing areas and the site boundaries.

The three subsections that follow discuss other aspects of general design and safety criteria.

2.3.1 Natural Phenomena Hazards Mitigation

It is the policy of DOE to design, construct, and operate its facilities so that workers, the general public, and the environment are protected from the impacts of natural phenomena hazards. DOE Order 5480.28, Natural Phenomena Hazards Mitigation (NPHM), identifies the responsibilities and requirements to execute this policy in a consistent manner.

The overall strategy for NPHM should be consistent with the graded approach illustrated in the Safety Analysis Report (SAR). The selection of structures, systems, and components (SSCs) that require NPHM design should be based on the safety classifications developed for them as established by the SAR. Mission importance and economic considerations should also be used in selecting these components. Once these SSCs are assessed, DOE Order 5480.28 specifies the hazard requirements to ensure that the components are adequately designed to resist natural phenomena hazards.

The natural phenomena hazard standard DOE-STD-1020-94 was developed from UCRL-15910 (Kennedy, 1990) and provides criteria to follow for design of new SSCs so that DOE can evaluate and upgrade them against the effects of such hazards as earthquakes, floods, and extreme wind. This DOE standard is used consistently throughout DOE sites and provides the means to implement DOE Order 5480.28 for all NPHM and to comply with DOE's safety policy.

DOE-STD-1020-94 essentially replaces the four-category hazard ranking system of UCRL-15910 with five performance categories (table 2.3).

The design and evaluation criteria for SSCs in Performance Categories 0, 1, and 2 are similar to those given in model building codes. Performance Category 0 recognizes that for certain lightweight equipment items, furniture, etc., and for other special circumstances where there is little or no potential impact on safety, mission, or cost, design or evaluation for natural phenomena hazards may not be needed. Assignment of an SSC to Performance Category 0 is intended to be consistent with, and not take exception to, model building code NPH provisions. Performance Category 1 criteria include no extra conservatism against natural phenomena hazards beyond that in model building codes that include earthquake, wind, and flood considerations. Performance Category 2 criteria are intended to maintain the capacity to function and to keep the SSC operational in the event of natural phenomena hazards. Model building codes would treat hospitals, fire and police stations, and other emergency-handling facilities in a similar manner to DOE-STD-1020 Performance Category 2 NPH design and evaluation criteria.

Performance Categories 3 and 4 SSCs handle significant amounts of hazardous materials or have significant programmatic impact. Damage to these SSCs could potentially endanger worker and public safety and the environment, or interrupt a significant mission. As a result, it is very important for these SSCs to continue to function in the event of natural phenomena hazards, such that the hazardous materials may be controlled and confined. For these categories, there must be a very small likelihood of damage due to natural phenomena hazards. DOE-STD-1020 NPH criteria for Performance Category 3 and higher SSCs are more conservative than requirements found in model building codes and are similar to DOD criteria for high-risk buildings and NRC criteria for various applications, as illustrated in table 2.4. Table 2.4 illustrates how DOE-STD-1020 criteria for the performance categories defined in DOE 5480.28 compare with NPH criteria from other sources.

For Performance Category 1 SSCs, the primary concern is preventing major structural damage or collapse that would endanger personnel. A performance goal annual probability of exceedance of about 10^{-3} of the onset of significant damage is appropriate for this category. This performance is considered to be consistent with model building codes at least for earthquake and wind considerations. The primary concern of model building codes is preventing major structural failure and maintaining life safety under major or severe earthquakes or winds. Repair or replacement of the SSC or the ability of the SSC to continue to function after the occurrence of the hazard is not considered.

Performance Category 2 SSCs are of greater importance due to mission-dependent considerations. In addition, these SSCs may pose a greater danger to onsite personnel than Performance Category 1 SSCs because of operations or materials involved. The performance goal is to maintain both capacity to function and occupant safety. Performance Category 2 SSCs should allow relatively minor structural damage in the event of natural phenomena hazards. This is damage that results in minimal interruption to operations and that can be easily and readily repaired following the event. A reasonable performance goal is judged to be an annual probability of exceedance of between 10^{-3} and 10^{-4} of structure or equipment damage, with the SSC being able to function with minimal interruption. This performance goal is slightly more severe than that corresponding to the design criteria for essential facilities (e.g., hospitals, fire and police stations, centers for emergency operations) in accordance with model building codes.

Performance Category 3 and higher SSCs pose a potential hazard to public safety and the environment because radioactive or toxic materials are present. Design considerations for these categories are to limit SSC damage so that hazardous materials can be controlled and confined, occupants are protected, and functioning of the SSC is not interrupted. The performance goal for Performance Category 3 and higher SSCs is to limit damage such that DOE safety policy is achieved. For these categories, damage must typically be limited in confinement barriers (e.g., buildings, gloveboxes, storage canisters, vaults), ventilation systems and filtering, and monitoring and control equipment in the event of an occurrence of severe earthquakes, winds, or floods. In addition, SSCs can be placed in Performance Categories 3 and 4 if improved performance is needed due to cost or mission requirements.

As discussed at the beginning of section 2, a qualitative assessment of the hazard and performance categories has been conducted, table 2.1 summarizes the results for the LTSMF, and table 2.2 provides the results for the HTSMF.

2.3.2 Design Engineering

The intent of Design Engineering is to ensure that sound engineering principals are applied and appropriate consideration is given to the expected period of use, sound construction practices, quality assurance, energy conservation, decontamination and decommissioning requirements, and the appearance of completed facilities. Whenever feasible, these facilities shall be planned and a layout developed on the basis of relative discrete processing steps, grouped according to facility services, and shall be contained in process rooms to the extent practical. The engineering quality process involved to accomplish these characteristics include achieving minimum construction costs consistent with programmatic, environmental, security, and safety requirements; achieving technical adequacy; and achieving optimum economy in operation and maintenance in the design of the proposed facilities. State, municipal, county, and other local building codes should be reviewed for possible conflicts with these criteria. The design professional is encouraged to cooperate with local officials to accommodate the intent and requirements of local codes and regulations.

Flexibility is considered a major design requirement for all facilities, even those with specialized functions. The design shall provide sufficient flexibility to accommodate for possible programmatic changes or operational modifications to the maximum extent practicable. The layouts and type of architectural, structural, mechanical, and electrical elements of all facilities shall address anticipated future needs. The placement of columns and beams shall be coordinated with the initial and estimated future equipment installations, utility services, and operational requirements. Design solutions shall demonstrate methods for modifications and expansion including modularity, additional capacities, and other techniques when justified as a functional requirement.

The design inspection process ensures that all activities during the construction process are conducted in accordance with plans and specifications, and that the quality of materials and workmanship remains consistent with the requirements of this project. The structures will be designed to meet the requirements of DOE Orders 4700.1, 6430.1A, and 5480.28, the Uniform Building Code (UBC), and DOE-STD-1020-94.

2.3.3 Site Preparation, Structure, and Appurtenances

Design shall include any required improvements to the land, site preparation for surveying and mapping, clearing and excavating, and backfill/compacting to bring the general area to grade. The related land improvements are to include installing railroad trackage outside, adjacent to, and inside the storage bays of the buildings. Site modifications also include the setting of ties and rails, hauling and spreading of ballast, construction of site related culverts, bridges and head walls, and installation of rail warning systems and guard gates.

Selection of the exterior wall systems should provide minimally acceptable requirements for facility design. However, the selection may be dictated by the governmental policy regarding various architectural environmental guidelines that require similar architectural elements be present on all buildings in a complex. Consideration shall be given to energy, heat loss, natural light requirements, and economics during the selection process.

The structure shall include permanently attached appurtenances, such as fire protection, lighting, plumbing, heating, ventilation, and built-in air conditioning systems; and the cost of piping, conduit, and cable permanently attached to and made part of the building. The divisional boundary between the building and outside utility system services is to be made at a point nominally 5 ft outside the building walls.

Building concrete includes concrete on or below grade, major concrete slabs, floors above grade, equipment foundations, and miscellaneous concrete (i.e., thresholds, stairs, lintels, walks). Specifically, it covers materials for forming, placing, and waterproofing concrete for building foundations, piers, grade beams, walls, columns, and slabs. This section should include all work associated with reinforcing steel, concrete encasement of structural steel columns, and any precast concrete requirements.

The structural design process will incorporate elements of risk assessment related to the level of risk associated with the operation of these facilities. Specific guidance should be obtained from DOE Order 5480.28. Erection of structural metals shall cover all materials for building superstructure steel, including crane rails and all steel members framed directly into the superstructure. This section is to include fabrication handling, hauling, erecting, and setting of base plates required to completely install the structural steel. It also includes materials required for process piping, structural steel supports and hangers, related base plates, operating platforms, ladders, interior and exterior metal door frames, toe plates, door and window lintels, metal sleeves in the building structure, and other miscellaneous structural steel and iron.

The conservation of energy will be considered in the design of all new mechanical systems. The architect-engineer (A-E) shall select equipment and/or the type of installation that provides the most cost-effective heat, ventilation, and air conditioning (HVAC) system that meets all requirements for a nonreactor processing facility. Mechanical equipment includes heating systems, ventilation systems, fire protection systems, and plumbing equipment, along with all associated piping, valves, controls, and instrumentation. This equipment is also to include cooling towers, boilers, chillers, etc., that are physically located outside the buildings. This equipment and its associated piping is considered part of the mechanical system. This section is also to include materials for filtration systems in connection with an environmental control system; this would include equipment such as electrostatic precipitators, and roughing/finishing filters.

The electrical design will incorporate an emergency lighting system, lighting, grounding, fire detection and alarm system, automated energy management systems, instrumentation systems, radiation alarm and monitoring system, unclassified computer equipment, and various other control systems. Electrical design and installation will comply with the applicable provisions for the National Fire Protection Association (NFPA), National Electric Code (NEC), DOE Order 6430.1A, and the American National Standards Institute (ANSI). The building electrical lighting system will include installation of the electrical lighting system for the various buildings from the low-voltage side of the unit substation or at the service entrance to the structures. The equipment shall include lighting transformers, panels, circuits, fixtures, conduit, wire, and the complete installation of the emergency lighting system. The electrical power system shall cover the installation from the building wall through the primary building substation and include equipment such as switchgears, transformers, etc. Building instrumentation lines run from the point of connection at the equipment within the building up to and including the control room or equivalent. The building alarm system is to include fire, smoke, seismic intrusion, and radiological alarm systems, and conduit, pull wire, outlet boxes, control panels, and detectors.

Process piping will meet the requirements of the operating conditions, with the level of conservatism applied by the design team. For the shielding facility, ANSI and ASME methods will be used.

Table 2.1: Qualitative Assessment of Hazard Ranking for the Low Temperature Shielding Manufacturing Facility (LTSMF)

Building/Area	Hazard Ranking/Category*	Qualitative Rationale
MPB	Low Performance Category 2	No offsite, minimal onsite consequences from non-reactive materials
SCAB	Low Performance Category 2	No releases with consequences; facility must continue to function after a seismic event or an accident
SCPSB and RSB	None - General Construction Performance Category 0-1	Release fractions effectively zero
WMB and USB	Low Performance Category 2	No offsite, minimal onsite releases with consequences, small source terms
GWSB, HPRACB, ESB, ATSB	Low Performance Category 2	Facilities must continue to function after a seismic event or an accident

*Appropriate hazard ranking per UCRL-15910 and approximate performance category per DOE-STD-1020-94.

Table 2.2: Qualitative Assessment of Hazard Rankings for the High Temperature Shielding Manufacturing Facility (HTSMF)

Building/Area	Hazard Ranking/Category*	Qualitative Rationale
MPB - Uranium Metal Storage and Casting Areas	Moderate Performance Category 3	Potential for significant onsite and offsite contamination and consequences from an event or accident
MPB - All other Areas	Low Performance Category 2	No offsite, minimal onsite consequences from non-reactive materials
SCAB	Low Performance Category 2	No releases with consequences; facility must continue to function after a seismic event or an accident
SCPSB and RSB	None - General Construction Performance Category 0-1	Release fractions effectively zero
WMB and USB	Low Performance Category 2	No offsite, minimal onsite releases with consequences, small source terms
GWSB, HPRACB, ESB, ATSB	Low Performance Category 2	Facilities must continue to function after a seismic event or an accident

*Appropriate hazard ranking per UCRL-15910 and approximate performance category per DOE-STD-1020-94.

Table 2.3: Structure, System, and Component (SSC) NPH Performance Goals for Various Performance Categories

Performance Category	Performance Goal Description [1]	NPH Performance Goal Annual Probability of Exceeding Acceptable Behavior Limits, P_F
0	No Safety, Mission, or Cost Considerations	No requirements
1	Maintain Occupant Safety	~10^{-3} of the onset of SSC[2] damage to the extent that occupants are endangered
2	Occupant Safety, Continued Operation	~5 x 10^{-4} of SSC damage to the extent that the component cannot perform its function
3	Occupant Safety, Continued Operation, Hazard Confinement	~10^{-4} of SSC damage to the extent that the component cannot perform its function
4	Occupant Safety, Continued Operation, Confidence of Hazard Confinement	~10^{-5} of SSC damage to the extent that the component cannot perform its function

(1) These performance goals are for each natural phenomena hazard (earthquake, wind, and flood).
(2) SSC refers to structure, distribution system, or component (equipment).
From: DOE-STD-1020-94

Table 2.4: Comparison of Performance Categories from Various Sources

Source	SSC Categorization			
DOE-STD-1020 - DOE Natural Phenomena Hazard Criteria	1	2	3	4
Uniform Building Code	General Facilities	Essential Facilities	-	-
DOD Tri-Service Manual for Seismic Design of Essential Buildings	-	-	High Risk	-
Nuclear Regulatory Commission	-		Evaluation of NRC Fuel Facilities	Evaluation of Existing Reactors
DOE UCRL-15910	None/ General	Low Hazard	Moderate Hazard	High Hazard

Note: Adapted from DOE-STD-1020-94

Figure 2.1: Layout of the Shielding Cask Assembly Building (SCAB)

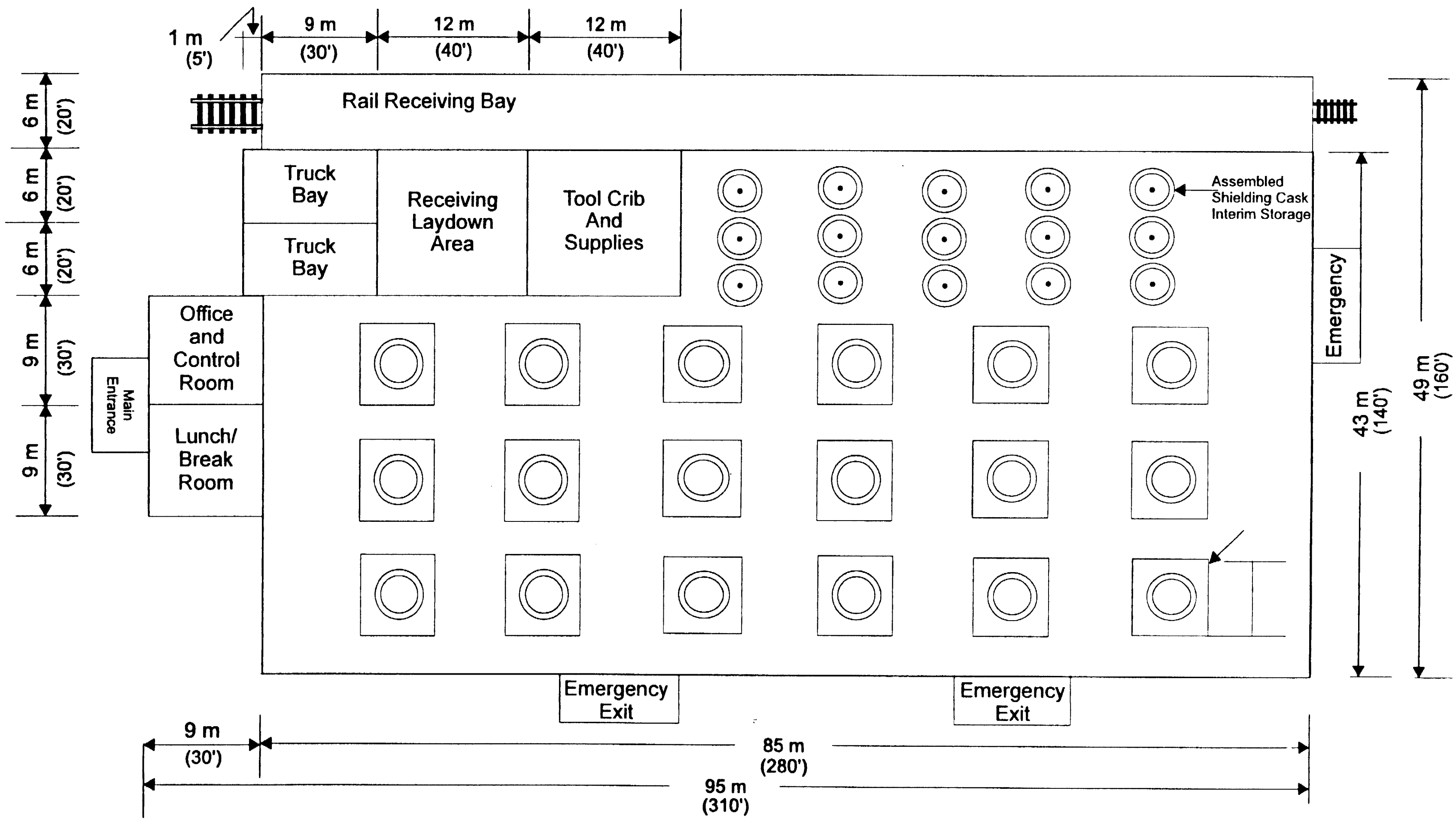


Figure 2.2: Layout of Main Processing Building (MPB) for the LTSMF

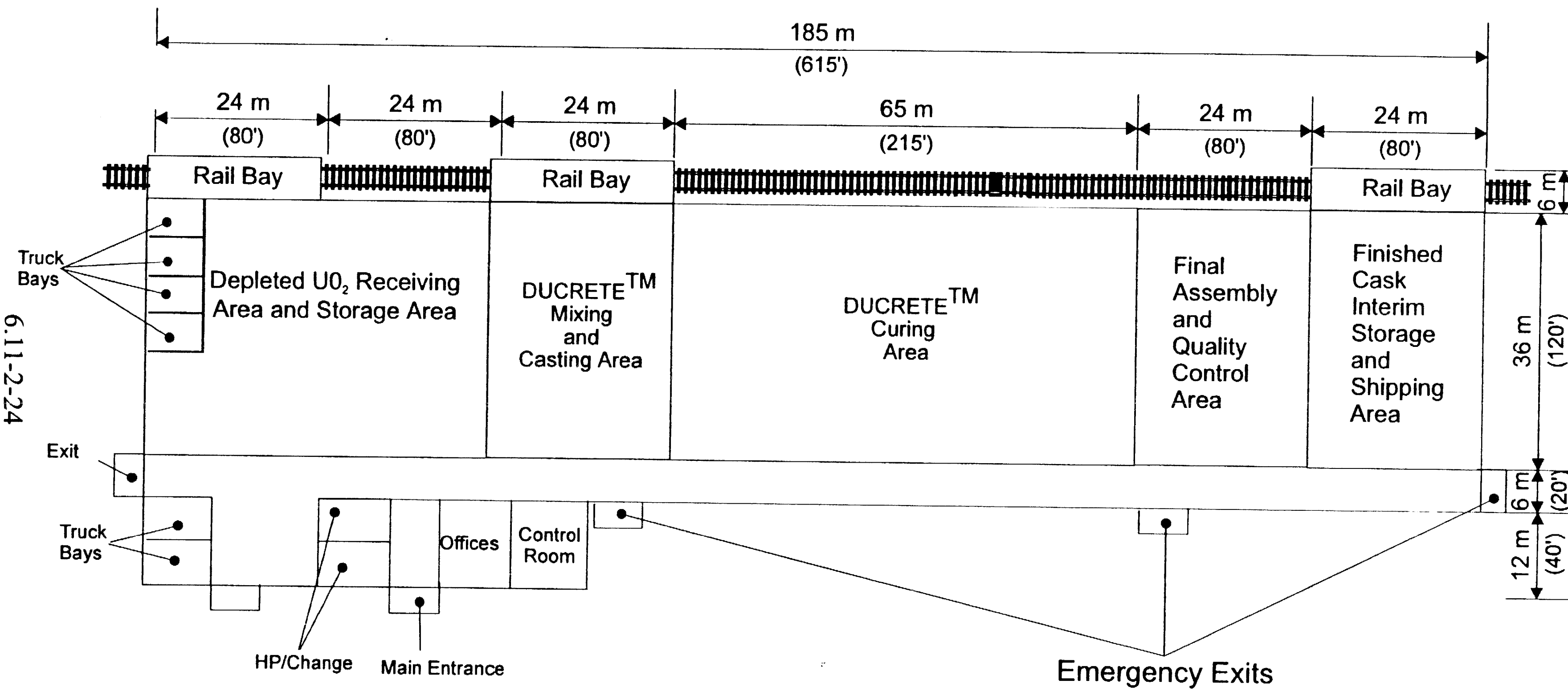


Figure 2.3: Layout of the Shielding Cask Product Storage Building (SCPSB)

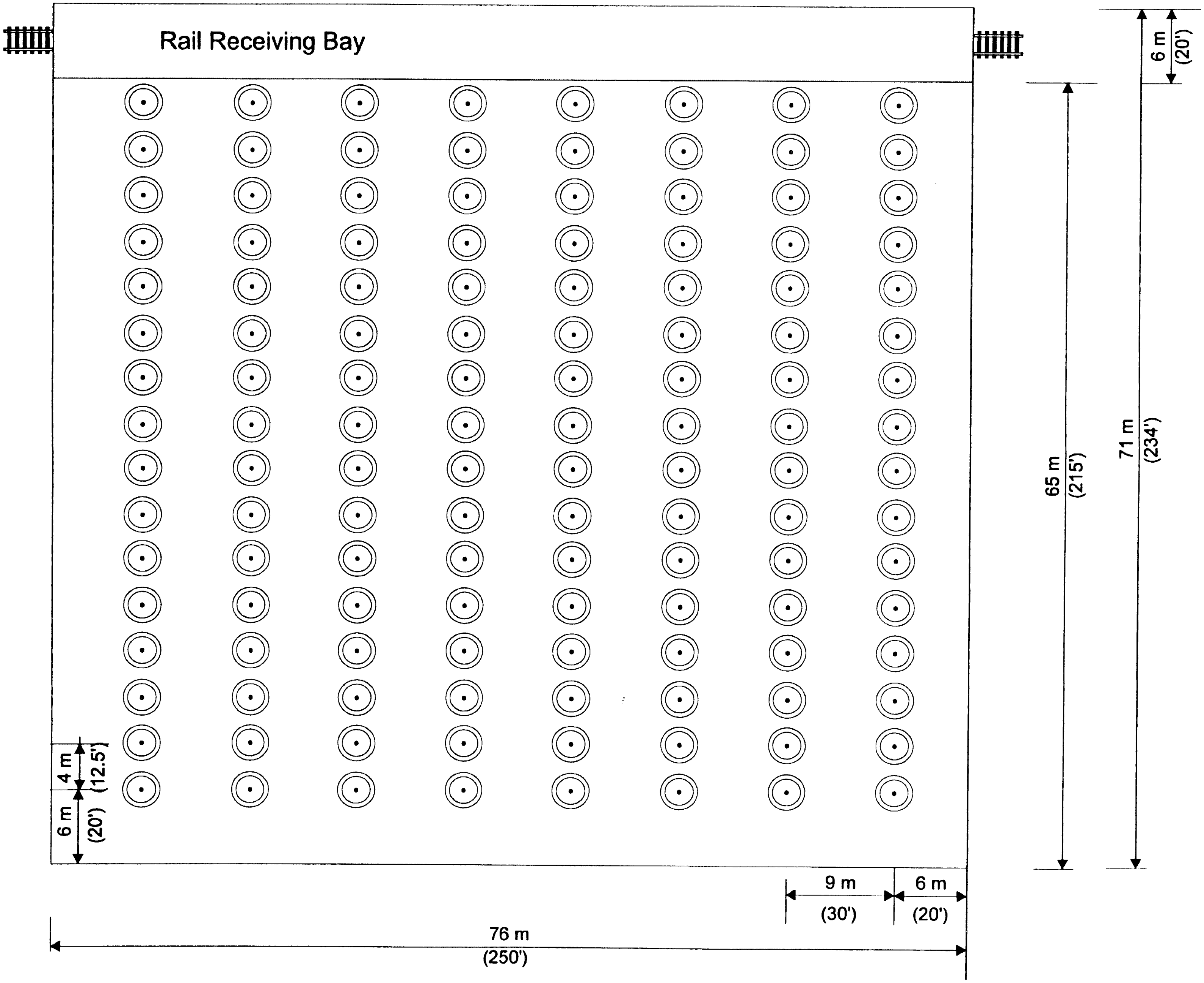


Figure 2.4: Layout of the General Warehouse and Storage Building (GWSB)

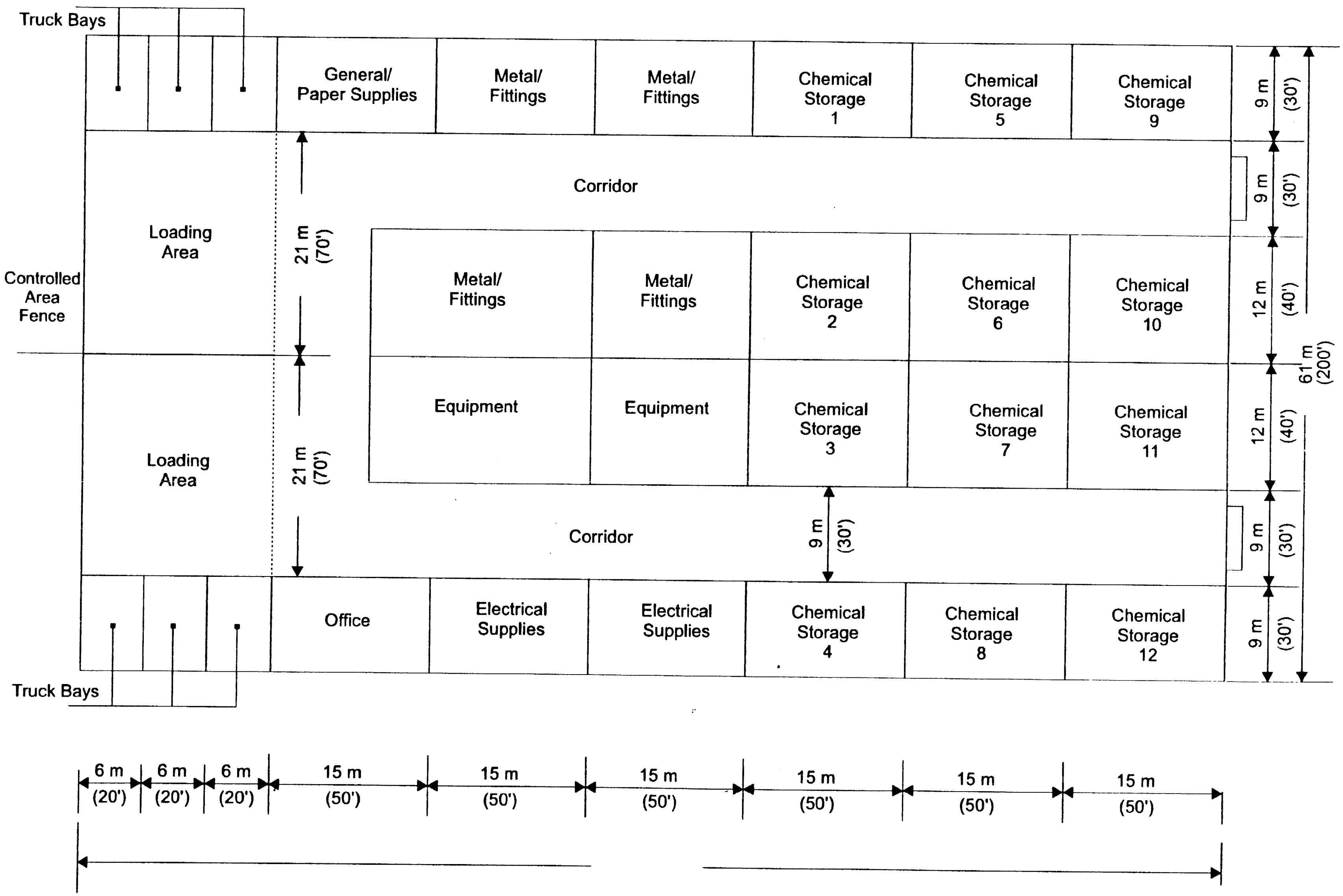


Figure 2.5: Layout of the Waste Management Building (WMB)

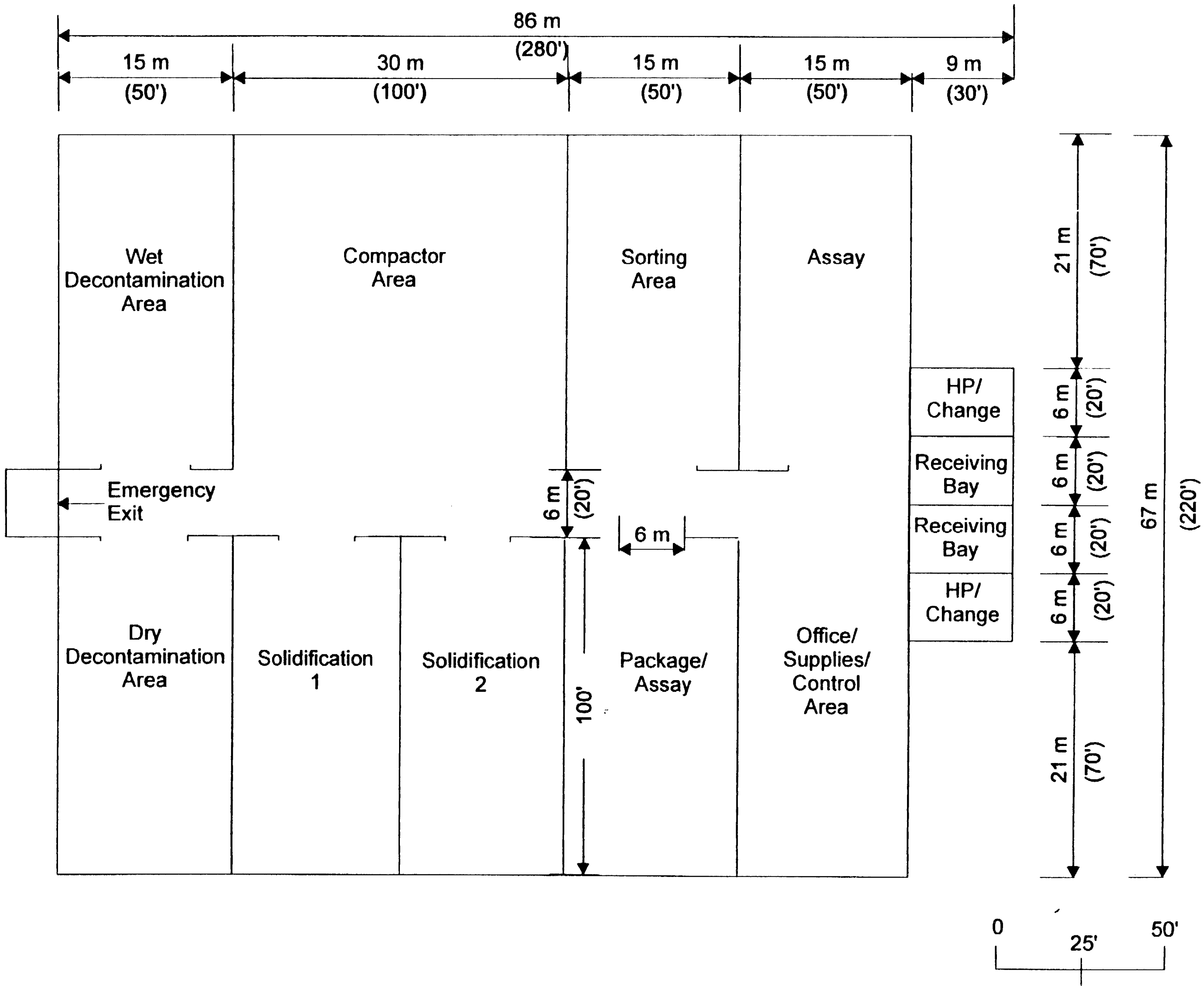


Figure 2.6: Layout of of the Roadwaste Storage Building (RSB)

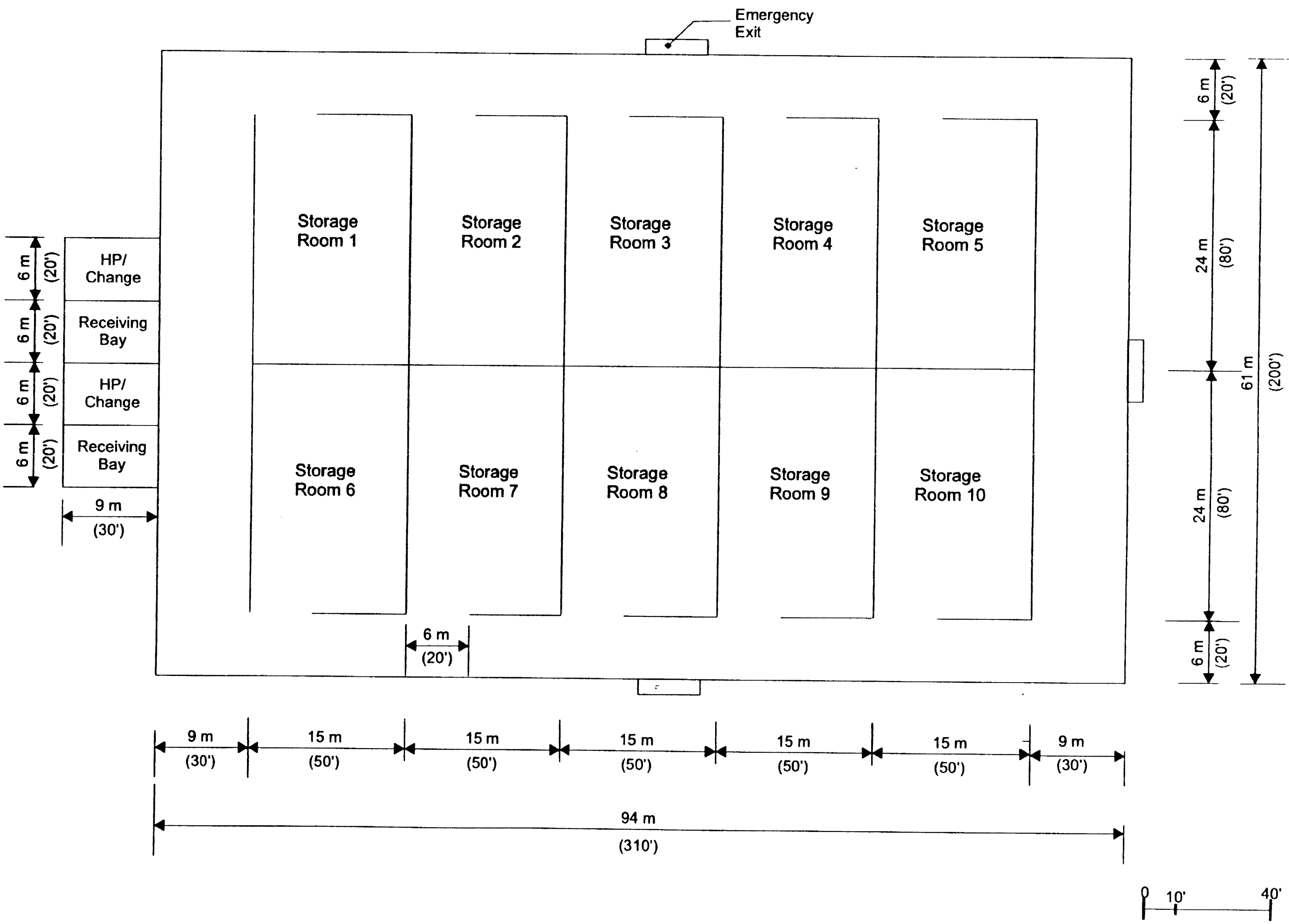


Figure 2.7: Layout of the Utility Supply Building (USB)

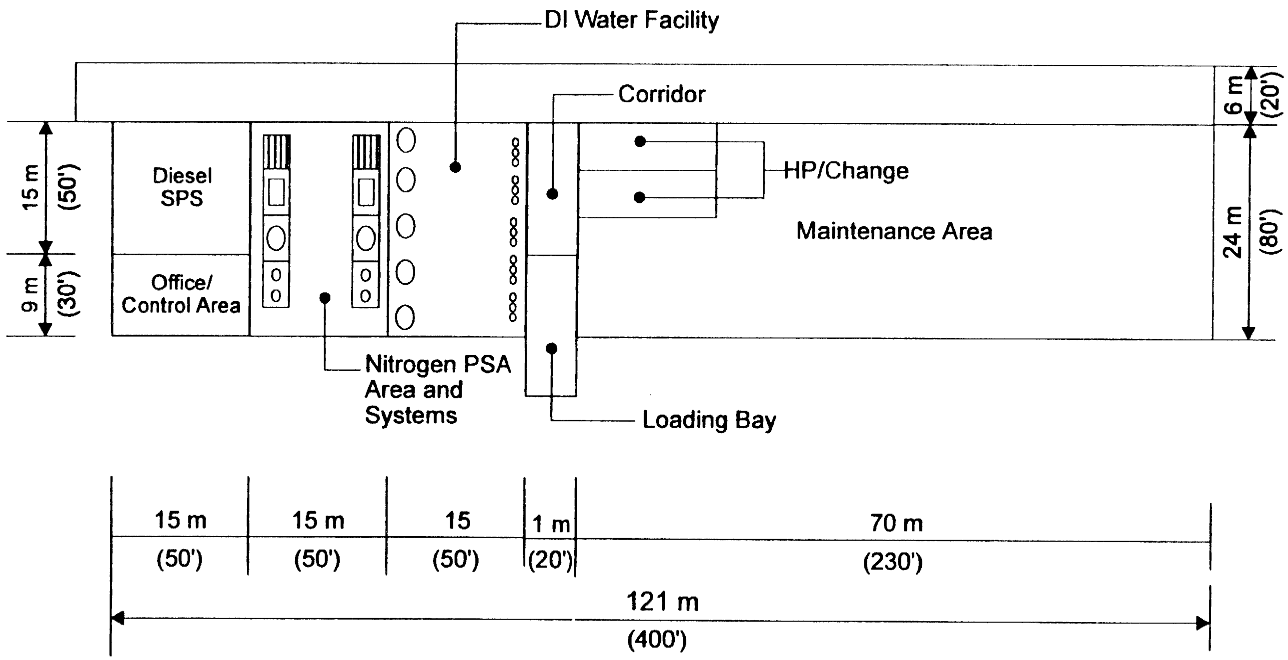


Figure 2.8: Layout of Health Physics and RCA Access Control Building (HPRACB)

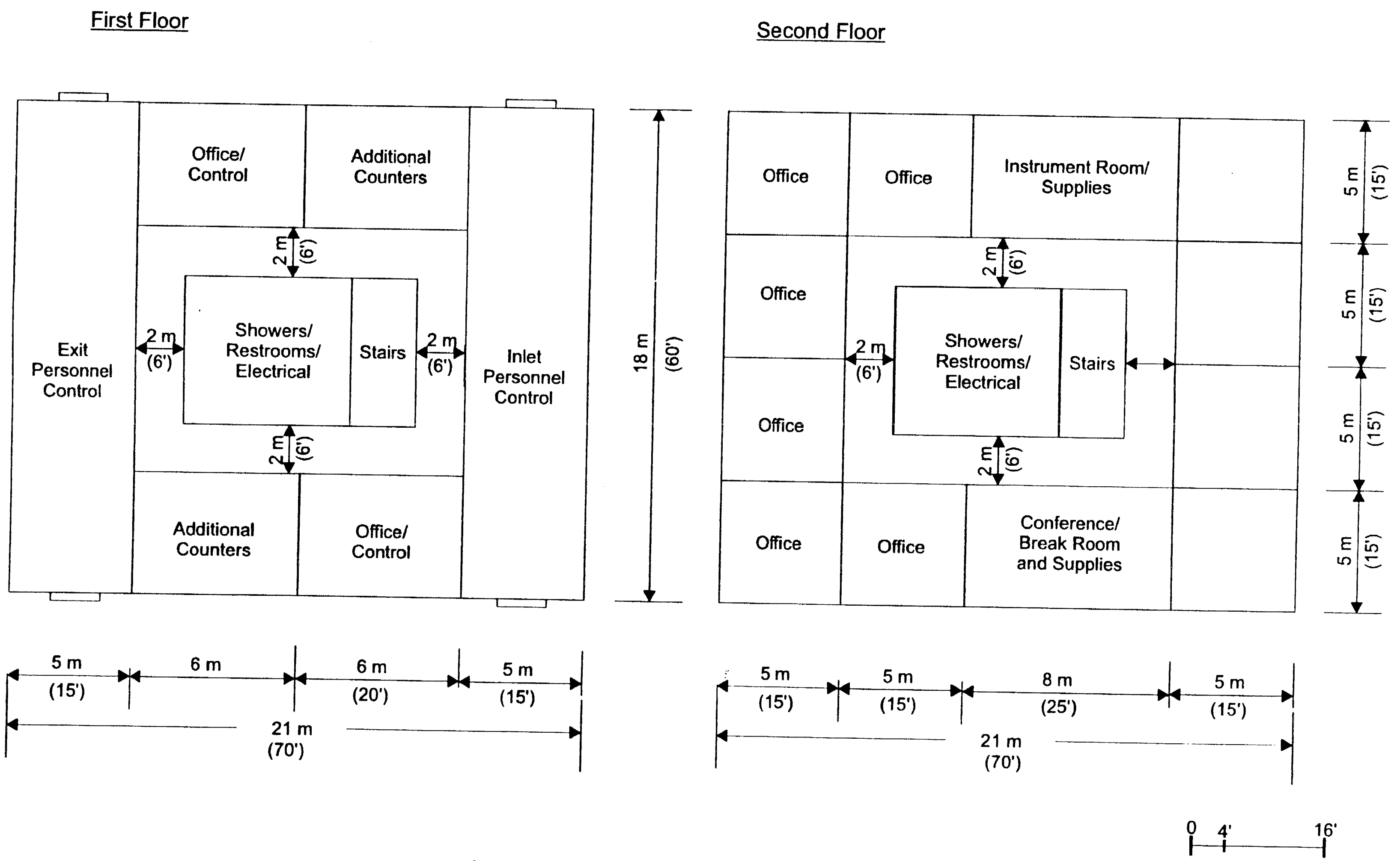


Figure 2.9: Layout of the Emergency Services Building (ESB)

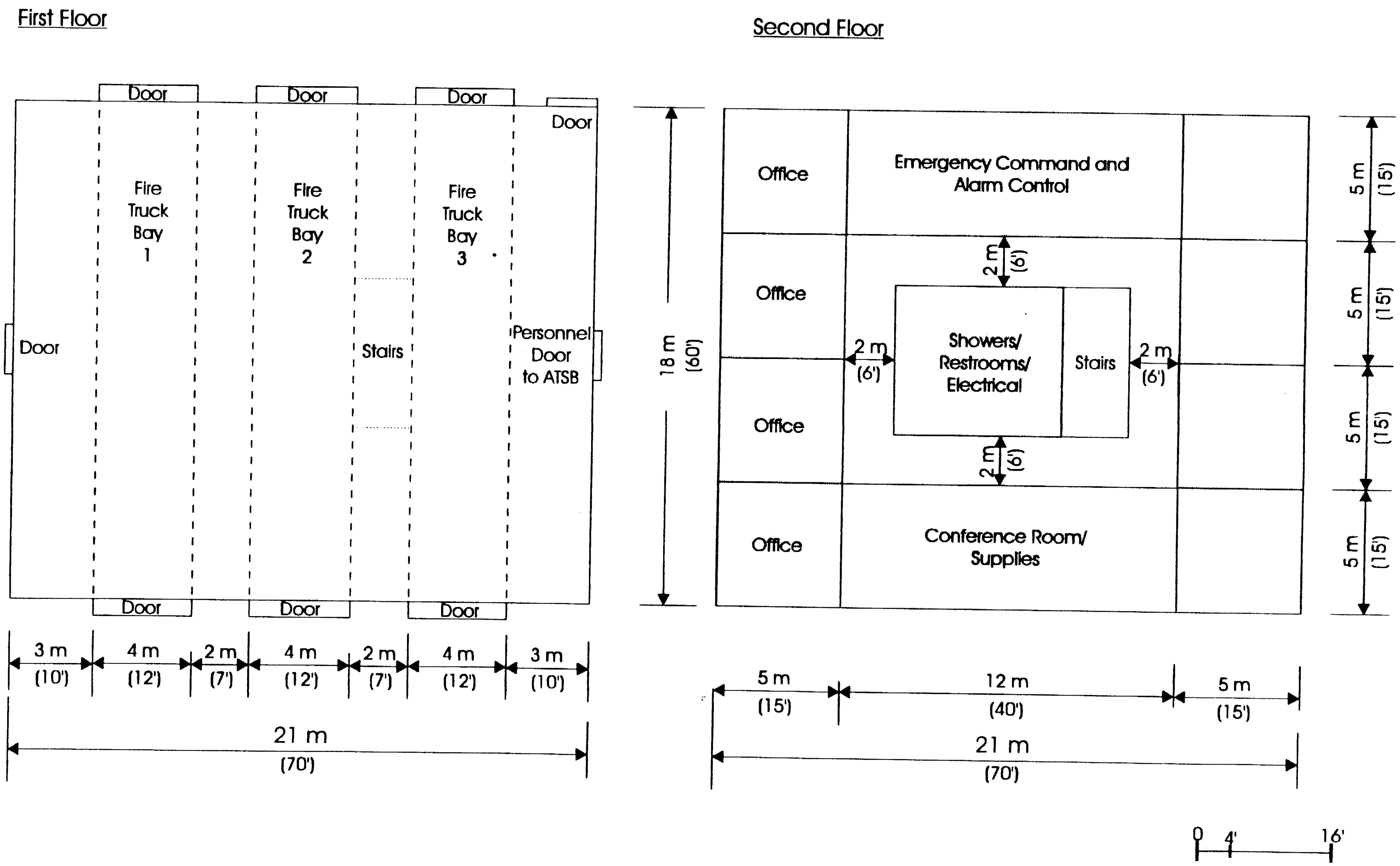


Figure 2.10: Layout of the Administration and Technical Services Building (ATSB)

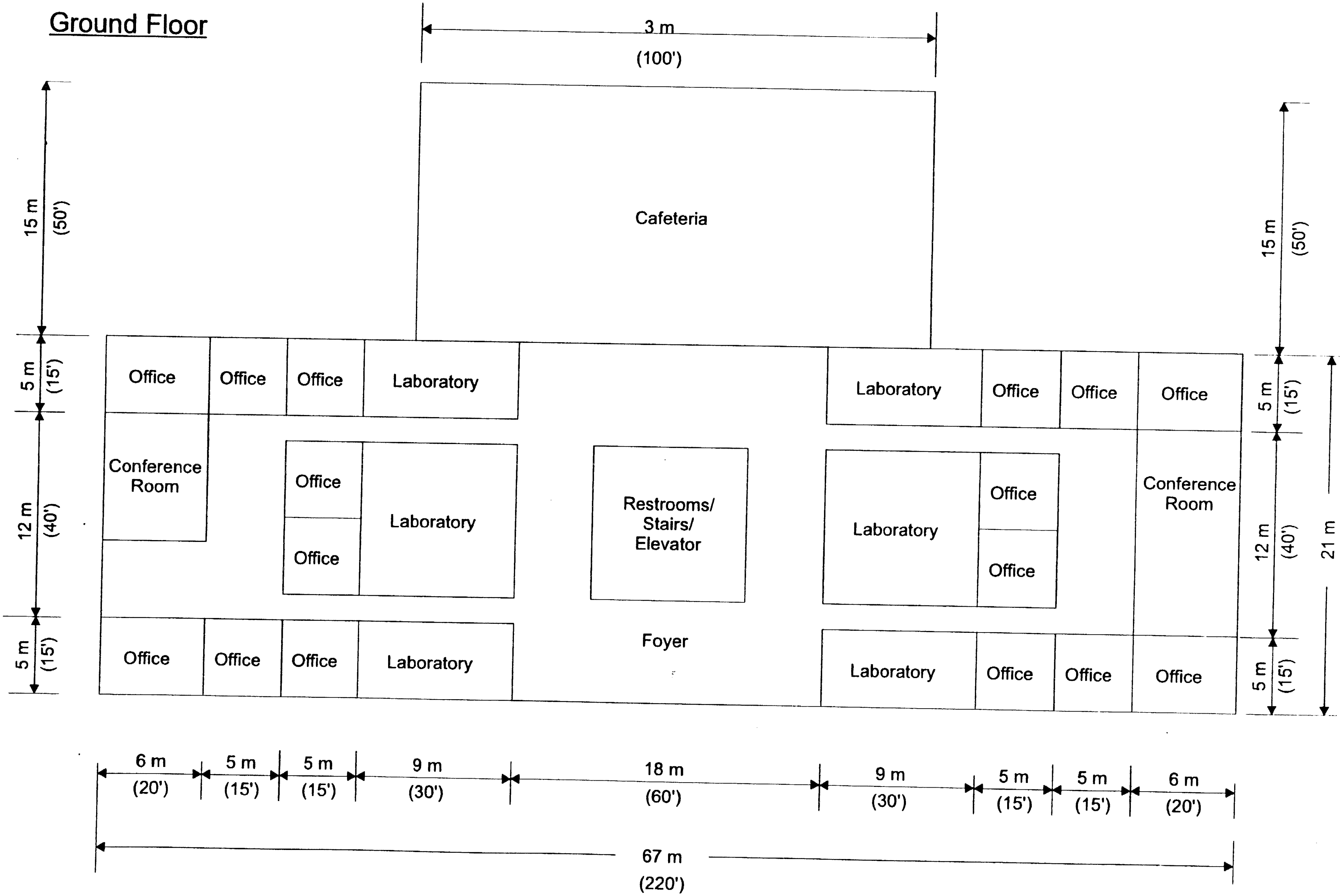


Figure 2.10: Layout of the Administration and Technical Services Building (ATSB) (Continued)

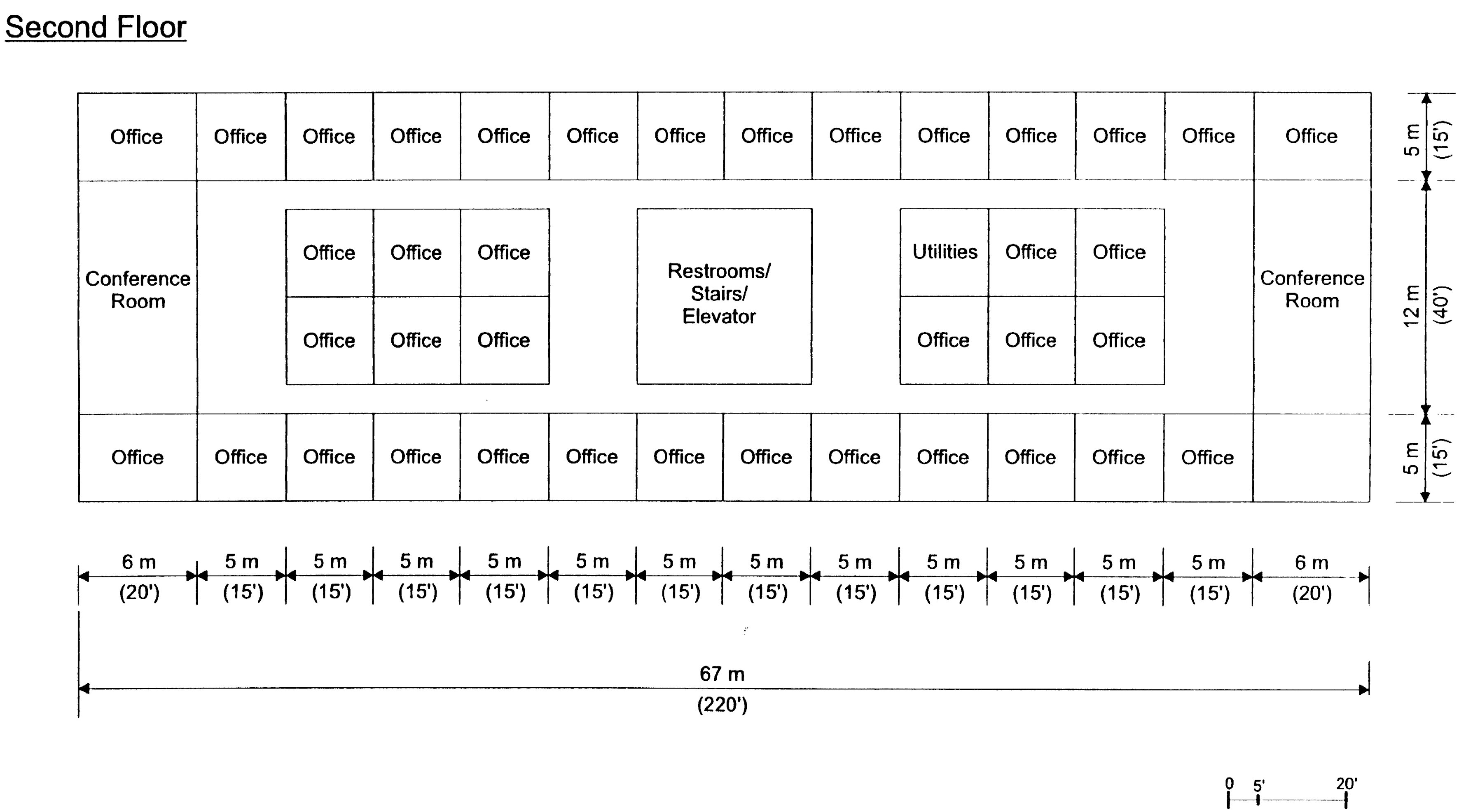


Figure 2.11: Layout of Depleted Uranium Dioxide Receiving Unit

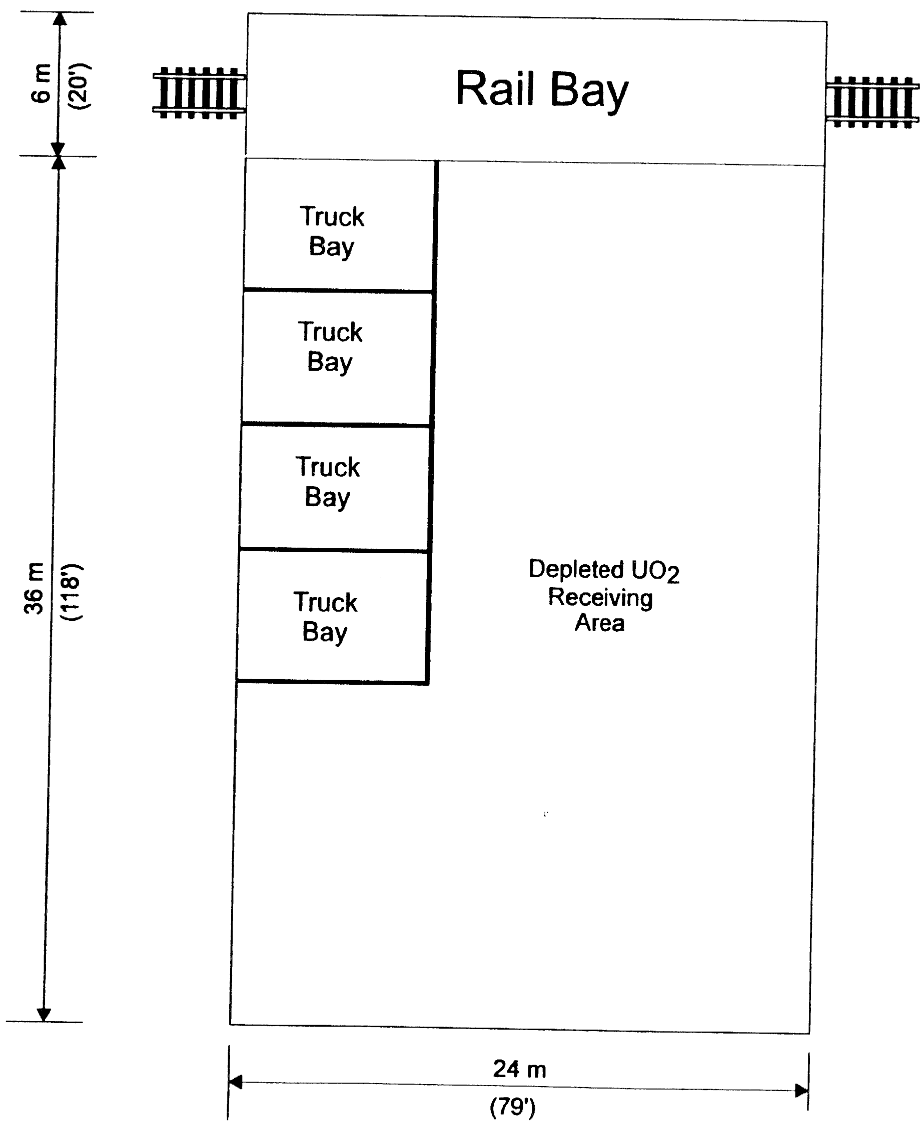
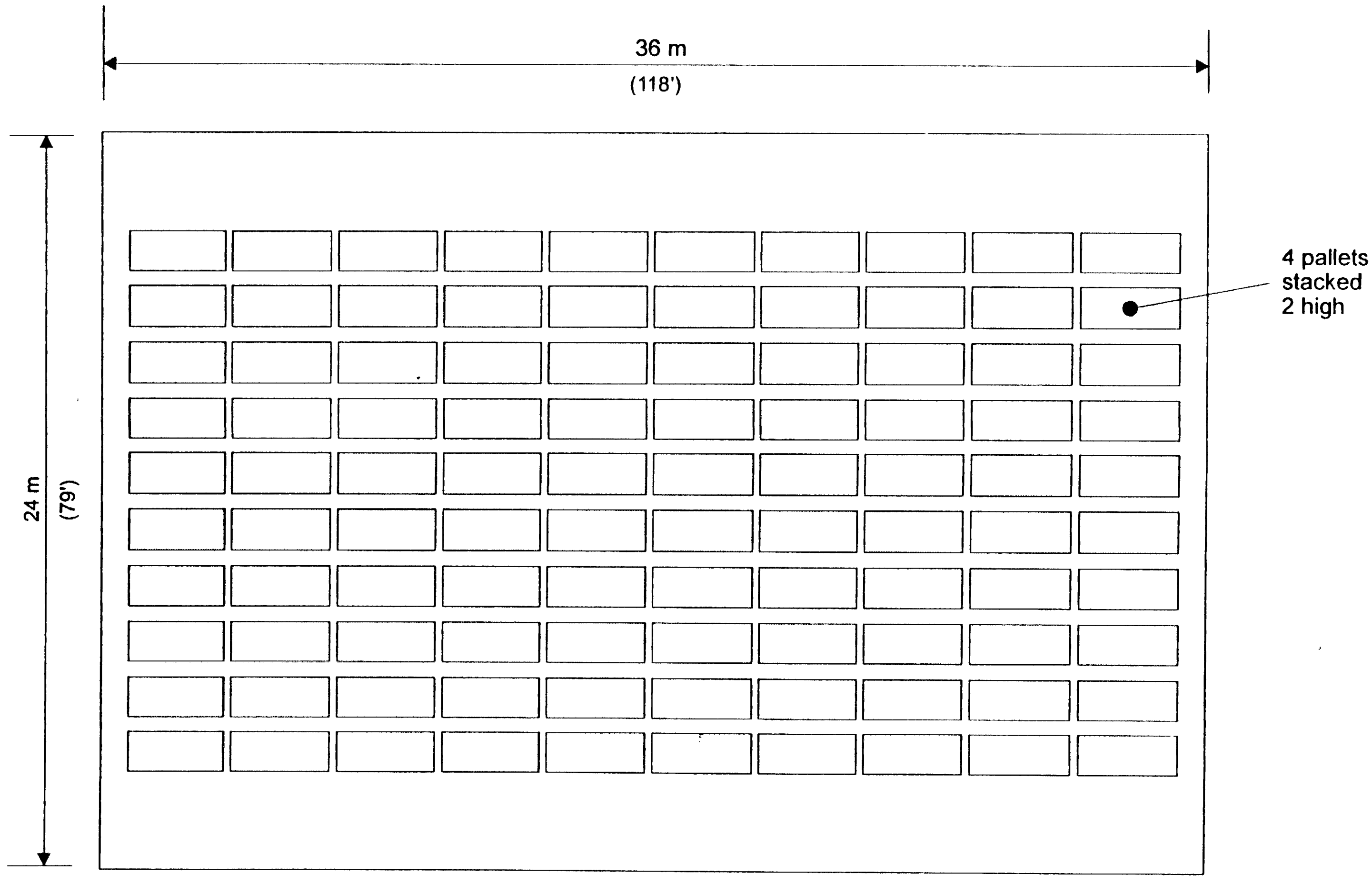


Figure 2.12: Layout of Depleted Uranium Dioxide Storage



Note: Not to Scale

Figure 2.13: Layout of Ducrete Mixing and Casting Unit

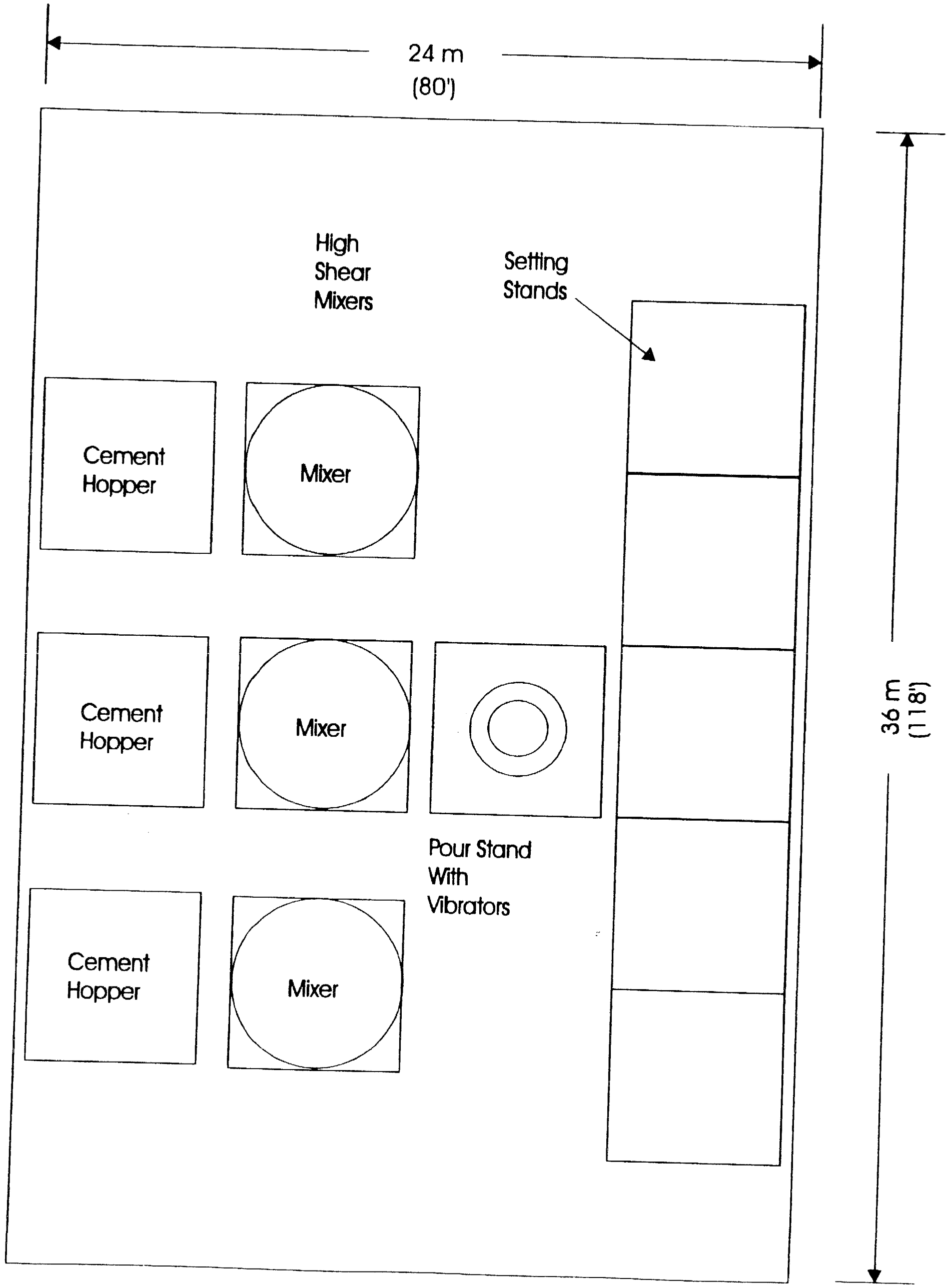


Figure 2.14: Layout of DUCRETE™ Curing Unit

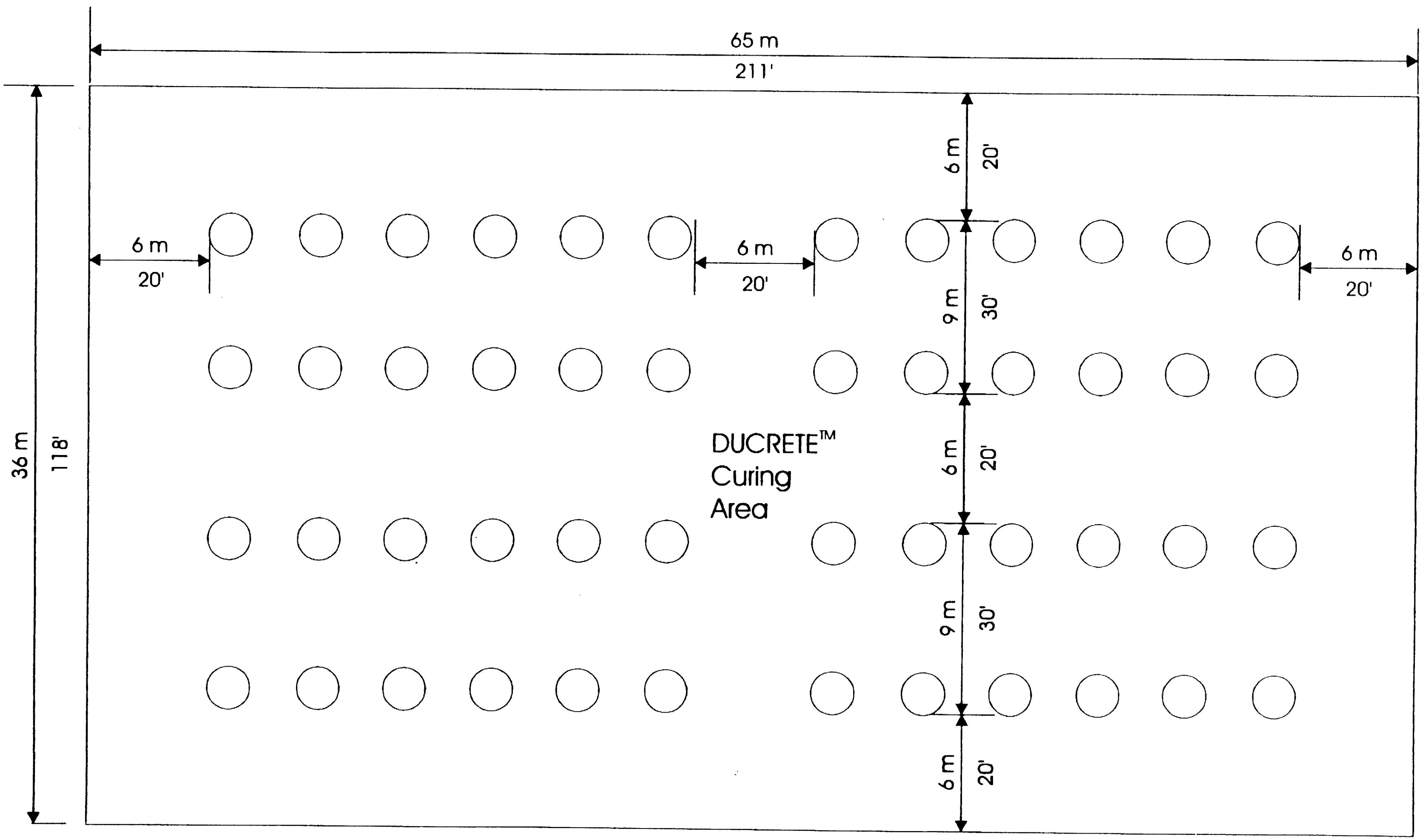


Figure 2.15: Layout of Final Assembly and Quality Control Unit

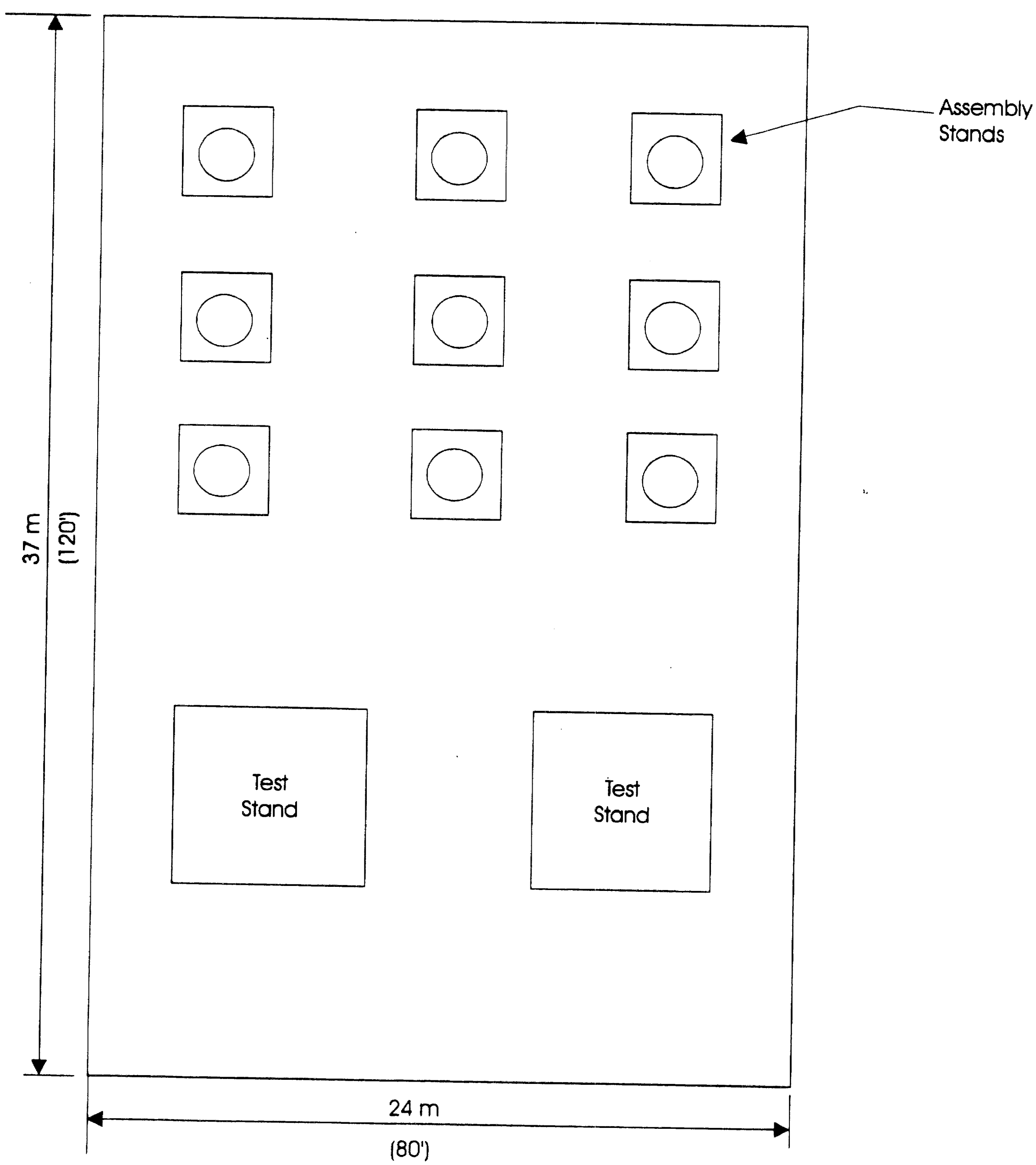


Figure 2.16: Layout of Finished Cask Interim Storage and Shipping Unit

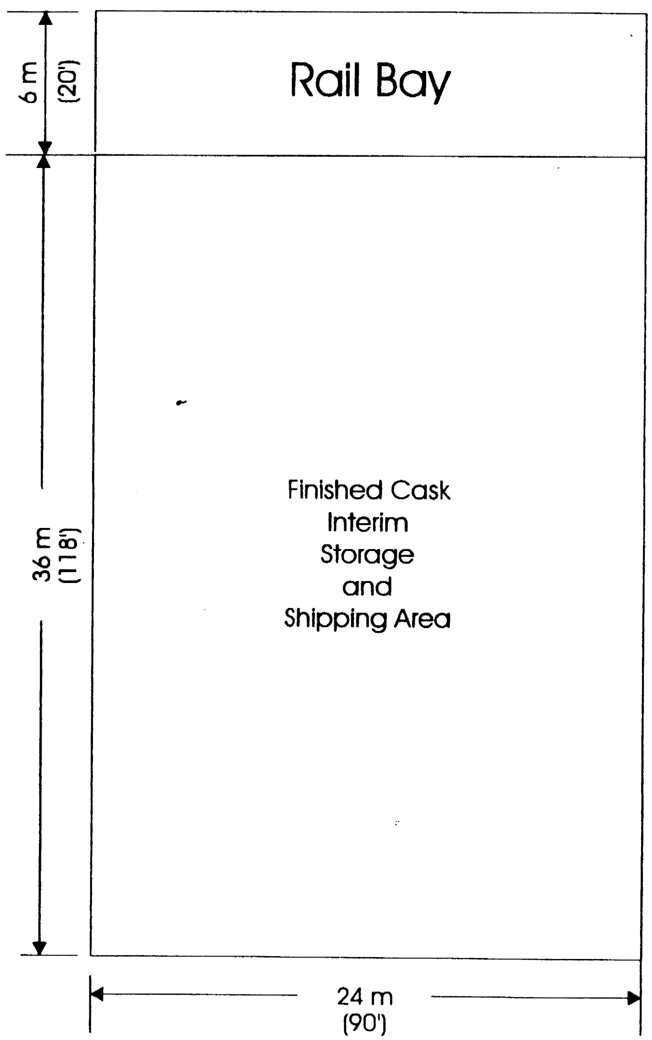


Figure 2.17: Layout of the HTSMF Main Processing Building (MPB)

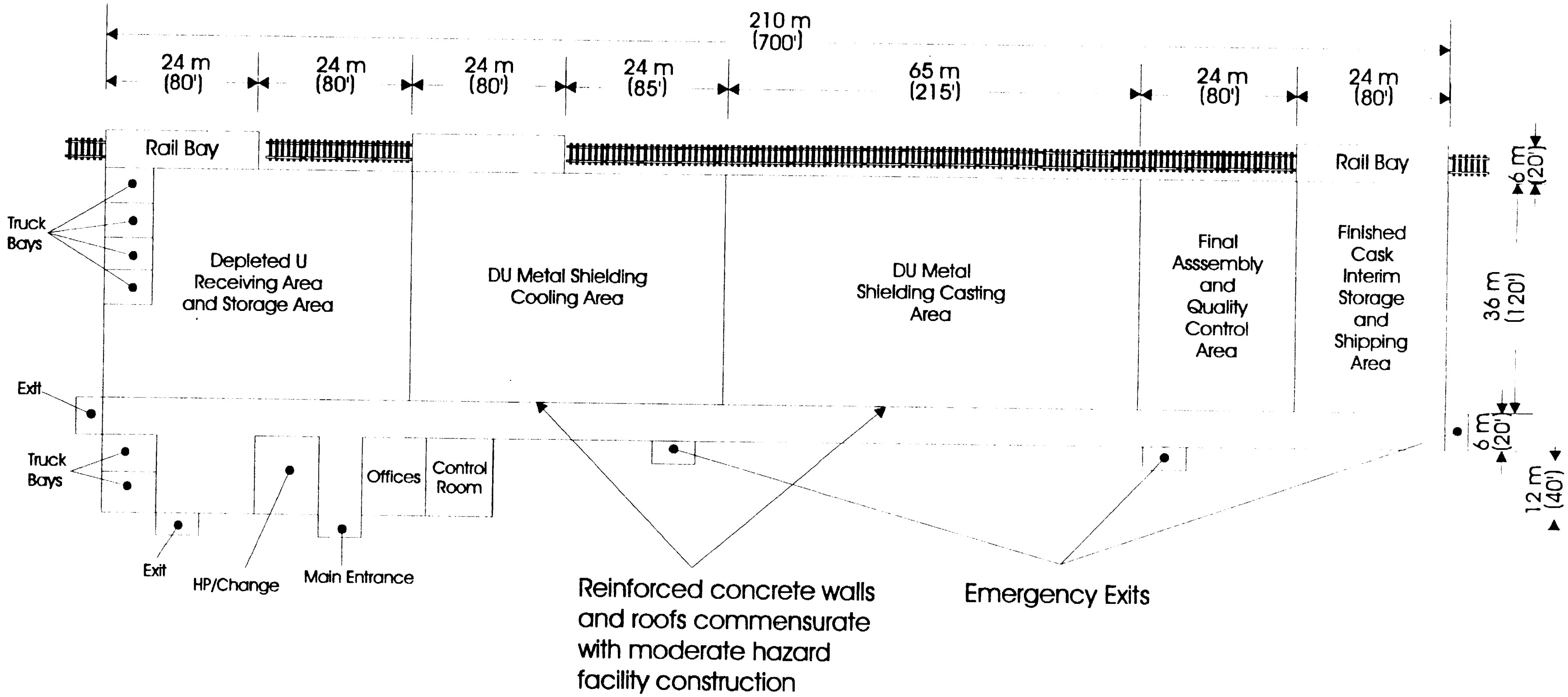
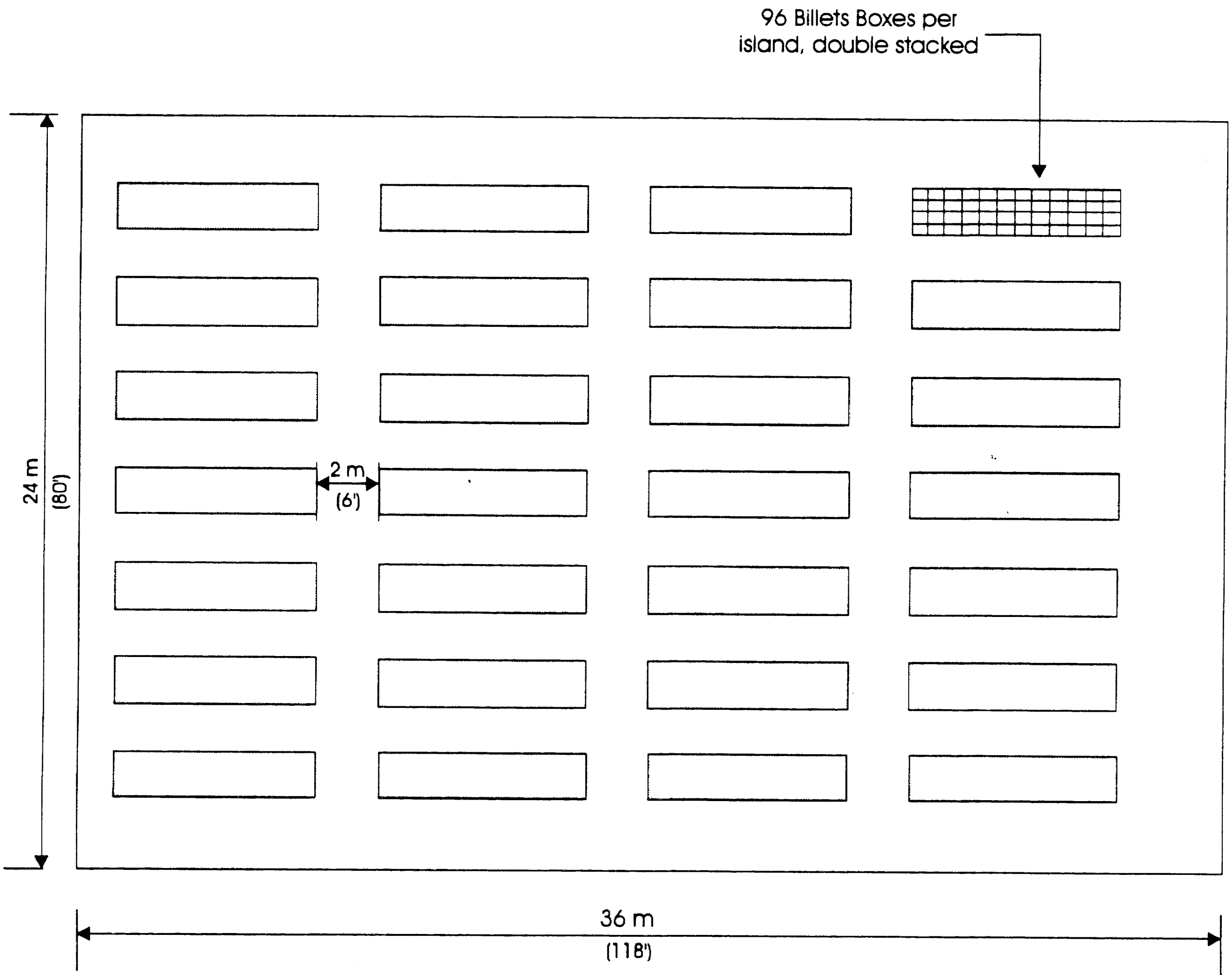


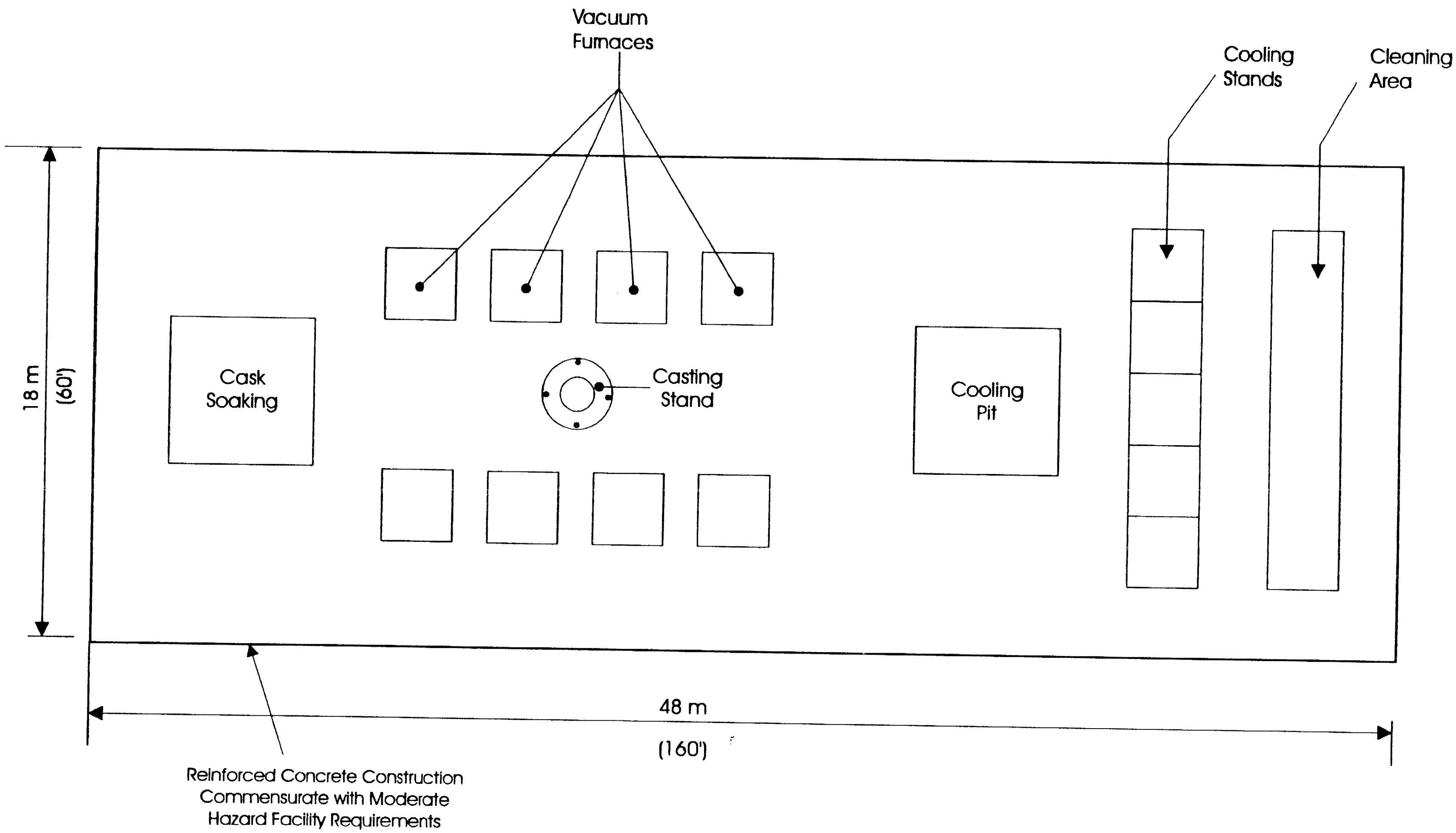
Figure 2.18: Layout of Depleted Uranium Metal Storage Unit



Note: Not to Scale

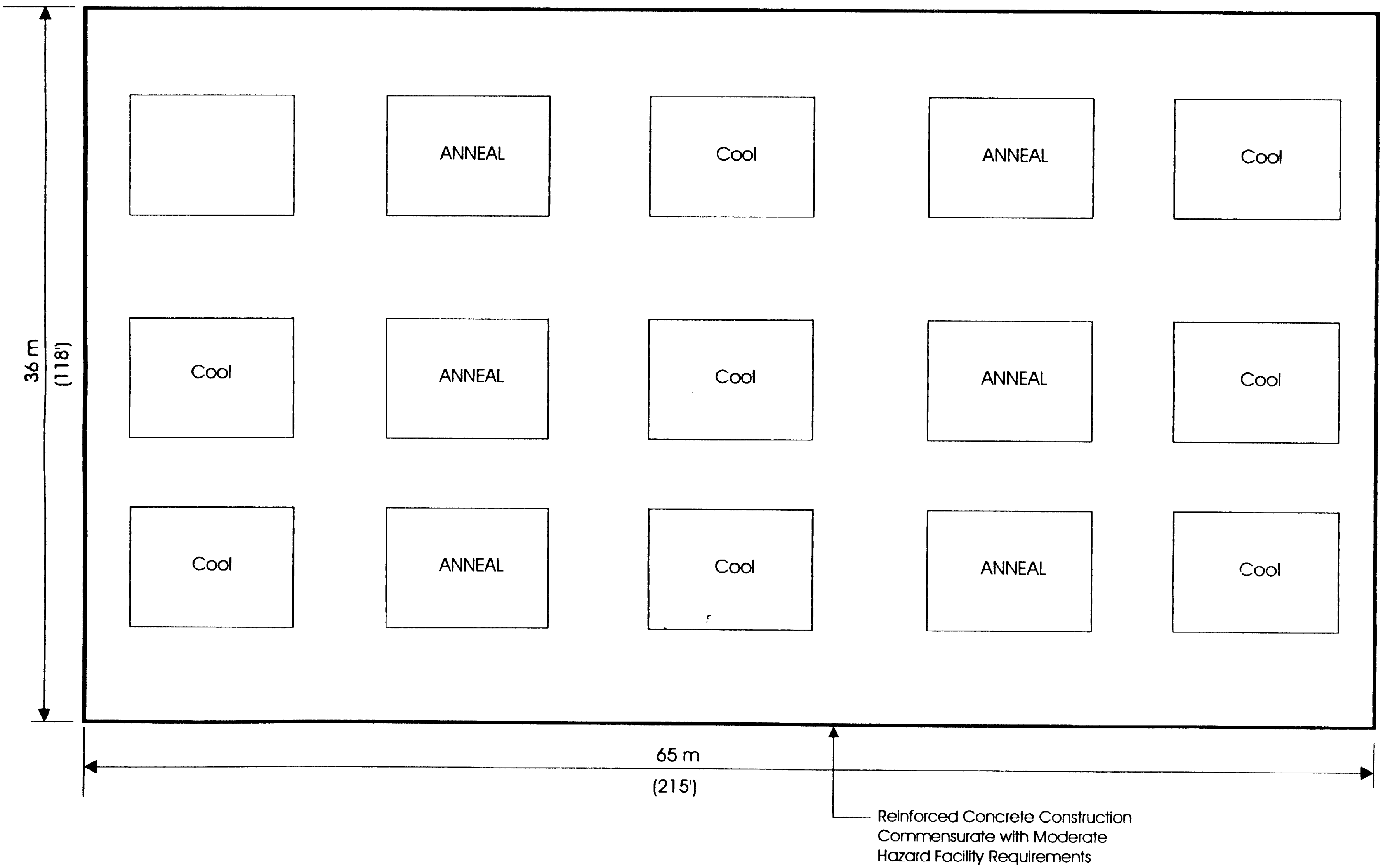
When storage unit is full, billet box islands will extend into receiving area

Figure 2.19: Layout of Depleted Uranium Metal Shielding Casting Unit



Note: This is one of two identical units in the depleted uranium metal shielding casting area.

Figure 2.20: Layout of Depleted Uranium Metal Shielding Cooling Unit



3.0 SITE MAPS AND LAND USE REQUIREMENTS

The design approach assumes a generic, flat site with access to a major public highway (preferably a State or Federal route), railroad spur, and utilities. Utilities include adequate electricity, potable water, and sanitary sewer capacity. The site is also assumed to have access to a surface water discharge. The approach further assumes that clearing and grading will be relatively minor and limited to those areas immediately surrounding the planned locations of the buildings. Site area does not change as the facility is completed and operations are initiated. The site layout uses the typical DOE/NRC approach, with an initial property fenceline and markers surrounding a fenced-in controlled area. The RCA represents that portion of the controlled area where radioactive materials are handled and the potential for contamination exists.

3.1 Depleted Uranium Concrete (DUCRETE™)

Potential accident scenarios could influence the location of site boundaries. A preliminary review of regulatory documents indicates no increase in site size due to the properties of the materials handled, the lack of dispersive energy, and the relative macroscopic sizes of the uranium species. Additional requirements are local ordinances (i.e., typical setbacks of 30 m [100 ft]) and clearance requirements for site material movements A minimum site size of approximately 36 ha (90 acres) is estimated by this report.

3.1.1 Site Map and Land Area Requirements During Construction of the DUCRETE™ Facility

Figure 3.1 displays anticipated arrangements at the LTSMF site. Initially, highway access would be created and a gravel road to the site established for construction vehicles. The trailers for the construction site headquarters would be located on the area adjacent to the planned visitors parking lot. This would establish site control. After the required clearing, the boundary markers, perimeter road, and a substantial fraction of the fences would be installed. Gravel roads would be laid following the routes of all of the final roads. The retention pond for storm water management would be graded in the same location as the final pond. The other construction trailers would be located near the construction of the main buildings in the RCA, on the site of a future employee parking lot.

The initial construction would focus on the completion of the ESB, the ATSB, and the GWSB. These buildings, once completed, would be used to support construction activities and staff for completion of the remaining facilities. Activities would then focus on the SCAB and the MPB. Subsequently, the remaining buildings would be completed. Clearing would be limited to that immediately required for construction of the various buildings and facilities; the remainder of the site would not be disturbed.

3.1.2 Site Map and Land Area Requirements During Operations at the DUCRETE™ Facility

The site perimeter fence and the controlled area fence are full height fences topped with barbed wire. The fences include monitors for emissions (both chemical and radioactive) and weather at various locations. Immediately inside the site perimeter fence, a perimeter road circles the site for security patrols, emergency vehicles, and environmental monitoring. The main entrance to the site has a guard house and a main gate. These establish the controlled area of the facility, and use standard badges and computer systems to monitor entry and egress. The size of the controlled area is essentially the same size as the site, namely 36 ha (90 acres).

Immediately inside the controlled area are the GWSB, the ESB, and the ATSB. The main road continues approximately 180 m (600 ft) to the RCA, which is marked by a full height fence topped with barbed wire. The HPRACB includes personnel and material monitoring equipment for entry to and egress from the RCA. The RCA itself is approximately 22 ha (54 acres) in size. The MPB and SCPSB are located along the left side of the RCA. The USB and WMB are located on the right side of the RCA. Table 3.1 provides footprint areas for the buildings. Table 3.2 summarizes site land parameters.

3.2 Depleted Uranium Metal

The regulatory and accident discussion of section 7 indicates there are potential scenarios by which significant offsite contamination can occur, and consequently, there would be some minimum distances required by the regulations and by local ordinances (i.e., typical setbacks of 30 m [100 ft]). This results in a site size of 36 ha (90 acres).

3.2.1 Site Map and Land Area Requirements During Construction of the Depleted Uranium Metal Facility

Figure 3.2 displays anticipated arrangements at the HTSMF site. Initially, highway access would be created and a gravel road to the site established for construction vehicles. The trailers for the construction site headquarters would be located on the area adjacent to the planned visitors parking lot. This would establish site control. After the required clearing, the boundary markers, perimeter road, and a substantial fraction of the fences would be installed. Gravel roads would be laid following the routes of all of the final roads. The retention pond for storm water management would be graded in the same location as the final pond. The other construction trailers would be located near the construction of the main buildings in the RCA, on the site of a future employee parking lot.

As with the LTSMF, the initial construction would focus on the completion of the ESB, the ATSB, and the GWSB. These buildings, once completed, would be used to support construction activities and staff for completion of the remaining facilities. Activities would then focus on the SCAB and the MPB. Subsequently, the remaining buildings would be completed. Clearing would be limited to that immediately required for construction of the various buildings and facilities; the remainder of the site would not be disturbed.

3.2.2 Site Map and Land Area Requirements During Operations at the Depleted Uranium Metal Facility

The site is surrounded by a perimeter fence that is near (but not necessarily at) the site boundary. This fence is a minimum of 5 ft high. The perimeter fence serves to avoid inadvertent intrusion onto the site by members of the public and excludes stray domestic and farm animals. The fence includes monitors for emissions (both chemical and radioactive) and weather at various locations. Immediately inside this fence, a perimeter road circles the site for security patrols, emergency vehicles, and environmental monitoring. The main entrance to the site has a guard house and a gate, which serve two principal functions: directing traffic to the appropriate locations on the site, and discouraging casual traffic. The main road leads up to the main gate of the facility. The GWSB and its parking lot are on the right, while the visitors parking lot, the ATSB, and the ESB are on the left. The main gate and guard house are located between the ATSB and the GWSB. These establish the controlled area of the facility, and use standard badges and computer systems to monitor entry and egress.

The main road continues approximately 180 m (600 ft) to the RCA, which is marked by a full height fence topped with barbed wire. The HPRACB includes personnel and material monitoring equipment for entry to and egress from the RCA. The RCA itself is approximately 22 ha (54 acres) in size. The MPB and SCPSB are located along the left side of the RCA. The USB and WMB are located on the right side of the RCA. Table 3.3 provides footprint areas for the buildings. Table 3.4 summarizes site land parameters.

Table 3.1: Low Temperature Shielding Manufacturing Facility (LTSMF) - Building Footprint Areas, m^2 (ft^2)

Building	Area, m^2 (ft^2)
SCAB	4,665 (50,106)
MPB	9,107 (98,027)
SCPSB (all four)	19,984 (215,110)
GWSB	6,710 (72,226)
WMB	5,762 (62,022)
RSB	5,734 (61,720)
USB	3,630 (39,073)
HPRACB	378 (4,069)
ESB	378 (4,069)
ATSB	1,899 (20,446)
TOTAL	58,238 (626,867)

Table 3.2: Summary of Site Land Parameters at the LTSMF

Parameter/Impact	Value
Site Land Area	36 ha (90 acres)
Total Fenced Area: Perimeter (entire site) RCA	 36 ha (90 acres) 22 ha (54 acres)
Building Footprint Area	58,238 m^2 (626,828 ft^2)
Total Paved Area	6 ha (15 acres)
Total Pond Area	1.1 ha (2.7 acres)
Total Excavated Material*	134,000 m^3 (175,000 yd^3)
Excavated Material Hauled Offsite*	65,400 m^3 (85,500 yd^3)

*Based upon slab-on-grade construction, with spread footer foundations for walls, 2-m excavation overbite, and 2-m depth for frost-free, load-bearing strata. Slab assumed to be 30-cm thick, with 300 cm of gravel (CRC or equivalent) underneath. Cask handling buildings have 60 cm of concrete on 60-cm-thick gravel base (U.S. DOE, 1995).

Table 3.3: High Temperature Shielding Manufacturing Facility (HTSMF) - Building Footprint Areas, $m^2(ft^2)$

Building	Area, m^2 (ft^2)
SCAB	4,655 (50,106)
MPB	10,145 (109,200)
SCPSB (all four)	19,984 (215,110)
GWSB	6,710 (72,226)
WMB	5,762 (62,022)
RSB	5,734 (61,720)
USB	3,630 (39,073)
HPRACB	378 (4,069)
ESB	378 (4,069)
ATSB	1,899 (20,446)
TOTAL	59,276 (638,041)

Table 3.4: Summary of Site Land Parameters at the HTSMF

Parameter/Impact	Value
Site Land Area	36 ha (90 acres)
Total Fenced Area: Perimeter (entire site) RCA	 36 ha (90 acres) 22 ha (54 acres)
Building Footprint Area	59,276 m^2 (638,041 ft^2)
Total Paved Area	7 ha (18 acres)
Total Pond Area	1.1 ha (2.7 acres)
Total Excavated Material*	138,000 m^3 (180,000 yd^3)
Excavated Material Hauled Offsite*	67,000 m^3 (88,000 yd^3)

*Based upon slab-on-grade construction, with spread footer foundations for walls, 2-m excavation overbite, and 2-m depth for frost-free, load-bearing strata. Slab assumed to be 30-cm thick, with 300 cm of gravel (CRC or equivalent) underneath. Cask handling buildings have 60 cm of concrete on 60-cm-thick gravel base (U.S. DOE, 1995).

Figure 3.1: LTSMF Site Map

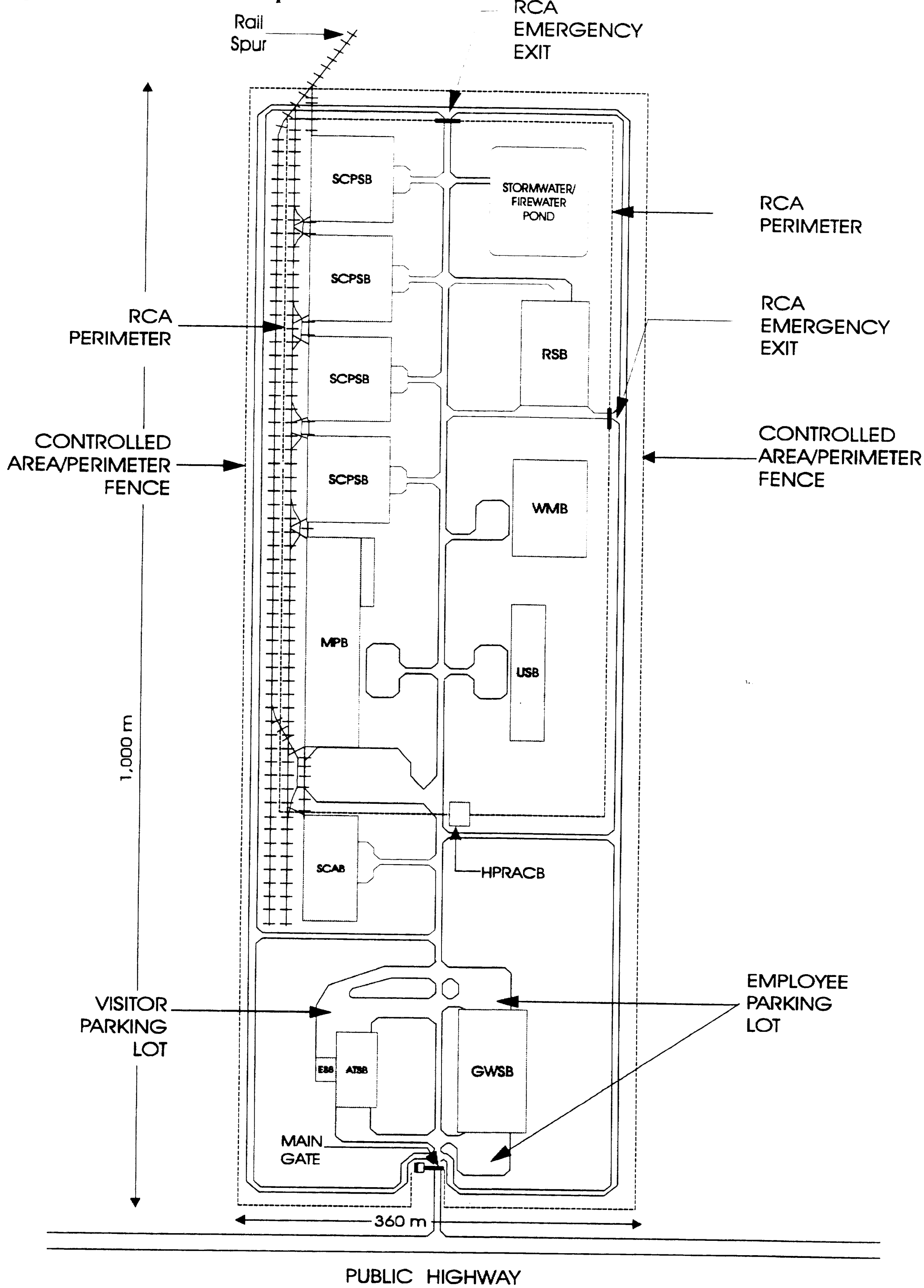
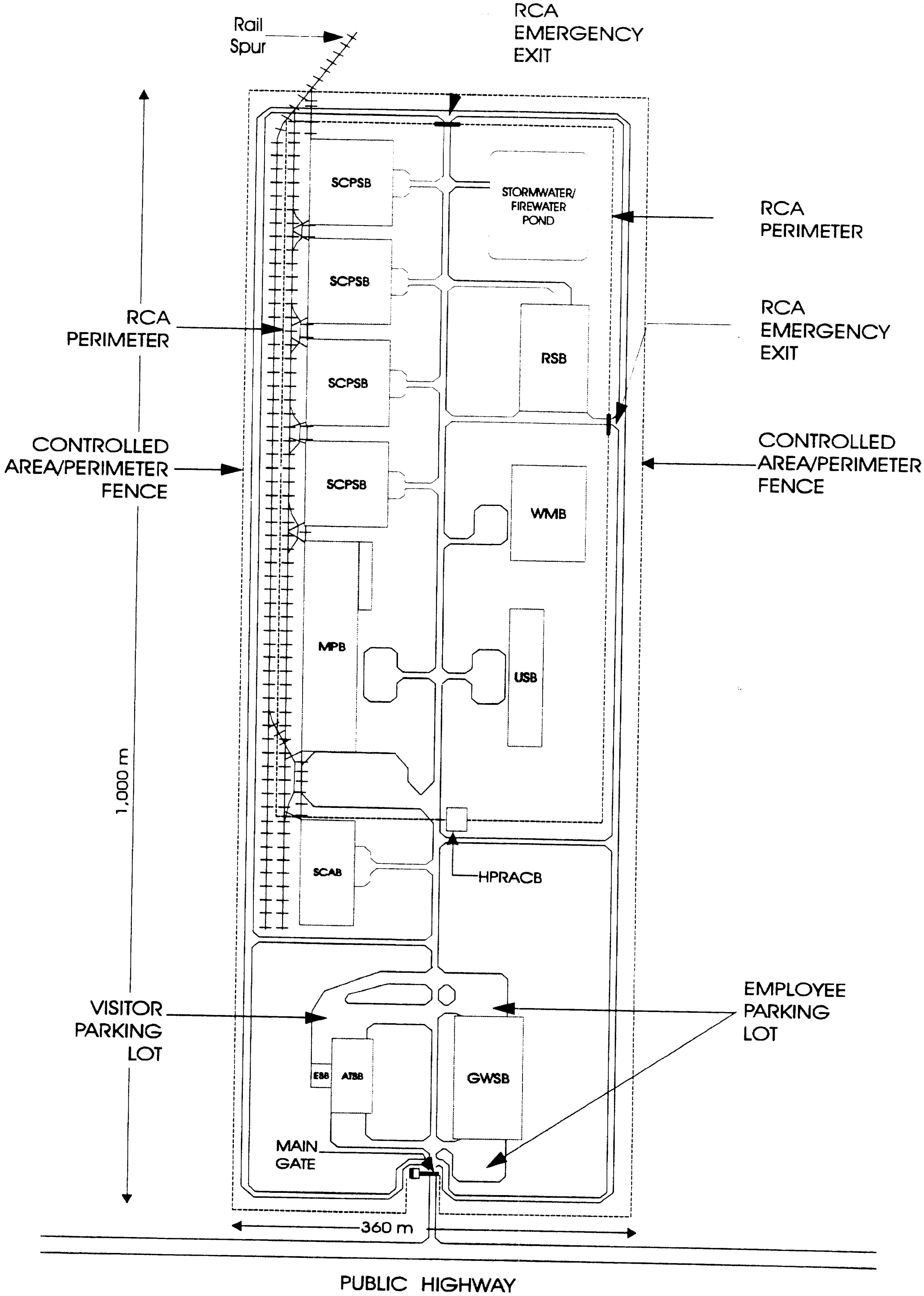


Figure 3.2: HTSMF Site Map



4.0 RESOURCE NEEDS

4.1 Materials and Resources Consumed During the Construction of the Shielding Manufacturing Facility

4.1.1 LTSMF - Depleted Uranium Concrete (DUCRETE™) Shielding

Table 4.1 summarizes the estimates of concrete, asphalt, steel, water, diesel fuel, and electricity used during construction. Table 4.2 shows concrete estimates. A more detailed design might result in some hardening of the walls for seismicity or other requirements, and this would increase concrete requirements. Most of the steel usage accrues from rebar in the concrete. Alloy usage is expected to be small. Fuel usage is estimated from an NRC environmental impact statement (EIS) (U.S. NRC, 1994).

4.1.2 HTSMF - Depleted Uranium Metal Shielding

Table 4.3 summarizes the estimates of concrete, asphalt, steel, water, diesel fuel, and electricity used during construction. Table 4.4 displays concrete estimates. The HTSMF uses more resources than the LTSMF due to the higher temperatures and the larger facilities. A more detailed design might result in some hardening of the walls for seismicity or other requirements, and this would increase concrete requirements. Most of the steel usage accrues from rebar in the concrete. Alloy usage is expected to be greater than the LTSMF. Fuel usage is estimated from an NRC EIS (U.S. NRC, August 1994).

4.2 Materials and Resources Consumed During Routine Operations of the Shielding Manufacturing Facility

4.2.1 LTSMF - Depleted Uranium Concrete (DUCRETE™) Shielding

4.2.1.1 Utilities and Fuel

Table 4.5 presents estimates of utility and fuel consumption. Diesel fuel consumption is small due to backup generator operation and intrasite truck operations. The analyses assume 15 18-kVA UPS/UBS systems and 5 7-kVA UPS/UBS combinations on automated test schedules of 20 minutes every 2 weeks, and 24 hours of actual runtime per year. The analyses also assume two 100-kW SPS diesel electric systems on schedules of 1 hour per month, and 24 hours of runtime per year. Onsite vehicle usage is based upon the intrasite transportation requirements from section 8. Natural gas usage comes from space heating (table 4.6). Space heating requirements depend on location; this analysis assumes heating for six months each year, at a rate of approximately 22 W/m^2 (8 $BTU/hr\text{-}ft^2$). As shown in table 4.6, this amounts to around 580,000 SCM.

The analyses estimate telephone requirements on a person basis, multiplied by the total staff. For 470 full time equivalents (FTEs), the design assumes around 900 telephones. Standard factors indicate annual usage of about 50,000 hours.

Electricity consumption consists of building and process loads. For the air conditioning fraction, the calculations use the same effective thermal load as the heating season for the remaining 6 months of the year, with a Seasonal Energy Efficiency Ratio (SEER) of 12 BTUs(t) per hour/Watt(e). The other principal building load arises from lighting. The estimates use a typical electricity lighting rate of approximately 34 watts (fluorescent) per square meter (around 3.2 watts per square foot). The estimates include energy and exhaust requirements due to HEPA filtration, using uniform, simplifying assumptions. HEPA effects upon heating and cooling effects are not directly calculated; i.e., an air/air heat exchanger and/or less climate control is assumed. HEPA system refinements would be part of a more detailed design phase.

Electricity usage is summarized in table 4.5. Tables 4.6 and 4.7 provide information on building electricity loads, while table 4.8 estimates process electricity loads. Process usage is a relatively small fraction of the total power consumption. Design refinements during a more detailed design phase would probably reduce building electricity usage.

The estimates in tables 4.5 through 4.7 represent rough, order of magnitude values because of the preconceptual nature of the design. A more refined design from a detailed design phase would better accommodate the different functions within the buildings and operating areas. For example, the final assembly area would have reduced HEPA and air requirements as compared to the mixing areas. Lighting would be affected in a similar manner; for example, a more refined design would reduce lighting in storage areas, or even turn it off. For current purposes, the values in tables 4.5 through 4.7 should be viewed as reasonable and bounding, subject to review and possible reductions during a more detailed design phase.

4.2.1.2 Water and Wastewater

Table 4.9 estimates water and wastewater generation. The site assumes potable water and publicly owned treatment work (POTW) connections. Employee use is estimated from standard values (U.S. DOE, 1995) and the personnel estimates of section 5. Process use comes from the DUCRETE™ mixing requirements. Steam and deionized water makeup are each estimated at 10 percent of the steam generation rate (i.e., 20 percent of the condensate is not recycled and is routed to the drains). Cooling water is used principally for the steam condenser. Blowdown is assumed to be comparable to evaporative losses (i.e., about 3.6 percent each). Cooling water treatment assumes an ozone-based system, and therefore, blowdown chemical content is not a concern. No separate process discharges are anticipated from LTSMF operations.

4.2.1.3 Chemicals

Table 4.10 summarizes chemical consumption at the LTSMF. The cement and colemanite sand for the DUCRETE™ are the main chemicals. The analyses assume small containers, although bulk shipments could be used. Stainless steel usage represents the largest weight of material because it becomes the annular shape of the cask. The numerous welding operations consume the argon.

4.2.1.4 Radioactive Materials

Table 4.11 estimates radioactive material usage at the LTSMF, and figure 4.1 shows the flow paths. Uranium dioxide is used in the largest quantities. Uranium dioxide is received in individual drums containing approximately 667 kg each. It is incorporated into the DUCRETE™ shielding, and shipped out as assembled, SNF storage casks. Radwaste is shipped to disposal in standard sized drums. The empty, half-sized drums are cleaned by vacuuming , and if necessary, by a dilute acid and detergent wash. Ninety-five percent of the drums are released free to commercial scrap dealers, while 5 percent are shipped offsite for commercial LLW treatment by melting, and subsequently sent to disposal. If the shielding manufacturing plant's operations are integrated with a conversion plant's operations, then the empty uranium dioxide drums can be recycled for reuse.

4.2.2 HTSMF - Depleted Uranium Metal Shielding

4.2.2.1 Utilities and Fuel

Table 4.12 through 4.15 present estimates of utility and fuel consumption at the HTSMF. Figure 4.2 displays the utility flow paths. As with the LTSMF, diesel fuel consumption is small. Natural gas usage accrues from space heating (table 4.13), and the soaking pit in the uranium casting area (table 4.15).

Table 4.12 summarizes electricity usage. Tables 4.13 and 4.14 provide information on building electricity loads, while table 4.15 estimates process electricity loads. Process usage amounts to approximately one-third of the total power consumption. Design refinements during a more detailed design phase would probably reduce building electricity usage.

4.2.2.2 Water and Wastewater

Table 4.16 estimates water consumption and wastewater generation at the HTSMF. Employee consumption uses standard values (U.S. DOE, 1995) and the personnel estimates from section 5. There is no direct process consumption of water for metal shielding. Steam, DI water, and cooling water makeup are estimated as 10 percent larger than the LTSMF due to the boiler on the soaking pit's exhaust gases. No separate process discharges are anticipated from HTSMF operations.

4.2.2.3 Chemicals

Table 4.17 summarizes chemical consumption at the HTSMF, and figure 4.3 shows the flow paths. Stainless steel constitutes the principal "material." Graphite linings for the melters and manifolds constitute the other main reagent consumed. Radwaste encapsulation uses cement.

4.2.2.4 Radioactive Materials

Table 4.18 estimates radioactive material usage at the HTSMF, and figure 4.4 shows the flow paths. The plant consumes around 19,500 te of uranium metal per year, arriving by road or by rail. The metal billets are assumed to be in boxes, each containing 19 billets weighing 34 kg apiece. Four boxes are loaded on to each pallet. Around 30,000 boxes arrive annually. The uranium metal becomes part of the shielding and is shipped out as part of the shielding cask. The empty billet boxes are cleaned. Some 95 percent are released free to commercial recyclers, while 5 percent are shipped offsite for commercial LLW treatment by melting (metal boxes assumed), and subsequently shipped to disposal. If the shielding manufacturing plant's operations are integrated with a conversion plant's operation, then the billet boxes can be recycled to the conversion facility for reuse.

Table 4.1: Materials and Resources Consumed During Construction of the Low Temperature Shielding Manufacturing Facility (LTSMF)

Material/Resource	Quantities
Concrete	45,981 m^3 (60,143 yd^3)
Asphalt	12,000 m^3 (15,700 yd^3)
Steel	10,500 te
Water	132 ML (35M gal)
Diesel Fuel	2.3 ML (0.61M gal)
Gasoline	0.6 ML (0.2M gal)
Electricity	4.7 MW-yrs

Table 4.2: Concrete Estimates for LTSMF Buildings

Building	Concrete Required, m^3 (yd^3)		
	Floor	Walls	Total
SCAB	3,724 (4,871)	1,382 (1,808)	5,106 (6,678)
MPB	7,286 (9,529)	2,842 (3,717)	10,128 (13,247)
SCPSB	15,988 (20,912)	4,083 (5,340)	20,071 (26,252)
GWSB	2,013 (2,633)	410 (536)	2,423 (3,169)
WMB	1,729 (2,261)	551 (721)	2,280 (2,982)
RSB	1,720 (2,250)	372 (487)	2,092 (2,736)
USB	1,089 (1,424)	544 (712)	1,633 (2,136)
HPRACB	227 (297)	187 (245)	414 (541)
ESB	227 (297)	187 (245)	414 (541)
ATSB	1,140 (1,491)	282 (369)	1,422 (1,860)
Totals	35,141 (45,964)	10,840 (14,179)	45,981 (60,143)

Table 4.3: Materials and Resources Consumed During Construction of the High Temperature Shielding Manufacturing Facility (HTSMF)

Material/Resource	Quantities
Concrete	47,042 m^3 (61,531 yd^3)
Asphalt	14,000 m^3 (18,300 yd^3)
Steel	11,000 te
Water	163 ML (43.1M gal)
Diesel Fuel	2.4 ML (0.63M gal)
Gasoline	0.7 ML (0.2M gal)
Electricity	4.9 MW-yrs.

Table 4.4: Concrete Estimates for HTSMF Buildings

Building	Concrete Required, m^3 (yd^3)		
	Floor	Walls	Total
SCAB	3,724 (4,871)	1,382 (1,808)	5,106 (6,678)
MPB	8,116 (10,615)	3,072 (4,018)	11,188 (14,633)
SCPSB (4)	15,988 (20,912)	4,083 (5,340)	20,071 (26,252)
GWSB	2,013 (2,633)	410 (536)	2,423 (3,169)
WMB	1,729 (2,261)	551 (721)	2,280 (2,982)
RSB	1,720 (2,250)	372 (487)	2,092 (2,736)
USB	1,089 (1,424)	544 (712)	1,633 (2,136)
HPRACB	227 (297)	187 (245)	414 (541)
ESB	227 (297)	187 (245)	414 (541)
ATSB	1,140 (1,491)	282 (369)	1,422 (1,860)
Totals	35,972 (47,051)	11,070 (14,480)	47,042 (61,531)

Table 4.5: Utilities and Fuels Used During Routine Operations at the LTSMF (Annual Basis)

Item	Annual Usage	
Diesel Fuel	7,500 L (2,000 gal)	(1,500 L backup generator 14,300 kWh, 6,000 L for trucks)
Gasoline	21,350 L (5,640 gal)	1 mile per day per employee
Fuel, Natural Gas (space heating)	5.8 x 10^5 SCM (20 MSCF)	
Telephone, hours	50,000	
Electricity: Total: kW(e)	3,811	
MPB	Building: 668 Process: 400 Total: 1,068	
SCAB	Building: 315 Process: 70 Total: 385	
SCPSB (4)	885	
GWSB	286	
WMB	290	
RSB	278	
USB	Building: 219 Process: 200 Total: 419	
HPRACB	33	
ESB	28	
ATSB	139	

Table 4.6: Building Energy Requirements for the LTSMF (Annual Basis)

Building	Natural Gas Heating, kW(t)	Electricity, kW(e)				
		Cooling	Lights	HEPA	Tools	Total
MPB	270	75	420	69	104	668
SCAB	90	25	152	0	138 (85 + 53)	315
SCPSB (4)	480	134	741	0	10	885
GWSB	147	43	230	0	13	286
WMB	126	35	194	44	17	290
RSB	127	36	198	43	0 (in WMB)	277
USB	80	25	135	27	32	219
HPRACB	17	5	13	0	15	33
ESB	17	5	13	0	10	28
ATSB	84	25	65	0	49	139
Totals	1,438 (2.0×10^{10} BTU/yr) 5.8×10^5 SCM (20M SCF)	408	2,161	183	388	3,140

Note: Heating and cooling are for 6-month seasons each; all other values are continuous. For electricity consumption averaged over the entire year, the cooling values would be halved.

Note: "Tools" include appliances, computers, hand tools etc., at 0.5 kW(e) per FTE.

Table 4.7: HEPA Filter Effects for the LTSMF

Building	HEPA Exhaust, m^3/min (SCFM)	Power, kW(e) (HP)
MPB	3,750 (132,400)	93 (125)
WMB	1,700 (61,600)	43 (58)
RSB	1,800 (62,000)	44 (58)
USB	3,500 (125,000)	88 (118)
Total	10,750 (381,000)	268 (359)

Note: Exhaust estimated at 1 SCFM/ft^2
Power at 50% efficiency, 3" water ΔP, ~9.424×10^{-4} HP/ft^2

Table 4.8: Process Electricity Loads in the LTSMF MPB

Area	Load, kW(e)
Receiving Area *	40
Storage Area *	60
Mixing/Coating	150
Curing Area*	40
Assembly/QC Area **	70
Shipping Area*	40
Total	400

* Assumes 50 hp motors in cranes, with, on average, one operating continuously
**Crane plus four, 30 Amp/240V welding stations

Table 4.9: Water Consumption and Wastewater Generation at the LTSMF

Item		Annual Quantity
Potable Water	Employees	15 ML
	Process	1.4 ML
	Process/DI and Steam	12 ML
	Total	28 ML (7.5M gal)
Wastewater	Sanitary Wastes - Construction	38 ML
	Sanitary Wastes - Operation	18 ML
	Total (Operations)	18 ML (4.8M gal)
Plant Discharge (either to NPDES discharge point or sanitary sewer)		0

*Estimated at 3.6%

Table 4.10: Chemical Consumption at the LTSMF

Chemical	Annual Quantity, te	Container Type/Size	Number of Containers Annually
Cement	2,909* te	100-kg drums	29,090
Colemanite Sand	3,350 te	100-kg drums	33,500
Cement Additives**	29 te	100-kg drums	290
Stainless Steel	9,610 te	Annular Shapes/Casks	480
Argon	245 te (137 ML)	High-Pressure Cylinders	24,240 (68/day)
Flocculants	10 te	100-kg drums	100
Drums, 55-gal	534 (#)	(-)	534
IX Resins	100 ft^3	5 ft^3 drums	20
PPE	9,400 ft^3	2 ft^3 boxes	4,700
Absorbents/ Swipes	9,400 ft^3	2 ft^3 boxes	4,700

*Note: Includes 39 te/yr for radwaste encapsulation (0.2 te/drum)
**Note: Assumed to be 1% of the cement usage

Table 4.11: Radioactive Materials at the LTSMF

Radioactive Material	Annual Quantities, te	Container Type/Size	Number of Containers Annually
UO_2	21,500	30-gal drum	32,150
UO_2	21,500	SNF Cask/80 te	480
Radwaste*	300	55-gal drum	534

*Density of 3 g/cc assumed

Table 4.12: Utilities and Fuels Used During Routine Operations at the HTSMF (Annual Basis)

Item	Annual Usage	
Diesel Fuel	7,500 L (2,000 gal)	(1,500 L backup generator 14,300 kWh, 6,000 L for trucks)
Gasoline	21,200 L (5,600 gal)	1 mile per day per employee
Fuel, Natural Gas (space heating and soaking pit)	0.896 M SCM (34 M SCF)	
Telephone, hours	54,000	
Electricity: Total: kW(e)	4,709	
MPB	Building: 717 Process: 1,250	Total: 1,967
SCAB	Building: 315 Process: 70	Total: 385
SCPSB (4)		885
GWSB		286
WMB		290
RSB		277
USB	Building: 219 Process: 200	Total: 419
HPRACB		33
ESB		28
ATSB		139

Table 4.13: Building Energy Requirements for the HTSMF (Annual Basis)

Building	Natural Gas Heating, kW(t)	Electricity, kW(e)				
		Cooling	Lights	HEPA	Tools	Total
MPB	292	81	452	77	107	717
SCAB	90	25	152	0	138 (85 + 53)	315
SCPSB (4)	480	134	741	0	10	885
GWSB	147	43	230	0	13	286
WMB	126	35	194	44	17	290
RSB	127	36	198	44	0 (in WMB)	277
USB	80	25	135	27	32	219
HPRACB	17	5	13	0	15	33
ESB	17	5	13	0	10	28
ATSB	84	25	65	0	49	139
Totals	1,460 ($2.1x10^{10}$ BTU/yr) $6.0x10^{5}$ SCM (21M SCF)	414	2,193	191	391	3,189

Note: Heating and cooling are for 6-month seasons each; all other values are continuous. For electricity consumption averaged over the entire year, the cooling values would be halved.

Note: "Tools" include appliances, computers, hand tools etc., at 0.5 kW(e) per FTE.

Table 4.14: HEPA Filter Effects for the HTSMF

Building	HEPA Exhaust, m^3/min (SCFM)	Power, kW(e) (HP)
MPB	3,093 (109,477)	77 (1037)
WMB	1,757 (61,990)	44 (58)
RSB	1,748 (61,689)	43 (58)
USB	1,107 (39,053)	27 (37)
Total	7,705 (271,876)	191 (256)

Note: Exhaust estimated at 1 SCFM/ft^2, including inert/purge gas streams. Cooling air contacts the steel shell and provides cooling via conduction. The molten uranium metal is not contacted by the cooling air.
Power at 50% efficiency, 3 " water ΔP, ~ 9.424 x 10^{-4} HP/ft^2

Table 4.15: Process Electricity and Natural Gas Loads in the HTSMF MPB

Area	Load, kW(e)
Receiving Area*	40
Storage Area*	60
Metal Casting Area	1,000
Metal Cooling Area	40
Assembly/QC Area**	70
Shipping Area*	40
Total	1,250
Natural Gas/Metal Casting Area+	351 kW(t) (1.05 x 10^{10} BTU/yr)

* Assumes 50 hp motors in cranes
**Crane plus four, 30 Amp/240V welding stations
\+ Soaking pit area

Table 4.16: Water Consumption and Wastewater Generation at the HTSMF

Item		Annual Quantity
Potable Water	Employees	15 ML
	Process	0 ML
	Process/DI and Steam	13 ML
	Total	28 ML (7.4M gal)
Wastewater	Sanitary Wastes - Construction	47 ML
	Sanitary Wastes - Operation	19 ML
	Total	19 ML (5.0M gal)
Plant Discharge (either to NPDES discharge point or sanitary sewer)		0

*Estimated at 3.6%

Table 4.17: Chemical Consumption at the HTSMF

Chemical	Annual Quantity, te	Container Type/Size	Number of Containers Annually
Stainless Steel	11,414	Annular Shapes	453
Graphite	1,000*	100-kg drums	10,000
Nitrogen	100	10-te tanks	10
Argon	245 (137 ML)	High-Pressure Cylinders	24,240
Cement	39**	100-kg drums	390
Drums, 55-gal	3,300 (#)	(-)	3,300
IX Resins	100 ft^3	5 ft^3 drums	20
PPE	9,320 ft^2	2 ft^3 drums	4,660
Absorbents/ Swipes	9,320 ft^2	2 ft^3 drums	4,660

* Graphite is used for melter and crucible linings. The linings are slowly consumed, forming a froth or a slag, by processing, with the graphite ultimately becoming waste.

** For radwaste encapsulation, about 0.2 te/drum

Table 4.18: Radioactive Materials at the HTSMF

Radioactive Material	Annual Quantity, te	Container Type/Size	Number of Containers Annually
U Metal	19,516	Pallet	7,350
U Metal	19,516	Shielding Cask	453
Radwaste*	1,875	55-gal. drum	3,300

*Specific gravity of 3 assumed

Figure 4.1: LTSMF Radioactive Material Flow Paths

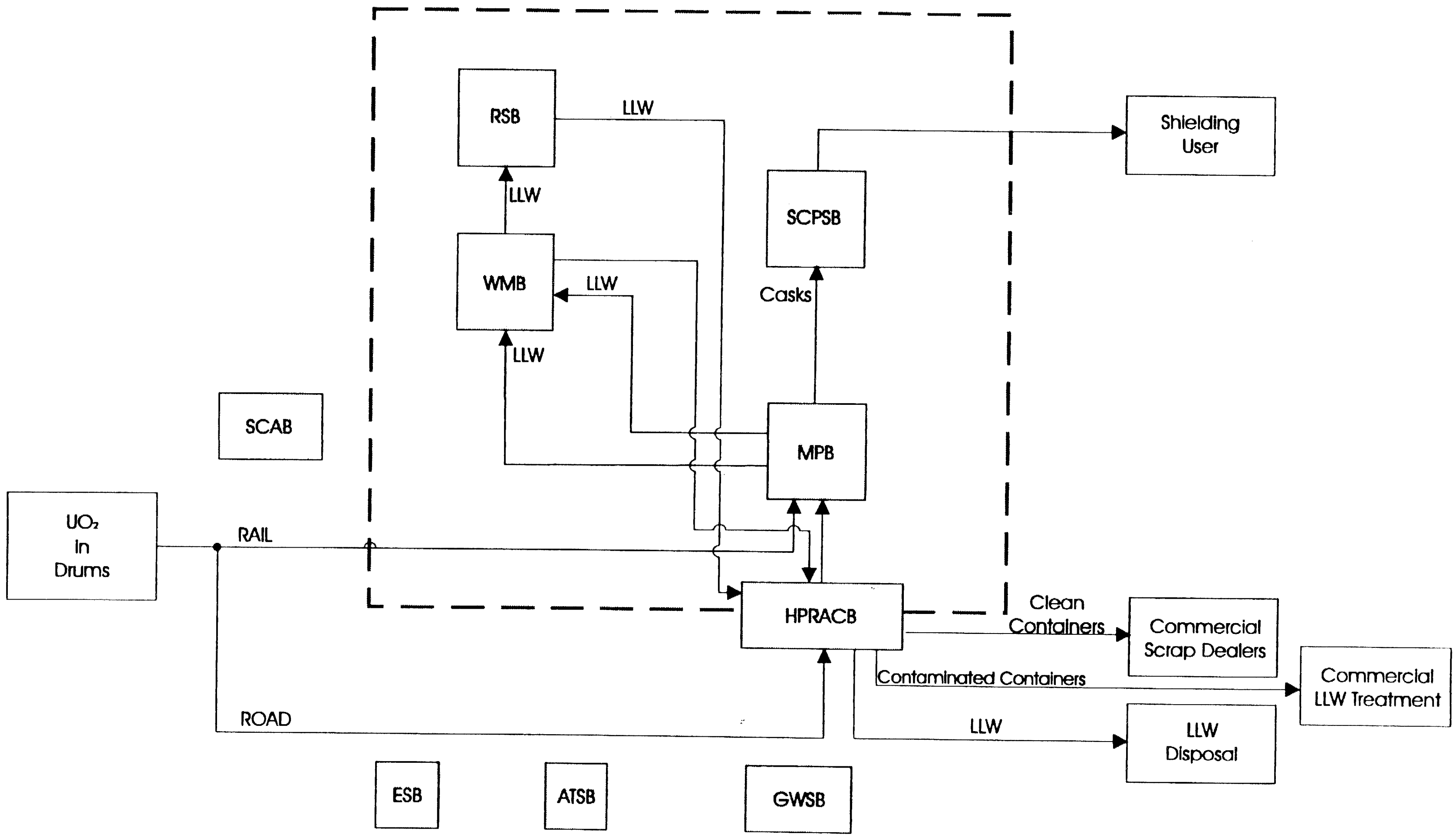


Figure 4.2: High Temperature Shielding Manufacturing Facility (HTSMF) Utilities, Fuel, and Water Usage

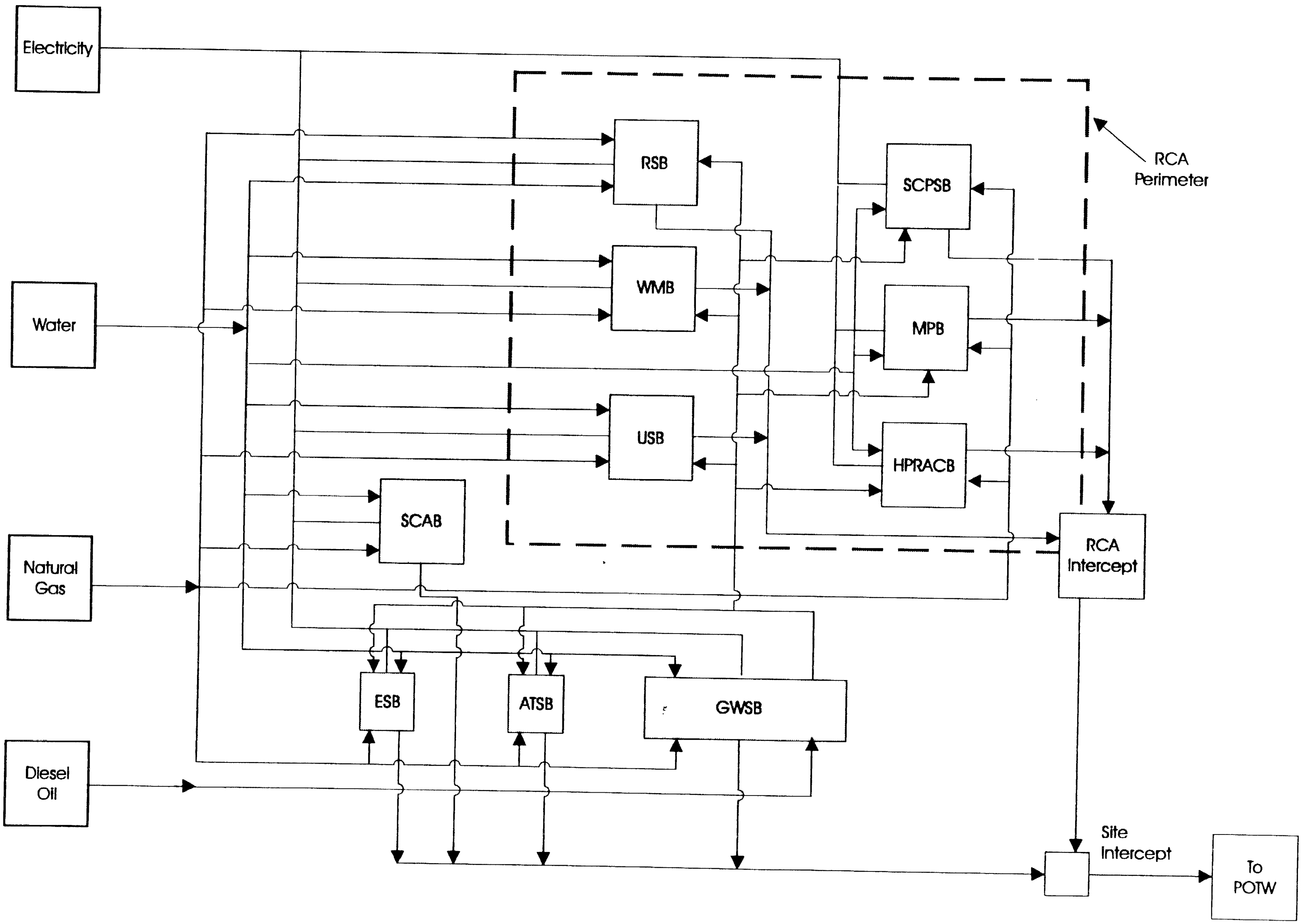


Figure 4.3: Reagent and Chemical Flow Paths at the HTSMF

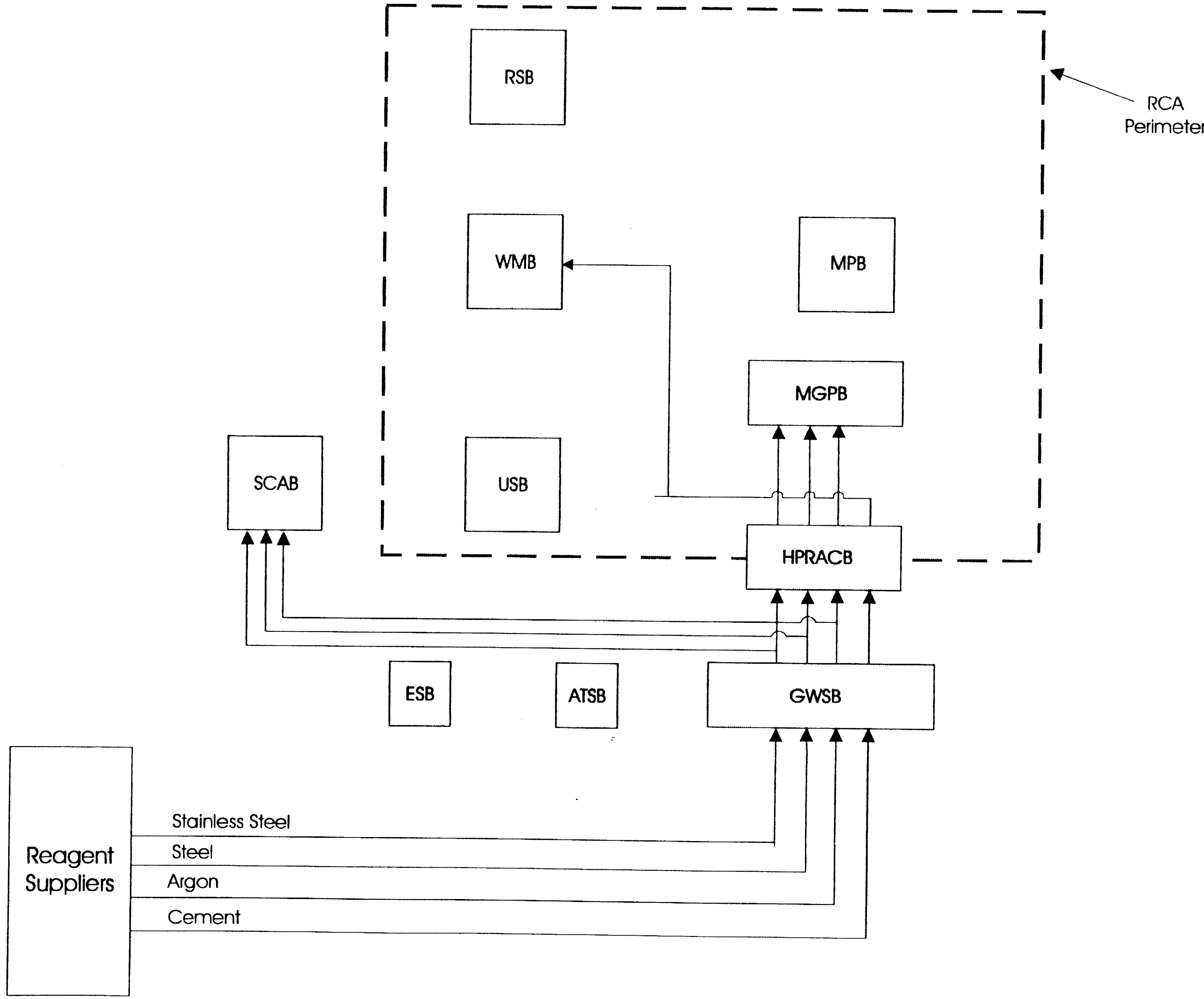
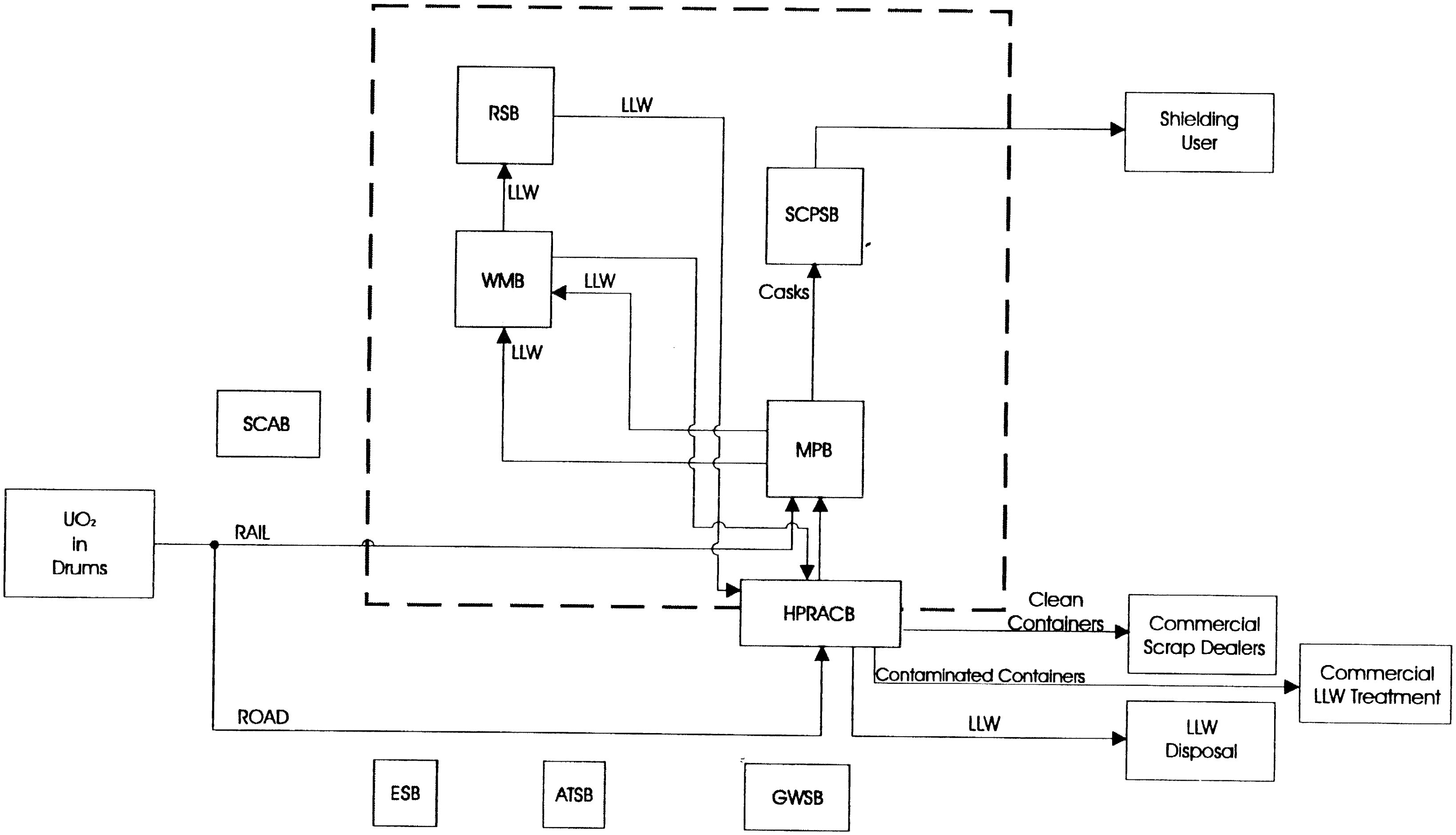


Figure 4.4: HTSMF Radioactive Material Flow Paths



5.0 PERSONNEL STAFFING ESTIMATES

Personnel and employee staffing estimates are preconceptual. As noted in sections 1 and 2, current shielding applications do not use depleted uranium in large quantities. Large-scale use of depleted uranium also requires fundamental changes in the current approach, including the use of a dedicated workforce at a centralized manufacturing facility. Personnel estimates have been generated using the process and facility descriptions from sections 1 and 2. These result in values approximately 28 percent less than current practices for concrete SNF casks. This difference appears to accrue from plant automation and the elimination of concrete form work. At this preconceptual level, the estimates should be considered as consistent with each other. These estimates are divided into construction and operational labor forces, and are discussed in the following sections.

5.1 Construction Labor Force

5.1.1 LTSMF - Depleted Uranium Concrete (DUCRETE™) Shielding

The construction labor force is organized as follows:

- Management, engineering, design, and permitting (Home Office): this category includes the management, planning, engineering (FSR through Title 3), and permitting personnel. Permitting would include licensing activities and National Environmental Policy Act (NEPA) documentation. This group would be located principally at a site different from the proposed shielding manufacturing facility. The level of effort is expected to be relatively constant over the construction period at a level around 20 FTEs per year, but the composition of the team would evolve.

- Management and supervision at the construction site (Field Office): this represents overall field management and supervision during construction. This group would be housed in trailers, although a significant fraction would transfer to finished buildings upon completion of the ATSB, ESB, and GWSB. The analyses anticipate a relatively constant level of approximately 20 FTEs per year.

- Site preparation: this includes the initial construction entrance, gravel roads, storm water mitigation, initial grubbing, temporary utilities, etc. This requires about 100 FTEs per year.

- Construction of ESB, ATSB, and GWSB: these are the initial buildings on the site and can be used to support construction activities. Construction would entail the use of around 100 FTEs per year.

- Construction of SCAB and MPB: these constitute the main processing buildings, and are designed for completion of the building shell, followed by equipment installation. As a rough order of magnitude estimate, some 300 FTEs per year would be required for construction.

- Construction of RSB and SCPSB: these are relatively simple buildings with minimal equipment, and construction would start after the civil work and building construction on the SCAB and MPB have been completed. Around 100 FTEs per year are required.

- Construction of WMB: construction on this building would take advantage of equipment installers and pipe fitters becoming available toward the completion of the SCAB and the MPB. Around 100 FTEs per year would be necessary.

- Construction of USB and HPRACB: the USB represents the third most complex building on site. This complexity is offset by the use of pre-engineered systems and skids. Construction requires about 300 FTEs per year.

- Site finishing: this includes final grading and road work, and the site fence lines. Around 100 FTEs per year would complete the work.

- Readiness reviews, checkout, and startup: these terms are used synonymously, and would include training (and certification, as required) of the operating staff. Estimates place the operating staff at around 600 FTEs for the shielding manufacturing facility per year (see section 5.2). This would increase to approximately 627 FTEs per year with the reviews and checkouts.

Figure 5.1 shows the organization of the construction workforce and activities. The total estimated construction workforce accrues to approximately 2,560 FTE-years, with an average workforce of around 410 FTEs and a peak workforce in years 6 and 7 of around 800 FTEs.

5.1.2 HTSMF - Depleted Uranium Metal Shielding

Construction of the HTSMF proceeds in a similar manner. The principal difference is the MPB, which is larger and requires the installation of additional equipment as compared to the LTSMF. Construction also has to accommodate the high temperatures of operations. This effect manifests itself as an approximate increase of 200 FTEs per year for 3 years. This brings the total construction effort to about 3,180 FTE-years. Figure 5.2 provides an overview of the construction workforce.

5.2 Operations Labor Force

5.2.1 LTSMF - Depleted Uranium Concrete (DUCRETE™) Shielding

Operation of the facility assumes 24-hour operation on a three-shift basis, with a fourth spare shift where appropriate. The analysis is also based upon a highly automated facility, where most operations are performed from the Main Control Room in the MPB. Figure 5.3 provides the overview of plant staffing, based upon the shift estimates summarized in table 5.1. The estimate totals around 470 FTEs. The relatively high number accruing to Administration and Technical Support is due to the inclusion of several operating functions (e.g., analyses, HP). This operational labor estimate for cask manufacture (essentially the MPB plus the SCAB staffs) is approximately 28 percent lower than published estimates for construction of onsite SNF storage facilities (Baltimore Gas and Electric, 1989). This appears to be due to automation and the elimination of concrete form work. For practical purposes, these labor estimates should be considered comparable to the literature values.

Most of the employees would be trained and badged for radioactive work. However, due to the plant layout, automation, and use of thick stainless steel shells for the shielding cask, relatively few employees would be exposed to radioactive materials on a routine basis. Radiation exposures are anticipated to approach background levels and be well within DOE and NRC regulatory requirements.

Personnel will not be required to wear personal protective equipment (PPE) for protection from chemical or radiological hazards during normal operations. PPE will be available on site for certain maintenance or special operational activities or emergency situations. However, the accident analysis takes no credit for the use of PPE following an accident or process upset condition.

5.2.2 HTSMF - Depleted Uranium Metal Shielding

Figure 5.4 provides an overview of the staffing estimate for the HTSMF, based upon the shift estimates in table 5.2. The estimate totals around 466 FTEs for the HTSMF route. This is due to the number of furnaces and high temperatures involved in the metal melting and casting operations.

Table 5.1: Personnel Staffing for Operations by Shift for the Low Temperature Shielding Manufacturing Facility (LTSMF)

Activity 2.1 Admin & Tech. Support

Activity 2.1.1 Plant Management

Shift	1	2	3	4 (Spare)	Total
Manager	1 (GM)	1	0	0	2
Exec. Sec.	1	1	0	0	2

Activity 2.1.2 Technical Services

Activity 2.1.2.1 Engineering

Shift	1	2	3	4 (Spare)	Total
Manager	1	0	0	0	1
Secretary/ Records	1	1	0	0	2
Engineer	4	3	1	2	10
Technical	4	3	1	2	10

Activity 2.1.2.2 Analytical and Chemistry Services

Shift	1	2	3	4 (Spare)	Total
Manager	1	0	0	0	1
Secretary/ Records	1	1	0	0	2
Engineer	4	2	2	2	10
Technical	4	2	2	2	10

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.1.3 Administration Services

Activity 2.1.3.1 Computers, Graphics, and Communications

Shift	1	2	3	4 (Spare)	Total
Manager	1	0	0	0	1
Secretary/ Records	1	0	0	0	1
Engineer	4	2	0	1	7
Technical	4	2	0	1	7

Activity 2.1.3.2 Plant Access and Security

Shift	1	2	3	4 (Spare)	Total
Manager	1	1 (Supervisor)	1 (Supervisor)	0	3
Secretary/ Records	1	0	0	0	1
Security					
Front Gate	2	2	2	1	7
Controlled Gate	2	2	2	1	7
RVSB	2	2	1	0	5
MPB	2	2	1	0	5

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.1.3.3 Procurement and Shipping/Receiving (in GWSB)

Shift	1	2	3	4 (Spare)	Total
Manager	1	1	0	0	2
Secretary/ Records	1	1	0	0	2
Procurement/ Engineer	3	1	0	0	4
Technical (GWSB)	6	4	0	0	10

Activity 2.1.3.4 Health Physics (in HPRACB)

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Secretary/ Records	1	1	0	0	2
HP-Engineering	4	2	1	0	7
HP-Techs	10	5	5	2	22

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Totals for Activity 2.1 Admin & Tech. Support

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	7	4	1	0	12
Secretary/ Records	7	5	0	0	12
Engineering	19	10	4	5	38
Technical	28	16	8	7	59
Guards	8	8	6	2	24
					145 FTEs

Activity 2.2 MPB

Activity 2.2.1 Main Control Room

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	4	4	1	2	11
Technical	2	2	0	0	4

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.2.2 Receiving and Storage Areas

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Engineer/ Operator	1	1	1	1	4
Technician	3	3	0	1	7

Activity 2.2.3 DUCRETE™ Mixing and Curing Areas

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	2	2	1	1	6
Technician	11	11	3	6	31

Activity 2.2.4 Final Assembly, QC, and Shipping Areas

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	2	2	1	1	6
Technician	5	5	0	2	12

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Totals for Activity 2.2 MPB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	4	3	0	0	7
Engineer/ Operator	9	9	4	5	27
Technical	21	21	3	9	54
					88 FTEs

Activity 2.3 SCPSB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Engineer/ Operator	1	1	0	0	2
Technical	3	3	0	1	7
					10 FTEs

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.4 SCAB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	3	3	1	1	8
Technician	43	43	2	10	98
					108 FTEs

Activity 2.5 RSB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Secretary/ Records	1	0	0	0	1
Engineer	0	0	0	0	0
Technical	4	4	0	0	8
					10 FTEs

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.6 WMB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	2	2	0	0	4
Secretary/ Records	2	0	0	0	2
Engineer	3	3	1	0	7
Technical	17	17	0	2	36
					49 FTEs

Activity 2.7 USB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	2	1	0	0	3
Secretary/ Records	1	1	0	0	2
Engineer	3	3	1	1	8
Technical	8	6	4	3	21
					34 FTEs

Table 5.1: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.8 ESB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Secretary/ Records	1	0	0	0	1
Firefighters	4	4	4	4	16
Paramedic	2	2	2	2	8
					26 FTEs

Totals for Activity 2.0 Operations

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	19	11	1	0	31
Secretary/ Records	12	6	0	0	18
Engineer	38	29	11	12	90
Technical	124	110	17	32	283
Guards	8	8	6	2	24
Firefighters	4	4	4	4	16
Paramedic	2	2	2	2	8
					470 FTEs

Table 5.2: Personnel Staffing for Operations by Shift for the High Temperature Shielding Manufacturing Facility (HTSMF)

Activity 2.1 Admin & Tech. Support

Activity 2.1.1 Plant Management

Shift	1	2	3	4 (Spare)	Total
Manager	1 (GM)	1	0	0	2
Exec. Sec.	1	1	0	0	2

Activity 2.2.2 Technical Services

Activity 2.1.2.1 Engineering

Shift	1	2	3	4 (Spare)	Total
Manager	1	0	0	0	1
Secretary/ Records	1	1	0	0	2
Engineer	4	3	1	2	10
Technical	4	3	1	2	10

Activity 2.1.2.2 Analytical and Chemistry Services

Shift	1	2	3	4 (Spare)	Total
Manager	1	0	0	0	1
Secretary/ Records	1	1	0	0	2
Engineer	4	2	2	2	10
Technical	4	2	2	2	10

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Activity 2.1.3 Administration Services

Activity 2.1.3.1 Computers, Graphics, and Communications

Shift	1	2	3	4 (Spare)	Total
Manager	1	0	0	0	1
Secretary/ Records	1	0	0	0	1
Engineer	4	2	0	1	7
Technical	4	2	0	1	7

Activity 2.1.3.2 Plant Access and Security

Shift	1	2	3	4 (Spare)	Total
Manager	1	1 (Supervisor)	1 (Supervisor)	0	3
Secretary/ Records	1	0	0	0	1
Security					
Front Gate	2	2	2	1	7
Controlled Gate	2	2	2	1	7
RVSB	2	2	1	0	5
MPB	2	2	1	0	5

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Activity 2.1.3.3 Procurement and Shipping/Receiving (in GWSB)

Shift	1	2	3	4 (Spare)	Total
Manager	1	1	0	0	2
Secretary/ Records	1	1	0	0	2
Procurement/ Engineer	3	1	0	0	4
Technical (GWSB)	6	4	0	0	10

Activity 2.1.3.4 Health Physics (in HPRACB)

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Secretary/ Records	1	1	0	0	2
HP-Engineering	4	2	1	0	7
HP-Techs	10	5	5	2	22

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Totals for Activity 2.1 Admin & Tech. Support

Shift	1	2	3	4 (Spare)	Total
Manager	7	4	1	0	12
Secretary/ Records	7	5	0	0	12
Engineering	19	10	4	5	38
Technical	28	16	8	7	59
Guards	8	8	6	2	24
					145 FTEs

Activity 2.2 MPB

Activity 2.2.1 Main Control Room

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	4	4	1	2	11

Activity 2.2.2 Receiving and Storage Areas

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Engineer/ Operator	2	2	0	1	5
Technician	2	2	0	1	5

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Activity 2.2.3 Depleted Uranium Metal Melting and Casting Areas

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	2	2	0	0	4
Engineer/ Operator	4	4	1	1	10
Technician	11	11	1	3	26

Activity 2.2.4 Final Assembly, QC, and Shipping Areas

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	2	2	1	1	6
Technician	5	5	0	2	12

Totals for Activity 2.2 MPB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	5	4	0	0	9
Engineer/ Operator	12	12	3	5	32
Technical	18	18	1	6	43
					84 FTEs

Table 5.2: Personnel Staffing for Operations by Shift for the LTSMF (continued)

Activity 2.3 SCPSB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Engineer/ Operator	1	1	0	0	2
Technical	3	3	0	1	7
					10 FTEs

Activity 2.4 SCAB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	1	0	0	2
Engineer/ Operator	3	3	1	1	8
Technical	43	43	2	10	98
					108 FTEs

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Activity 2.5 RSB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Secretary/ Records	1	0	0	0	1
Engineer	0	0	0	0	0
Technical	4	4	0	0	8
					10 FTEs

Activity 2.6 WMB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	2	2	0	0	4
Secretary/ Records	2	0	0	0	2
Engineer	3	3	1	0	7
Technical	17	17	0	2	36
					49 FTEs

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Activity 2.7 USB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	2	1	0	0	3
Secretary/ Records	1	1	0	0	2
Engineer	3	3	1	1	8
Technical	8	6	4	3	21
					34 FTEs

Activity 2.8 ESB

Shift	1	2	3	4 (Spare)	Total
Manager/ Supervisor	1	0	0	0	1
Secretary/ Records	1	0	0	0	1
Firefighter	4	4	4	4	16
Paramedic	2	2	2	2	8
					26 FTEs

Table 5.2: Personnel Staffing for Operations by Shift for the HTSMF (continued)

Total for Activity 2.0 - Operations

Shift	1	2	3	4 (Spare)	Total
Manager	20	12	1	0	33
Secretary/ Records	12	6	0	0	18
Engineer	41	32	10	12	95
Technical	121	107	15	29	272
Guards	8	8	6	2	24
Firefighter	4	4	4	4	16
Paramedic	2	2	2	2	8
					466 FTEs

Figure 5.1: Overview of LTSMF Construction Workforce

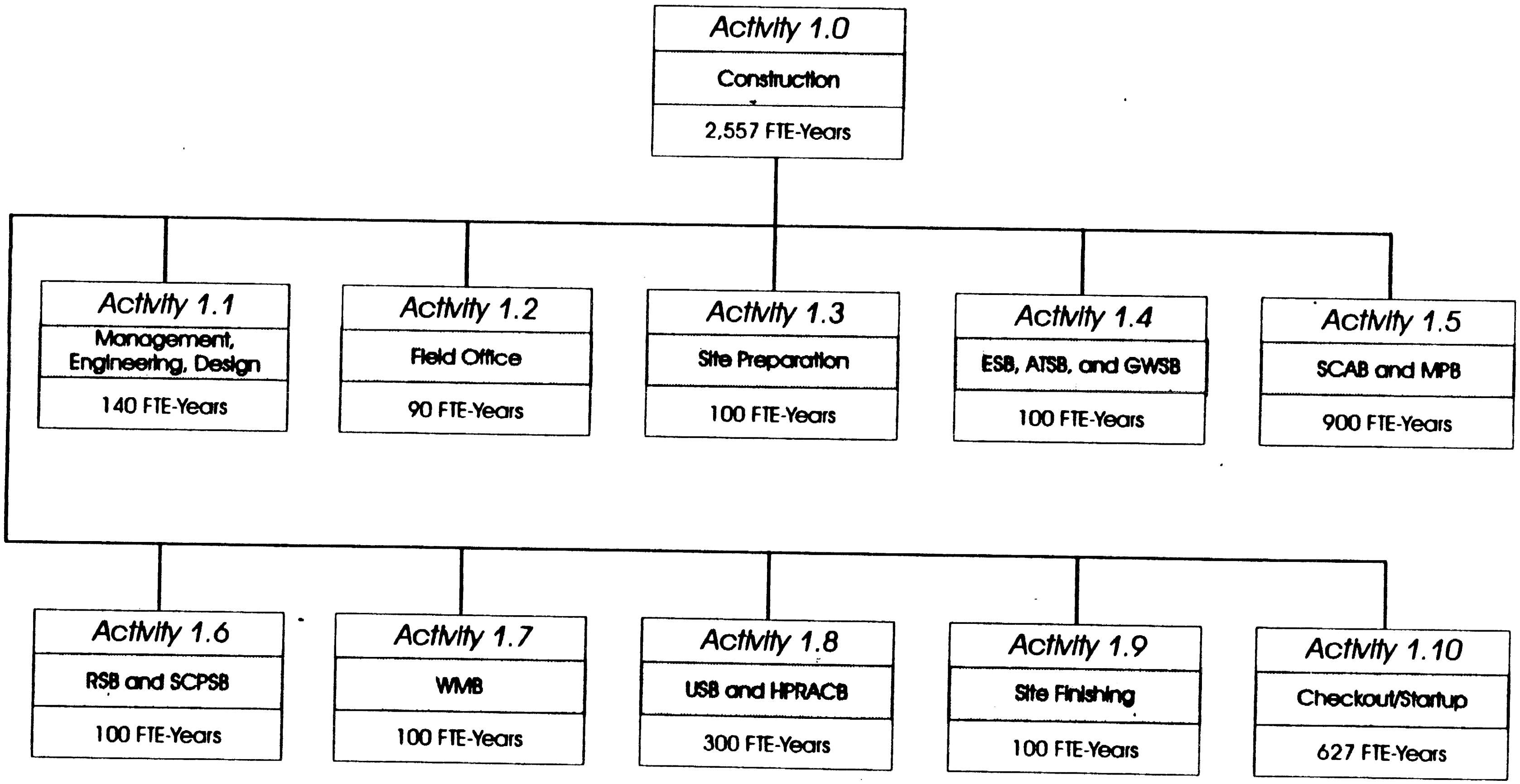


Figure 5.2: Overview of Construction Workforce for the High Temperature Shielding Manufacturing Facility (HTSMF)

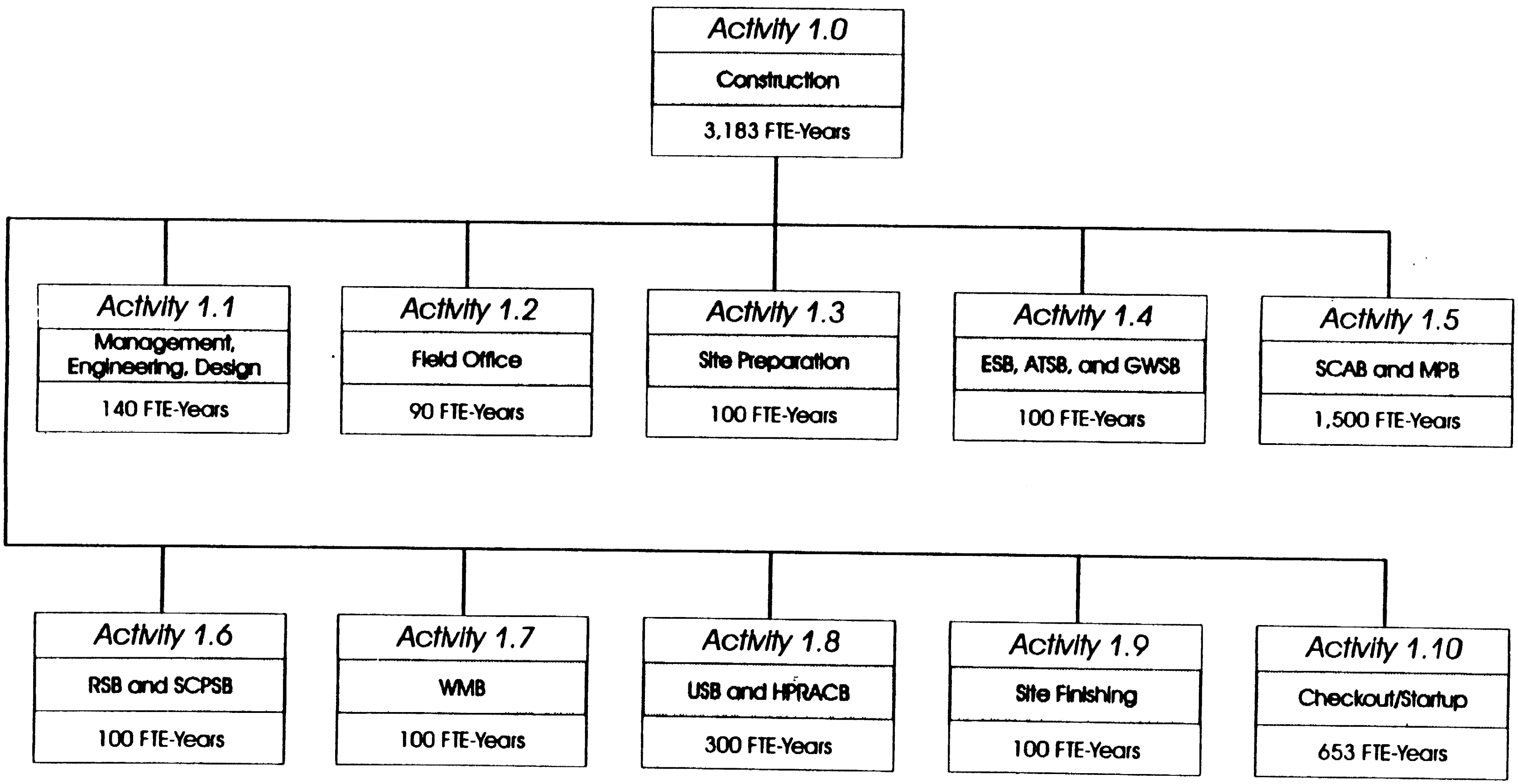


Figure 5.3: Overview of Plant Staffing and Organization at 100% Capacity of the LTSMF (in FTEs)

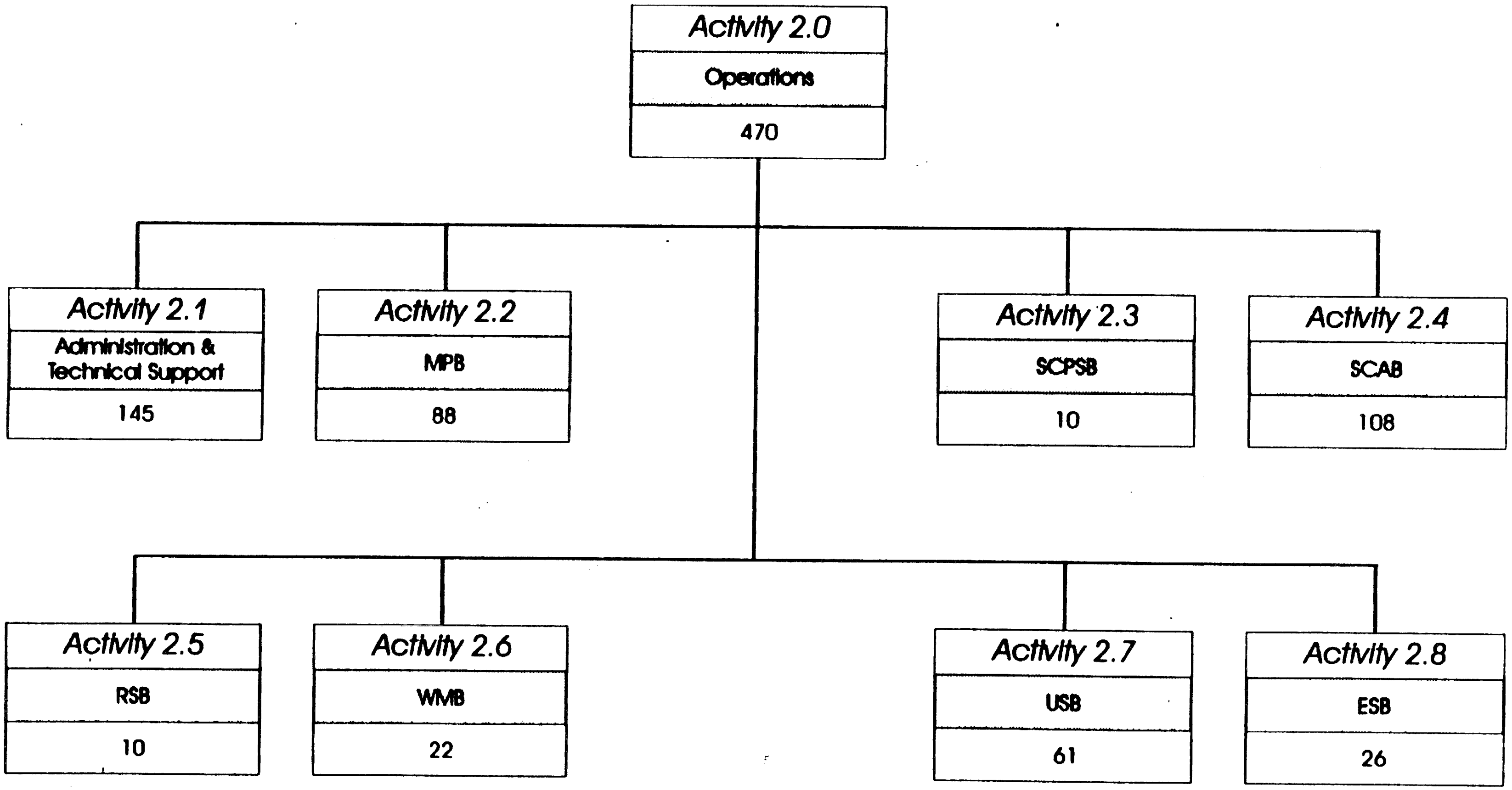
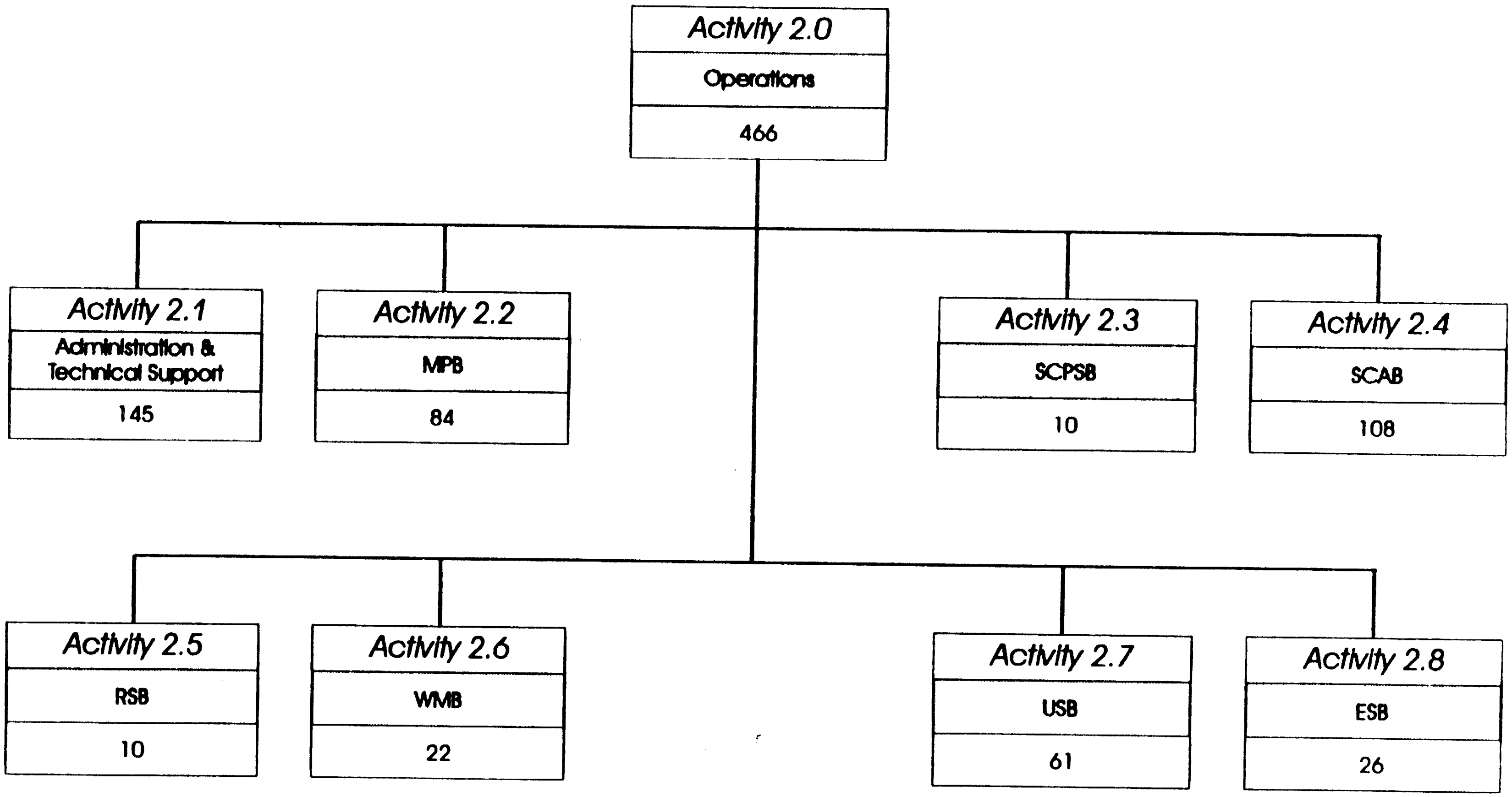


Figure 5.4: Overview of Plant Staffing and Organization at 100% Capacity of the HTSMF (in FTEs)



6.0 FACILITY WASTES AND EMISSIONS

6.1 Estimates of Wastes and Emissions Generated During Construction

6.1.1 LTSMF-Depleted Uranium Concrete (DUCRETE™) Shielding

6.1.1.1 Estimates of Emissions to the Atmosphere

Heavy construction is a source of pollutants that may have temporary adverse impact on local air quality. Emissions released during facility construction are associated mostly with land clearing, blasting, ground excavation, fill operations, and construction itself. Emissions vary substantially from day to day depending on the level of activity, the specific operation, and the prevailing weather conditions.

Air quality regulations have been established by Federal and state agencies to protect the public health from the harmful effects of air pollution. The Clean Air Act established primary National Ambient Air Quality Standards (NAAQS) for several pollutants, including carbon monoxide, hydrocarbons, nitrogen dioxide, sulphur dioxide, and particulate matter. These pollutants are known as criteria air pollutants. The NAAQS define the ambient concentration below which no adverse impact to human health is expected. A listing of the NAAQS for these criteria air pollutants is provided in table 6.1.

To estimate emissions from various sources of air pollution, the U.S. Environmental Protection Agency (EPA) has developed emission factors. During facility construction, vehicle exhaust and fugitive dust can be expected to cause air pollution. The approximate emissions factor for heavy-construction equipment exhaust is based on engine type and annual operating time. Table 6.2 presents the total emissions estimates for the criteria air pollutants that would be released during construction operations.

The approximate emission factor for construction operations is expressed per acre of construction per month of activity. Facility construction is expected to disturb 21 ha (53 acres) of land at most. Using this emissions factor, the annual quantity of fugitive dust emissions from facility construction would be about 1 ton annually.

The emissions estimates represent the maximum expected values during facility construction. The implementation of control methods can significantly reduce these quantities and thereby lessen their environmental impact. For example, watering is often selected as a control method to reduce fugitive dust emissions. According to the EPA, an effective watering program (that is, twice daily watering with complete coverage) is estimated to reduce dust emissions caused by up to 50 percent.

6.1.1.2 Estimates of Effluents to the Surface Waters

Local hydrology and storm water management specific to a site may result in effluents. The potential impacts of site preparation and construction on local hydrology can be expected to include changes in the flow rate and direction of surface water, in the elevation and flow direction of groundwater beneath the site, and in the quality of surface water and groundwater. Site preparation and construction activities such as excavation and filling for a facility foundation, parking lots, and storage yards may alter the topography of the site. Changes in the amount of infiltration and runoff of surface water and effects on drainage patterns are expected. The usual clearing of site vegetation and the movement of construction equipment tends to compact site soils, decreasing infiltration, and increasing both runoff and possible soil erosion. Surface waters could experience increased sedimentation during normal precipitation and storm events. Actual local conditions will contribute to variations in this potential effect. Techniques for minimizing soil erosion during construction, such as dikes, beams, silt fences, quick revegetation of exposed soils, and sediment traps, should be considered.

During site preparation and construction, the potential also exists for impacts to surface waters as a result of fuel or oil spills from heavy-construction equipment and any tank failures from onsite storage or transport of fuels. Quantities of these potentially hazardous liquids stored and transported during construction should be kept as small as possible and a spill contingency plan meeting the National Pollution Discharge Elimination System (NPDES) permit for storm water discharges from construction sites would need to be developed. The implementation of best management practices to control surface runoff and sedimentation would ensure the protection of wetlands and aquatic ecosystems during construction.

6.1.1.3 Waste Generation Estimates

6.1.1.3.1 LLW

There will be no LLW generated during construction of the LTSMF for two reasons. First, no radioactive materials are used during construction; second, the generic site is noncontaminated.

6.1.1.3.2 Radioactive Mixed Waste (RMW)

There will be no RMW generated during construction.

6.1.1.3.3 Hazardous Wastes

Table 6.3 estimates hazardous wastes generated during construction of the LTSMF and provides treatability categories for secondary waste streams. These would be sent to disposal using existing, commercial disposal avenues.

6.1.1.3.4 Other Wastes (Construction Plus Sanitary Wastes)

Uncompacted, conventional (construction plus sanitary) waste is estimated at 60 ML.

6.1.2 HTSMF-Depleted Uranium Metal Shielding

6.1.2.1 Estimates of Emissions to the Atmosphere

Table 6.4 estimates emissions due to construction of the HTSMF. The estimates use the same EPA protocols.

6.1.2.2 Estimates of Effluents to the Surface Waters

No direct effluents are anticipated during construction at the generic site. As with the LTSMF, site-specific conditions may produce effluents that require management and mitigation.

6.1.2.3 Waste Generation Estimates

6.1.2.3.1 LLW

As with the LTSMF, construction assumes a greenfield site and does not use radioactive materials, therefore, no LLW is generated.

6.1.2.3.2 RMW

There will be no RMW generated during construction.

6.1.2.3.3 Hazardous Wastes

Table 6.5 estimates hazardous wastes generated during construction of the HTSMF and provides treatability categories for secondary waste streams. These are slightly greater than the LTSMF values due to the larger MPB.

6.1.2.3.4 Other Wastes

Uncompacted, conventional waste is estimated at 70 ML.

6.2 Estimates of Wastes and Emissions Generated by Routine Operations

6.2.1 LTSMF Depleted Uranium Concrete (DUCRETE™) Shielding

6.2.1.1 Estimates of Emissions to the Atmosphere

Tables 6.6 and 6.7 estimate emissions from routine operations of the LTSMF. All of the HEPA exhausts are on the roofs of the buildings, and are considered general area sources. The MPB processes uranium dioxide with mean sizes of 300 microns or more at the rate of 21,477 te/yr. The operations that potentially generate emissions are:

- Emptying of the drums
- Charging (filling) of the mixers
- Discharging of the mixers into the cask annulus
- Curing of the DUCRETE™

Emptying the drums (e.g., by vacuum/conveyor methods), with an airborne release fraction of 10^{-7} and a HEPA efficiency of 99.9 percent, results in a potential annual emission of 2.16 g. Charging of the mixers results in an equivalent emission. The discharging operation should have a lower release fraction (the uranium dioxide has been agglomerated within the grout), but as a bounding approximation, 2.16 g is assumed. DUCRETE™ curing is not expected to generate any emissions because the uranium dioxide has a high density, the macroscopic sizes are large, the surface area is limited, there is no material transfer/movement, and the annulus has a temporary cap/seal during curing. Therefore, the total MPB emission becomes 6.48 g per year.

The WMB performs seven operations with the potential for uranium releases: sorting, compaction, packaging, wet and dry decontamination, and two solidifications. Section 1 has generated rough, order of magnitude estimates for the uranium content of the waste streams. The uranium content is expected to be below 1 percent of the annual throughput. However, using 10 percent as an absolute upper bound (i.e., 2,160 te/yr) and an airborne release fraction of 1×10^{-7} (i.e., dense, macroscopic uranium dioxide), the internal release per operation becomes 216 g/yr. For seven operations in an area with HEPA filtration, the environmental release term is 1.5 g/yr. The RSB handles the solidified LLW from the WMB. No routine uranium releases are anticipated because the waste is encapsulated and the containers are sealed. The uranium content of DAW varies considerably. Personal protective equipment (PPE) and DAW generally have low concentrations (hundreds of ppm) of uranium, while absorbents and swipes might have over 1,000 ppm of uranium. Using 1,000 ppm uranium as the basis, the uranium in the DAW becomes 800 kg. Maintenance activities at the USB may also generate uranium emissions. Assuming 1 percent of the annual throughput as the maximum inventory, an airborne release fraction of 1×10^{-7}, HEPA filtration, and on average, four operations, the annual uranium release becomes 0.1 g. The total annual emission of uranium is estimated to be 8 g.

Emissions from diesel generators are not regulated by the EPA due to the fact that they are minimal. Therefore, emissions from the backup generators were assumed to be negligible for the purposes of this report.

6.2.1.2 Estimates of Effluents to the Surface Waters

No process effluents are anticipated. Storm water effluents would occur and be determined as part of a more detailed design phase.

6.2.1.3 Waste Generation Estimates

6.2.1.3.1 LLW

Table 6.8 estimates LLW generation and provides treatability categories of secondary waste streams. The largest volume of waste comes from the DAW, and it contains approximately 800 kg of uranium. The greatest contribution to the uranium in the waste comes from removed and failed equipment. In particular, the broken mixers contain DUCRETE™, which has around 8 te of uranium. All of the radwaste is categorized as LLW Class A by the NRC, and should be suitable for near-surface disposal. Approximately 500 drums/yr are shipped to disposal. At the end of the SNF storage period, the SNF is removed, and the empty DUCRETE™ shielding assemblies sent to LLW disposal. As a first approximation, the uranium concentration is 200,000 p Ci/g for the empty DUCRETE™ casks. This is still Class A LLW, but it may require disposal in a special cell or a mined cavity. The disposal volume of the casks exceeds the manufacturing facility's LLW generation over its entire 20-year operating period.

6.2.1.3.2 RMW

No RMW will be generated by LTSMF operations.

6.2.1.3.3 Hazardous Wastes

Hazardous wastes generated over the 20-year lifetime of the LTSMF are expected to be around four times the values in table 6.3.

6.2.1.3.4 Sanitary Wastes

Approximately 250 te of sanitary waste would be generated annually and sent to commercial landfills.

6.2.2 HTSMF-Depleted Uranium Metal Shielding

6.2.2.1 Estimates of Emissions to the Atmosphere

Tables 6.9 and 6.10 present estimates of emissions from the HTSMF. All of the HEPA exhausts are located on the roofs of the buildings and are considered general area sources. The MPB at the HTSMF processes uranium metal billets at a rate of 19,516 te/yr. The uranium handling operations involved are:

- Breakdown of the pallets and opening of the billet boxes
- Inspection of the billets
- Charging (filling) of the furnaces
- Discharging of the furnaces into the cask annulus (casting)
- Cooling of the uranium metal
- Additional heat treatments and machining

For the first three operations, the 1mm thick oxide layer with an airborne release fraction of 1.75 x 10^{-4} is assumed (see section 7). With a single HEPA filter, a decontamination factor of 1 x 10^{-3} results, producing a 47 g/yr emission rate (as U_3O_8). For the purpose of these calculations, it was assumed that the different uranium forms have similar particle sizes. Furnace discharging involves molten uranium metal, with a higher airborne release fraction of 6 x 10^{-3}. Using two HEPA filters, a decontamination factor of 2 x 10^{-6} results, the annual emission becomes 3.2 g as U_3O_8. The same exposed volume is assumed. No emissions are anticipated from the cooling step because the surface area is limited, there is no material transfer/movement, and a temporary cap/seal is attached. Additional heat treatments and machining are necessary even with direct casting of the uranium metal. These involve the exposure of a small fraction of the uranium metal (at most, 1 percent). Using the oxide layer airborne release fraction of 1.75 x 10^{-4} and two HEPA filters, the emission becomes less than 1 g/yr, while the emissions from the MPB total 50 g/yr. Both releases are in the form of U_3O_8. The RSB stores solidified radwaste, and thus, its routine uranium releases are zero. The existing plant data imply uranium losses of a few percent to the radwaste. Using 1 percent of the uranium inventory as the maximum for maintenance, and an average of four operations, the USB releases become less than 1 g as U_3O_8.

As in the LTSMF, the HTSMF's WMB performs seven operations: sorting, compaction, packaging, wet and dry decontamination, and two solidifications. The uranium content of the waste is expected to be below 5 percent of the plant's annual throughput. Using 10 percent as an absolute upper bound, an airborne release fraction of 1.75 x 10^{-4}, a HEPA efficiency of 99.9 percent, and seven operations, the WMB emissions rate becomes less than 1 g/yr as U_3O_8.

The HTSMF emissions are considerably higher than the LTSMF releases. These values would be verified in a more detailed design phase, and if required, mitigating design features would be added. These might include double banks of HEPA filters for selected areas that reduce emissions by about two orders of magnitude below the table 6.9 values.

6.2.2.2 Estimates of Effluents to the Surface Waters

There are no process effluents to the surface waters.

6.2.2.3 Waste Generation Estimates

6.2.2.3.1 LLW

Table 6.11 estimates LLW generation and provides treatability categories of secondary waste streams. As in the LTSMF, the largest volume of waste occurs from the DAW. The DAW consists primarily of PPE, swipes, and spent graphite linings, all containing uranium. In particular, the spent graphite linings are expected to contain uranium metal inclusions and globules. Operations in the MPB release about 1650 kg/yr uranium to the HEPA filters. Clearly, avoidance of uranium losses to the waste has tremendous benefits. Ultimately, the depleted uranium metal cask is sent with the SNF to disposal in the Federal Repository. This volume is approximately 180 ML. However, thermal properties of the SNF determine repository size, and current estimates indicate no volume effect from using depleted uranium shielding.

6.2.2.3.2 RMW

No RMW will be generated by HTSMF operations.

6.2.2.3.3 Hazardous Wastes

Hazardous wastes generated over the lifetime of the HTSMF are expected to be four times the values in table 6.5.

6.2.2.3.4 Other Wastes

Approximately 300 te of sanitary waste would be generated annually and sent to commercial landfills.

Table 6.1: National Ambient Air Quality Standards (NAAQS) for Criteria Air Pollutants

Criteria Air Pollutant	Averaging Time	Primary Standard ($\mu g/m^3$)
Carbon monoxide (CO)	1-hour[b] 8-hour[b]	40 mg/m^3 10 mg/m^3
Hydrocarbons (HC)	3-hour	160
NOx (as N_2O)	Annual	100
SO_X (as SO_2)	24-hour[b] Annual	365 80
Particulate matter[a]	24-hour[b] Annual	150 50

a. Refers to respirable particulate matter (measuring less than 10 microns in size)
b. Not to be exceeded more than once a year

Ref: 40 CFR § 50.0 et seq.

Table 6.2: Total Air Emissions from Construction of the Low Temperature Shielding Manufacturing Facility (LTSMF)

Potential Air Pollutant	Total Average Emissions (ton)
SO_2	15.2
NOx	234
NMHC'S	19.2
CO	50.0
PM-10	16.8

Table 6.3: Wastes Generated During Construction of the LTSMF and Treatability Categories of Secondary Waste Streams

Hazardous	L	kg	Treatability Category
Paints, thinners, solvents	64,000	64,000	Hazardous Organic (Liquid) Waste
Phenol	1,600	1,000	Hazardous Organic (Liquid) Waste
Mercury (lamps)	765	10	Compressed Gas
Sulfuric Acid	800	800	Other Hazardous Waste
Naphtha	2,200	1,600	Other Hazardous Waste
Lead (batteries)	N/A	180	Batteries
Pesticides	2,200	1,800	Other Hazardous Waste
Totals	71,565	69,410	N/A

Uncompacted, Conventional Waste: 60×10^6 L

Table 6.4: Total Air Emission from Construction of the High Temperature Shielding Manufacturing Facility (HTSMF)

Potential Air Pollutant	Total Average Emissions (ton)
SO_2	16.4
NO_x	250
NMHC'S	20.4
CO	53.2
PM-10	17.2

Table 6.5: Wastes Generated During Construction of the HTSMF and Treatability Categories of Secondary Waste Streams

Hazardous	L	kg	Treatability Category
Paints, thinners, solvents	70,000	70,000	Hazardous Organic (Liquid) Waste
Phenol	1,800	1,100	Hazardous Organic (Liquid) Waste
Mercury (lamps)	830	11	Compressed Gas
Sulfuric Acid	900	900	Other Hazardous Waste
Naphtha	2,400	1,800	Other Hazardous Waste
Lead (Batteries)	N/A	200	Batteries
Pesticides	2,400	2,000	Other Hazardous Waste
Totals	79,530	77,011	N/A

Uncompacted, Conventional Waste: 70 x 10^6 L.

Table 6.6: Emissions Points and Flow Information for LTSMF Operations

Building	Exhaust, m^3/min (SCFM)	Number of Exhaust Points	Height, m (ft)	Exhaust Velocity, m/sec (ft/sec)	Stack Diameter, m (ft)	Annual Uranium Release, g UO_2*
MPB All Areas	2,500 (88,000)	21	18.3 (60)	3 (10)	0.91 (3)	6.5
WMB	1,700 (61,000)	14	12 (40)	3 (10)	0.91 (3)	1.5
RSB	1,800 (62,000)	15	9.1 (30)	3 (10)	0.91 (3)	0
USB	3,500 (125,000)	30	12 (40)	3 (10)	0.91 (3)	0.1
Totals	9,800 (350,000)	80	(N/A)	(N/A)	(N/A)	8

* Composition is 0.001% U-234, 0.25% U-235, and 99.75% U-238, with a specific activity of 4×10^{-7} Ci/g.

Table 6.7: Annual Air Emissions During Operations of the Low Temperature Shielding Manufacturing Facility (LTSMF)

Potential Air Pollutant	Total Annual Average Emissions (ton/yr)
SO_2	0.16
NO_x	3.15
NMHC'S	0.21
CO	0.91
PM-10	0.19

Table 6.8: Radioactive Waste Estimates from LTSMF Operations (Annual Basis) and Treatability Categories of Secondary Waste Streams

Stream Description	Treatment	Initial Volume, L/yr (ft^3/yr)	Final Volume, L/yr (ft^3/yr)	Uranium Dioxide Content, kg	55-gallon drums (#)	Treatability Category
Facility Waste	Compaction	13,000 (460)	3,900 (140)	< 100	21	Combustible Non-Compactible Solid (LLW)
Facility Waste	Cement Solidification	13,000 (460)	39,000 (1,380)	7,560	206	Non-Combustible, Non-Compactible Solid (LLW)
HEPAs	Boxing	25,000 (880)	25,000 (880)	6	16 (boxes)	Non-Combustible Compactible Solid (LLW)
Activated Carbon	Drumming	2,000 (70)	2,000 (70)	< 1	11	Organic Solid (LLMW)
DAW*	Compaction	532,766 (18,820)	53,280 (1,880)	800	282	Combustible Solid (LLW)
Ion Exchange Resins	Dewater/Drum	2,800 (100)	2,800 (100)	< 1	15	Organic Solid (LLW)
Total	(N/A)	588,566 (20,790)	125,977 (4,450)	8,468	534	N/A
DUCRETE™ Casks	None-Direct Disposal	73.6 ML (2.6 M ft^3) Total**	N/A	432 x 10^6 (Total)	N/A	N/A

* includes PPE and swipes
** corresponds to disposed casks over the 20 year life of the facility

Table 6.9: Emissions Points and Flow Information for HTSMF Operations

Building	Exhaust, m^3/min (SCFM)	Number of Exhaust Points	Height, m (ft)	Exhaust Velocity, m/sec (ft/sec)	Stack Diameter, m (ft)	Maximum Annual Uranium Release, g U_3O_8*
MPB						
Furnace Areas:	255 (9,000)	1	30 (100)	3 (10)	1.3 (4.4)	3
All Others	2,795 (99,000)	23	18.3 (60)	3 (10)	0.91 (3)	47
WMB	1,700 (61,600)	14	12 (40)	3 (10)	0.91 (3)	< 1
RSB	1,800 (62,000)	15	9.1 (30)	3 (10)	0.91 (3)	0
USB	3,500 (125,000)	30	12 (40)	3 (10)	0.91 (3)	< 1
Totals	10,050 (360,000)	84	(N/A)	(N/A)	(N/A)	~ 50

* Composition is 0.001% U-234, 0.25% U-235, and 99.75% U-238, with a specific activity of 4×10^{-7} Ci/g. All metal particles are assumed to oxidize to U_3O_8.

Table 6.10: Annual Air Emissions from High Temperature Shielding Manufacturing Facility Operations (HTSMF)

Potential Air Pollutant	Total Annual Average Emissions (ton/yr)
SO_2	0.16
NO_x	3.59
NMHC'S	0.22
CO	1.13
PM-10	0.21

Table 6.11: Radioactive Waste Estimates from HTSMF Operations (Annual Basis) and Treatability Categories of Secondary Waste Streams

Stream Description	Treatment	Initial Volume, L/yr (ft^3/yr)	Final Volume, L/yr (ft^3/yr)	Maximum Annual Uranium Content, kg U_3O_8	55-gallon drums (#)	Treatability Category
Facility Waste	Compaction	13,000 (460)	3,900 (140)	< 100	21	Non-Combustible Non-Compactable Solid (LLW)
Facility Waste	Cement Solidification	13,000 (460)	39,000 (1,380)	< 100	206	Non-Combustible, Non-Compactable Solid (LLW)
HEPAs	Boxing	25,000 (880)	25,000 (880)	1,650	16 (boxes)	Non-Combustible Compactable Solid (LLW)
Activated Carbon	Drumming	2,000 (70)	2,000 (70)	< 1	11	Organic Solid (LLW)
DAW*	Compaction	528,232 (18,650)	52,823 (1,870)	800	279	Combustible Solid (LLW)
Graphite (DAW)	Drumming	526,244 (18,580)	526,244 (18,580)	1,400	2,781	Combustible Solid (LLW)
Ion Exchange Resins	Dewater/Drum	2,800 (100)	2,800 (100)	< 1	15	Organic Solid (LLW)
Total	(N/A)	1,110,276 (39,210)	651,767 (23,020)	< 4,000	3,312	N/A

* includes PPE and swipes

7.0 DESCRIPTIONS OF POTENTIAL ACCIDENTS

The different depleted uranium shielding manufacturing facilities have a common radiological source that influences the nature and type of accident analyses. The only source of radiological accidents is the presence of depleted uranium in one of two chemical forms: uranium metal (U) and UO_2 pellets. Detailed analyses of postulated releases of uranium in NUREG-1140 for nuclear fuel fabrication plants have shown that the chemical toxicity of uranium is much greater than any dose rate associated with the radiation emitted by the uranium. Specifically, a chemically toxic lethal exposure from uranium would occur with a radiation dose of no more than 1 rem, which is not considered to have any significant health effects. Therefore, the accident analyses for a depleted uranium shielding manufacturing facility will deal principally with the calculation of uranium air concentration or intake resulting from postulated releases. However, it should also be noted that 10CFR20, 40CFR61, and 40CFR190 set specific public radiation dose standards that limit routine operational releases of radioactive material.

7.1 Regulatory Analysis of Generic Nonradiological Accidents at Cask Manufacturing Facilities

7.1.1 Depleted Uranium Concrete (DUCRETE™) Low Temperature Shielding Manufacturing Facility (LTSMF)

Depleted uranium is expected to be delivered to the LTSMF in 30-gallon drums, which would contain 667 kg of UO_2 pellets each. When delivered to the plant site, the drums are immediately placed inside a storage building equipped with a HEPA filtration system. All processing of the material from the drums is performed inside buildings with HEPA filtration systems. The HEPA systems are assumed to be nuclear safety grade.

UO_2 is an inert chemical form of depleted uranium with a melting point of 4440 °F (2449 °C) (McLain, 1964). UO_2 is a ceramic material that was selected for commercial light water reactor (LWR) fuel designs because of its non-reactive chemical properties.

The ability of UO_2 particles to become airborne in an accident is an important factor in calculating the health effects of postulated accidents that release depleted uranium to the environment. Particles can become airborne due to a force that propels them, such as an explosion. For particles greater than 1 micron in diameter to remain airborne, the air flow drag force must be equal to or greater than the gravitational force. Calculations of the required minimum air velocity as a function of particle diameter (Slade, 1968) show that an air velocity of 10 to 50 mph (15 to 75 ft/s) is required to maintain the UO_2 particles airborne. Although these velocities are possible, they would coincide with an atmospheric dispersion that would greatly dilute the concentration of uranium.

Another important parameter in evaluating accident consequences for the UO_2 shielding material is the respiratory intake of particles. Established data and models used in the nuclear industry (ICRP,

1987) show that particles greater than 10 microns in diameter are retained in the nasal region, if they can even be inhaled, and subsequently released from the nasal region with little residence time. Therefore, the presence of particles with a diameter greater than 10 microns will not pose any inhalation health hazard. It is important to note that inhalation is the primary means by which uranium particles would be expected to pose a toxic hazard.

The UO_2 shielding material is capable of direct release to the environment only during two phases of the plant operation: (a) arrival of the 30-gallon drums, and (b) shipment of completed shielding structures from the plant. As previously discussed, the chemical form and size of the UO_2 is inherently stable, nonreactive, and extremely difficult to be introduced into the respiratory or digestive system. Since there is no external toxic chemical hazard from this depleted uranium, the only means of posing a health effect is to transform the UO_2 into particles less than 10 microns in diameter.

Extremely high temperatures (i.e., > 4440 °F) and/or an explosion could result in converting the shielding into a respirable or ingestible form. Using data from gas/oil fire gases in a furnace, the American Society for Testing and Materials (ASTM) developed a standard temperature-time curve with a peak flame temperature of 2300 °F (Drysdale, 1985). This curve is used in the qualification of fire resistant components. By comparison, any fire temperature would be more than 2,000 degrees less than the melting points of the UO_2. Therefore, while a fire could distort or increase particle size by surface oxidation, it is unlikely to cause size attrition resulting in fine particles and releases of uranium to the environment. This would have to be verified by specific analyses and testing as part of the licensing process.

A sufficiently powerful explosion could transform the UO_2 into respirable particles. However, there is no source of explosive material expected at this plant, including the outside receipt and shipping areas. Therefore, for direct environmental release, the chemical form of the UO_2 precludes any release due to fire, and the lack of explosive materials eliminates an explosion as a source of release.

The other postulated accident outside the plant buildings involves the mishandling (i.e., drum drop or impact) of the UO_2 drums or finished shielding. Any mishandling would, at the worst, cause the drum wall to rupture and release its contents of UO_2. As previously discussed, the chemical form and particle size of the UO_2 precludes it from being dispersed in the atmosphere and inhaled. Therefore, there would be no health effects from rupturing any drums of UO_2.

Inside the plant, the UO_2 would either be combined into DUCRETE™ using a mixer, or, if a carbon mixture was selected for the shielding, combined with resin materials and heated to a temperature between 200 and 300 °C. Neither of these two manufacturing operations provide the potential for any accidents involving the introduction of sufficient energy to release the UO_2 into the environment in the form of respirable particles.

The final form of the UO_2 would be within stainless steel-lined shielding structures. This welded steel outer container provides another layer of confinement beyond the chemically inert form of the depleted uranium.

7.1.2 Depleted Uranium Metal High Temperature Shielding Manufacturing Facility (HTSMF)

Depleted uranium is expected to be delivered to the HTSMF as billets, each weighing about 34 kg. The billets are contained within wooden boxes. Four boxes are loaded onto each pallet, providing a total net weight of 2.5 - 2.9 te uranium per pallet (see section 8). This analysis assumes 3 te as the uranium handling quantity. When delivered to the plant, the palletized billets are immediately placed inside a storage building equipped with a HEPA filtration system.

Unlike UO_2, metallic uranium is a chemically reactive material that readily oxidizes in air, water, or steam, and should not be exposed to most reagents. At room temperature air exposure, massive uranium (i.e., billets) tarnishes, but further oxidation continues. Finely divided uranium spontaneously ignites at room temperature and massive uranium burns steadily at 1292 °F (Benedict, 1981). Water contact with uranium metal results in disintegration of the metal and the evolution of heat. In the molten state, uranium metal would react explosively to the introduction of any water. The melting point of pure uranium metal is 2070 °F, but the metal changes phases at 1220 °F and 1400 °F (McLain, 1964; Benedict, 1981).

DOE-Handbook-3010-94 states that hyperstoichiometric UO_2 formed at the metal-to-atmosphere interface is adhering and limits oxygen availability. At temperatures less than 200 °C, the hyperstoichio metric dioxide, UO_{2+x}, is the principal product. At slightly higher temperatures, a mixture of various suboxides (e.g., U_3O_7 and U_3O_8) are found. At temperatures greater than 275 °C, UO_2 and predominantly U_3O_8 are produced. In the temperature range of 350 °C to 600 °C, the UO_2 formed rapidly oxidizes to U_3O_8 and falls away as a fine black powder. In the temperature range of 650 °C to 850 °C, the UO_2 forms a protective layer, which at some point breaks away. At a temperature greater than 900 °C, the UO_2 is adherent and protective. The presence of water vapor accelerates oxidation in air at a temperature less than 300 °C and in carbon dioxide at temperatures between 350 °C and 500 °C. Uranium reacts with hydrogen, nitrogen, and carbon at elevated temperatures and the presence of surface inclusions accelerates oxidation.

Unlike plutonium, uranium is difficult to ignite. The presence of an adherent, protective layer of hyperstoichiometric dioxide at the interface limits oxygen availability. Also, the heats of reaction are lower. At surface to mass ratios less than 1.0 cm^2/g, the ignition temperature exceeds 500 °C and is increasing rapidly, indicating that large pieces of uranium are very difficult to ignite as large amounts of external heat must be supplied and serious heat loss prevented.

The particle size distributions of residual oxides produced under a variety of conditions have also been measured and are shown in the DOE-Handbook-3010-94. The distribution becomes coarser and the solubility in simulated lung fluid decreases as the temperature increases. Oxidation of the metal at less than 450 °C generated a fine, black, non-adherent powder. At temperatures around 535 °C, the oxide was a fine black powder sintered into lumps. At temperatures greater than 700 °C, the oxide appeared to be a hard black scale.

Based on the aforementioned chemical sensitivity of uranium metal, any exposure of the metal to water, steam, chemicals, fire, or an explosion is postulated to result in a significant chemical reaction and the concomitant release of respirable particles of uranium. A direct pathway to the environment for uranium exists during unloading and transfer of the ingots to the storage building and shipping of the finished shielding product out of the facility. It is assumed that the 3-te ingots arrive encased in a suitable container to isolate the uranium from the atmosphere and maintain it under an inert cover gas.

Accidents outside the plant buildings must result in a failure of the uranium billet container confinement barrier (i.e., the wooden box) to initiate an environmental release. A prolonged high-temperature fire, an explosion, or a significant mishandling of the billet container could result in a breach of the container's structural integrity. Container mishandling or a drop without any subsequent exposure of the uranium to water, high temperatures, or chemical reagents would not result in a release of respirable uranium particles to the environment. A fire or explosion that breached the container housing could initiate an exothermic chemical reaction in the uranium that would release respirable uranium particles, usually in the form of U_3O_8, to the atmosphere. As with the LTSMF, no explosion source outside the facility buildings is expected to exist.

For postulated accidents inside facility buildings, it is assumed that all buildings that contain uranium metal are equipped with nuclear safety grade HEPA filters with a minimum design particle removal efficiency of 99.9 percent. The possibility of an explosion inside the facility building cannot be discounted because of the presence of furnaces and the handling of molten uranium metal, which is highly susceptible to violent reactions if accidentally exposed to air or water.

7.1.3 Scoping Assessment of Accidents

To gain an understanding of the risks associated with the operation of a depleted uranium shielding manufacturing facility, a scoping assessment of the occurrence frequencies of six potential accidents has been conducted. The results of this assessment are shown in table 7.1. Details of the frequency estimation process are provided in the following sections.

Mishandling/Drop of UO_2 Drum or U-Metal Billet Container

Drums of UO_2 pellets for the LTSMF, or ingot containers of uranium metal for the HTSMF, are transported into the facility using a series of cranes and hoists. There is a potential that they may rupture if mishandled during transport. The probability of creating a leak from mishandling UF_6 cylinders is applied to handling drums and/or billet containers. This probability was calculated to be 1.1 x 10^{-5}/operation where an operation is defined as the handling of a cylinder, drum, or billet container while moving it from one location to another.

The containers are palletized. However, for uranium metal, the billets are contained in four wooden boxes per pallet, and these are handled as individual units. For UO_2, the analysis assumes a drum as the basic handling unit, even though each pallet contains four drums.

Using an annual production rate of 19,516 te of uranium metal or 21,477 te of UO_2, and 3-te metal ingot containers or 1.02-te UO_2 drums, the shielding manufacturing facility receipt rate is:

19,516 te/3 te per pallet = 6,505 metal pallets/yr, or

21,477 te/1.02 te per drum = 21,056 UO_2 drums/yr

Assuming that each drum (or pallet) is handled twice, once to unload the truck or rail car and once to move it into the facility building, the probability of a mishandling accident is:

6,505 pallets/yr x 2 operations/pallet x 1.1 x 10^{-5}/operation = 1.4 x 10^{-1}/yr

21,056 drums/yr x 2 operations/drum x 1.1 x 10^{-5}/operation = 4.6 x 10^{-1}/yr

The estimated frequency for ingot container mishandling at the HTSMF is 1.4 x 10^{-1}/yr and the estimated frequency for UO_2 drum mishandling at the LTSMF is 4.6 x 10^{-1}/yr.

For the LTSMF, the material at risk (MAR) contains approximately 667 kg (i.e., one drum). There are essentially no respirable particles (i.e., release fraction of 5 x 10^{-5}, based on DOE-HANDBOOK-0013-93). HEPA filtration is expected to remove 99.9 percent of the particles. Thus, the environmental release source term is 33 mg as uranium dioxide.

For the HTSMF, the material at risk contains approximately 3,000 kg (i.e., the entire pallet). Using a tarnish (oxide) layer 100 microns thick, a surface area of around 17,500 cm^2, and an oxide density of 3 g/cm^3, the release fraction becomes 1.75 x 10^{-4}. HEPA filtration removes 99.9 percent of the oxide particles. Consequently, the environmental release source term becomes 525 mg as U_3O_8.

Fire, Explosion, or Chemical Reagent Contact Inside the Facility

A detailed design would be needed to accurately calculate the frequency of a fire, explosion, or release of a chemical reagent that could cause a release of uranium particles inside the facility. It is likely that the initiator of such an accident would be the leak or rupture of a furnace, tank, or pipe. Some furnace, tank, and pipe rupture frequencies have been previously calculated for UF_6 processing to be from 5.8 x 10^{-6}/yr to 9.6 x 10^{-6}/yr. As a conservative estimate, because a pipe, tank, or furnace rupture or failure may not necessarily lead to a fire, explosion, or chemically induced uranium release, the largest of these frequencies, 9.6×10^{-6}/yr, is assumed for this accident in both the HTSMF and the LTSMF.

For the LTSMF, the maximum material at risk would be 4,000 kg (essentially two containers are charged to each mixer at any one time, and there are three mixers per unit). Again, the respirable release fraction is 5×10^{-5}. The HEPA filters are 99.9 percent efficient. The environmental source term would become 0.2 g as UO_2.

For the HTSMF, the maximum material at risk would be during the casting operation. Assuming a cask annulus nearly full with molten uranium, the material at risk would be 45,000 kg. Under the right conditions, this material would react spontaneously with the air, producing fine oxide particles. However, a maximum of about 1 percent of the material could escape from the narrow confines of the annulus into an area in which it could be violently oxidized. The respirable release fraction given for molten uranium in DOE-HANDBOOK-3010-94 is 6×10^{-3}. HEPA filtration removes 99.9 percent of the oxide particles. The environmental source term would become 2.7 g as UO_2.

Mixer/Melter Charging Accident

The depleted uranium material has to be charged to the "shield maker." For the HTSMF, the pallets have to be broken down, the boxes opened, individual billets inspected, and billets charged to the furnace. Assuming these four operations, the accident frequency becomes:

59,000 billets/yr x 4 operations/billet x 1.1×10^{-5}/operation = 25/yr
(i.e., will occur 25 times annually).

The material at risk is 34 kg (one billet). The damage fraction is 30 percent. The respirable release fraction is 4×10^{-3}. HEPA filtration removes 99.9 percent of the particles. The environmental source term becomes 41 mg as U_3O_8.

For the LTSMF mixer, charging uses the individual drums. Again, there are four operations. The accident frequency becomes:

21,056 drums/yr x 4 operations/drum x 1.1×10^{-5}/operation = 0.924

The material at risk is 667 kg. The damage fraction is 1. HEPA filtration removes 99.9 percent of the particles. The respirable release fraction is 1×10^{-7}. The environmental source term becomes 33 mg.

Mixer/Melter Accident

The mixer/melter can fail during operation, due to either a vessel failure or an operational/handling event. The vessel failure accident could involve an oxidizing agent such as the cooling water; however, it is assumed that it will not. For melter handling events at the HTSMF, there are 6,330 melter loads annually. Assuming two handling operations (one related to loading, and one related to unloading), the frequency becomes:

$$6{,}330 \text{ melter loads/yr} \times \frac{2 \text{ operations}}{\text{melter}} \times 1.1\text{x}10^{-5}/\text{operation} = 0.14/\text{yr}$$

The material at risk is 3,000 kg as molten uranium metal. The damage fraction is 1 percent. The airborne release fraction is 6 x 10^{-3}. HEPAs remove 99.9 percent of the particles. The environmental release quantity becomes 180 mg as U_3O_8.

For mixer handling events at the LTSMF, there are around 10,500 mixer loads annually. Again, assuming two handling operations, the frequency becomes:

$$10{,}500 \text{ mixer loads/yr} \times \frac{2 \text{ operations}}{\text{melter}} \times 1.1 \times 10^{-5}/\text{operation} = 0.23/\text{yr}$$

The material at risk is 1,334 kg as uranium dioxide. The damage fraction is 1. The airborne release fraction is 5 x 10^{-5}. HEPAs remove 99.9 percent of the particles. The environmental release quantity becomes 66.7 mg as UO_2.

Mixer/Melter Discharging Accident

Accidents can occur during the discharge of the uranium material to the cask annulus, such as the misalignment of the discharge manifold. For the HTSMF, a maximum of eight melters can discharge simultaneously. The frequency becomes:

$$6{,}330 \text{ melter loads/yr} \times \frac{1 \text{ operations}}{\text{melter}} \times 8 \text{ melters} \times 1.1 \times 10^{-5}/\text{operation} = 0.56/\text{yr}$$

The material at risk is 3,000 kg as molten uranium metal. The damage fraction is 1 percent. The airborne release fraction is 6 x 10^{-3}. HEPA filtration removes 99.9 percent of its particles. The environmental release quantity is 0.18 g as UO_2.

For the LTSMF, a maximum of three mixers discharge simultaneously. The frequency estimate is:

$$10{,}500 \text{ mixer loads/yr} \times \frac{1 \text{ operations}}{\text{mixer}} \times 3 \text{ mixers} \times 1.1 \times 10^{-5}/\text{operation} = 0.35/\text{yr}$$

The material at risk is 4,000 kg as UO_2. The damage fraction is 1. The airborne release fraction is 5×10^{-5}. HEPAs remove 99.9 percent of the particles. The environmental release quantity becomes 200 mg as UO_2.

Shield Failure After Casting

The cask annulus can fail after it has been filled with depleted uranium. There are three potential accident modes: mechanical/rupture failure, handling accident, and chemical reactivity accident. For the HTSMF, the frequencies become:

Rupture Failure: $$9.6 \times 10^{-6} \frac{\text{rupture}}{\text{cask}} \times \frac{453 \text{ casks}}{\text{yr}} = 4.35 \times 10^{-3}$$

Handling: $$\frac{1.1 \times 10^{-5}}{\text{operation}} \times \frac{2 \text{ operations}}{\text{cask}} \times \frac{453 \text{ casks}}{\text{yr}} = 9.97 \times 10^{-3}$$

Reaction: $$9.6 \times 10^{-6} \frac{\text{rupture}}{\text{cask}} \times \frac{453 \text{ casks}}{\text{yr}} = 4.35 \times 10^{-3}$$

The total estimated frequency is the sum, i.e., 1.81×10^{-2}. The material at risk is the cask annulus, filled with around 45,000 kg of molten uranium metal. The damage fraction is 0.1 percent because of the narrow confines of the annulus. The material reacts spontaneously with air, for an airborne release fraction of 6×10^{-3}. HEPAs remove 99.9 percent of the particles. The environmental source term becomes 0.27 g as U_3O_8.

For the LTSMF, the frequencies become:

Rupture Failure: $$9.6 \times 10^{-6} \frac{\text{rupture}}{\text{cask}} \times \frac{480 \text{ casks}}{\text{yr}} = 4.61 \times 10^{-3}$$

Handling: $$\frac{1.1 \times 10^{-5}}{\text{operation}} \times \frac{2 \text{ operations}}{\text{cask}} \times \frac{480 \text{ casks}}{\text{yr}} = 1.06 \times 10^{-2}$$

Reaction: "Incredible" - $< 1 \times 10^{-6}$/yr

The total frequency sums to 1.52×10^{-2}/yr. The material at risk is 44,000 kg. Since the UO_2 is formed into a concrete, the airborne release fraction is assumed to be much lower (1×10^{-7}) than for pure UO_2. HEPA filtration is 99.9 percent efficient. The environmental source term is 4.4 mg as UO_2.

Externally Initiated Events

Externally initiated events tend to be site specific. As a first approximation, the DOE performance category frequencies are used in the estimates. The release fractions for internal events are based on small amounts of material placed in precarious conditions (i.e., lifted or melted). Most of the material at risk (MAR) for externally initiated, whole-site events are less susceptible to release, therefore lower release fractions are generally applicable.

For both the LTSMF and HTSMF two externally initiated, credible events were considered: (1) Earthquake and (2) Tornado. Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes flooding.

The accidents described below are judged to be unlikely, i.e., an annual frequency less than 10^{-2} and greater than or equal to 10^{-4}. For the earthquake accidents, the duration is 30 minutes, while a 30 second duration is assumed for the tornado accidents.

Design Basis Earthquake - LTSMF The primary release is from the Feed Storage area which contains about 1800 te MAR. It is postulated that 10% of the drums are damaged, and 50% of the drum contents are released and fall to the floor for a resulting damage factor of 0.05. It is also postulated that the building containment is breached and the ventilation system is not operable (i.e., leak factor of unity). The respirable airborne fraction is taken as 1.6×10^{-6}. The resulting release to the environment is 0.143 kg UO_2. The release point is at grade. In addition, earthquake damage in the Process area (DUCRETE ™ mixing), with 44 te at risk, gives a release (at grade) to the environment of about 0.007 kg UO_2. The total source term is then 0.150 kg UO_2.

Design Basis Tornado - LTSMF Similarly, the primary release is from the Feed Storage area. It is postulated that a tornado wind driven missile impacts a single storage drum and releases the entire 1 te inventory of the drum. The respirable airborne fraction is taken as 7×10^{-4}. Again building containment is breached and the ventilation system is not operable. The resulting release to the environment is 0.716 kg UO_2. The release point is at grade. In addition, tornado damage in the Process area leads to an estimated release (at grade) to the environment of about 0.007 kg UO_2. The total source term is then 0.723 kg UO_2.

Design Basis Earthquake - HTSMF The primary release is from the Casting area which contains liquid uranium in eight casting furnaces and a total MAR of 24 te. It is postulated that the seismic event causes the spillage of the entire contents of one furnace (3 te). The spilled liquid uranium rapidly oxidizes when exposed to air at elevated temperatures, and the uranium oxide forms a stable oxide layer on the exposed surfaces of the molten uranium. Since the induction furnaces are normally water cooled, the released cooling water causes localized steam explosions. It is assumed that 10% of the uranium oxidizes and is available for release. DOE Handbook 3010-94 gives a respirable airborne fraction of 6×10^{-3} for a violent uranium release situation. Based on a reduced HEPA filtration efficiency of 0.99, the estimated release to the environment from the process stack is then 0.021 kg UO_2/U_3O_8 mixture.

A design basis earthquake or tornado could breach the Feed Storage area containment (as above). However, due to the size and density of the uranium metal billets, an insignificant fraction of the uranium would be broken into airborne respirable particles.

Design Basis Tornado - HTSMF The source term for the design basis tornado is estimated to be the same or bounded by the release for the design basis earthquake.

Table 7.1: Scoping Assessment of Accidents

Accident	Frequency (per year)	Frequency Range			Effective MAR	RAF	RF	Leak Path	Source Term	Release Duration
		$>10^{-2}$/yr	10^{-2} to 10^{-4}/yr	$<10^{-4}$/yr						
Mishandling/ Drop of Drum/Billet HTSMF	1.4×10^{-1}	x			3,000 kg	1.75×10^{-4}		1×10^{-3}	525 mg (U_3O_8)	Puff
Mishandling/ Drop of Drum/Billet LTSMF	4.6×10^{-1}	x			667 kg	5×10^{-5}		1×10^{-3}	33 mg UO	Puff
Fire, Explosion, or Chemical Reagent Contact Inside HTSMF	9.6×10^{-6}			x	450 kg	6×10^{-3}		1×10^{-3}	2.7 g U (UO_2)	Puff
Fire, Explosion, or Chemical Reagent Contact Inside LTSMF	9.6×10^{-6}			x	4,000 kg	51×10^{-5}		1×10^{-3}	0.2 g UO	Puff
Mixer/Melter Charging Accident HTSMF	2.5×10^{1}	x			10.2 kg	4×10^{-3}		1×10^{-3}	41 mg U (U_3O_8)	Puff

Table 7.1: Scoping Assessment of Accidents (Continued)

Accident	Frequency (per year)	Frequency Range			Effective MAR	RAF	RF	Leak Path	Source Term	Release Duration
		$>10^{-2}$/yr	10^{-2} to 10^{-4}/yr	$<10^{-4}$/yr						
Mixer/Melter Charging Accident LTSMF	9.24×10^{-1}	x			667 kg	5×10^{-5}		1×10^{-3}	33 mg U_3O_8	Puff
Mixer/Melter Operational Accident HTSMF	1.4×10^{-1}	x			30 kg	6×10^{-3}		1×10^{-3}	0.18 g U (UO_2)	Puff
Mixer/Melter Operational Accident LTSMF	2.3×10^{-1}	x			1,334 kg	5×10^{-5}		$1x\ 10^{-3}$	66.7 g UO_2	Puff
Mixer/Melter Discharging Accident HTSMF	5.6×10^{-1}	x			30 kg	6×10^{-3}		1×10^{-3}	0.18 g U (UO_2)	Puff
Mixer/Melter Discharging Accident LTSMF	2×10^{-2}	x			4,000 kg	5×10^{-5}		1×10^{-3}	200 mg UO_2	Puff
Shield Failure After Casting HTSMF	2×10^{-2}	x			45 kg	6×10^{-3}		1×10^{-3}	0.27 g U (UO_2)	Puff
Shield Failure After Casting LTSMF	1.4×10^{-1}	x			44,000 kg	1×10^{-7}		1×10^{-3}	4.4 mg (UO_2)	Puff

8.0 TRANSPORTATION AND SITE MATERIAL MOVEMENT

There are very few differences between the DUCRETE™ and uranium metal shielding transportation requirements. Thus, this section discusses transportation in general terms for the DUCRETE™ shielding facility (LTSMF), and notes the differences for the uranium metal facility (HTSMF), where appropriate.

8.1 Intrasite Transportation

Intrasite transportation moves materials and products between the buildings on the site. The principal routes are:

- GWSB to MPB via HPRACB: this constitutes truck transport of materials from storage to the manufacturing areas where they are used. Using the container quantities from section 4 (table 4.11), the daily (3-axle) truck shipments become:
  - two for cask supplies,
  - one for cement and sand (LTSMF only), and
  - Two for general supplies.

  The total number of shipments is five.

- SCAB to MPB: this designates rail transport of the assembled cask (without shielding) to the shielding fabrication areas. There is an average of two shipments daily.

- MPB to SCPSB: this represents rail transport of the finished cask product from the processing areas to storage. There is an average of two shipments daily.

- There are also daily runs for waste collection, distribution of general supplies to other buildings, and equipment. There is an average of four shipments daily.

Therefore, there is an average of 15 intrasite shipments daily. A facility of this size would also be expected to have a fair amount of onsite traffic for personnel, samples, and other items. More detailed designs could minimize the number of shipments, thus reduce the potential for truck accidents. For example, cement and sand could be handled in bulk (e.g., by truck or rail) and be pneumatically transported to the mixer areas.

8.2 Offsite Transportation

8.2.1 Supplies and Input Materials

Table 8.1 estimates supplies and input material transportation for the LTSMF, while table 8.2 provides the same information for the HTSMF. The design assumes that the uranium (either uranium dioxide or the metal) arrives by truck or by rail. For trucks, standard designs and regulations limit the gross vehicle weight to 19,000 kg (42,000 lb). Using the UO_2 pellets as a basis for uranium dioxide, the approximate bulk density becomes 5.9 g/cc (cubic centimeter). For a 30-gallon drum, this corresponds to a net weight of 667 kg (1,470 lb). Assuming four drums per pallet, six pallets (24 loaded drums) represents the maximum load per truck shipment that definitively remains below the standard weight limits. Consequently, over 1,340 annual shipments are necessary. Railcars allow higher limits. Standard railcars can accommodate higher weights and loadings, typically on the order of 54,000 kg (~120,000 lb). Using this as a basis, and assuming four drums per pallet, a maximum of 20 pallets (80 drums) are loaded per railcar. Thus, rail deliveries are 403 railcars. These are organized into shipments of four railcars at a time. On an approximate ten days basis, about four railcars (one shipment) would be received. This is equivalent to 101 railcar shipments per year.

Depleted uranium metal receipts are based upon metal billets produced by the Continuous Metallothermic Reduction (CMR) process. The calculations assume a 97% uranium/3% iron composition, with a bulk density of around 17 g/cc. Each billet has the approximate dimensions 2" x 3" x 20", and weighs around 22.7 kg (50 lb). Each box holds 19 billets, with a net weight of 670 kg (1,475 lb). A pallet contains four boxes for a net weight of 2,600 kg of uranium (CMR alloy basis) or 2,680 kg (100% uranium basis). Seven pallets are placed on each truck. This requires around 1,075 truck shipments. Similarly, each railcar accommodates around 20 pallets. Annual shipments amount to around 94 organized as four railcars each.

Shielding cask shells would be received predominantly by rail. These would be organized into one shipment per week of around four standard railcars each. Other shielding components for assembly would be received by truck, probably on a weekly basis.

Cement, sand, PPE, and other supplies would be received on a weekly basis by truck. Perhaps seven deliveries per week would occur.

8.2.2 Products and Output Materials

The yield of DUCRETE™ shield annually is 43,200 metric tons, while the shielding cask product is only 41,200. These translate to 480 packaging containers per year of DUCRETE™ shield and 453 containers per year of shielding cask product. Shipments occur once a month, resulting in 40 packages per shipment of DUCRETE™ shield and 38 packages per shipment of metal shield.

The completed shielding cask product would be shipped to user sites by rail on depressed center load railcars. Approximately two shielding casks per day are generated on average, each requiring a railcar. Thus, around 480 railcars would be needed annually. These would probably be shipped in relatively large groups to user sites, perhaps in quantities equivalent to a month's production.

Decontaminated uranium containers would be shipped to scrap dealers; again, half would be by truck and half would be by rail. Approximately 100 containers could be placed on each truck (i.e.,

volume, not weight limited), which results in around 140 shipments per year. Around 150 containers could be placed on each railcar. Again, a regular shipment could be organized of up to two railcars total resulting in 48 annual shipments. Contaminated containers would be shipped offsite by truck only.
There would be no more than 15 annual shipments of radwaste to a disposal cell. For the HTSMF, radwaste shipments increase to 83. These shipments would be made by truck. All radioactive waste except HEPA filters will be in 55-gallon drums. The boxed HEPA filters will not significantly affect the shipping efforts.

Table 8.3 summarizes the product and output material transportation requirements for the LTSMF, while table 8.4 does the same for the HTSMF.

Table 8.1: Offsite Transportation - Supplies and Input Materials for the Low Temperature Shielding Manufacturing Facility (LTSMF)

	Input Material 1A	Input Material 1B	Input Material 2	Input Material 3	Input Material 4	Input Material 5	Input Material 6
Chemical content/ composition	100% UO_2*	100% UO_2*	100% cement	100% colemanite	100% stainless steel	various	100% Ar
Type/ Chemical	UO_2	UO_2	Cement	Colemanite	Shielding Shells	General Supplies	Argon
Physical Form	solid, at ambient	solid, at ambient	solid, at ambient	solid, at ambient	solid, at ambient	solid, at ambient	gas, pressurized 2,000 psig
Packaging Type	30-gal drum	30-gal drum	100 kg, fiberboard	100 kg, fiberboard	as is	various	200 SCF cylinder
Container weight, kg	27	27	~3	~3	22,000	various	30
Material weight, kg	667	667	100	100	22,000 (same)	various	10
Annual Quantity, te/yr	21,477	21,477	2,909	3,350	9,610	"small"	245
Packaging Containers, no./yr	32,150	32,150	29,090	33,500	480	various	24,240
Transportation Mode	truck	rail	truck	truck	rail	truck	truck
Number of Packages per Shipment	24	304	230	230	5	various	100
Number of Annual Shipments	1,340	106	125	146	104	52	240

* UO_2 in pellet form

Table 8.2: Offsite Transportation - Supplies and Input Materials for the High Temperature Shielding Manufacturing Facility (HTSMF)

	Input Material 1A	Input Material 1B	Input Material 2	Input Material 3	Input Material 4	Input Material 5
Chemical Content Composition	100% U	100% U	100% stainless steel	100% C	100% Ar	various
Type/Chemical	U Metal	U Metal	Shielding Shells	Graphite	Argon	General Supplies
Physical Form	solid billets, ambient	solid billets, ambient	solid, ambient	solid, ambient	gas, pressurized	solid, ambient
Packaging Type	"Billet Boxes"	"Billet Boxes"	as is	100 kg fiber	200 SCF cylinder	various
Container weight, kg	~23	~23	28,000	~3	~30	various
Material weight, kg	646	646	28,000 (same)	~100	~10	various
Annual quantity, te/yr	19,516	19,516	11,414	1,000	245	"small"
Packaging containers, no./yr	30,100	30,100	453	24,240	24,240	various
Transportation Mode	truck	rail	rail	truck	truck	truck
Number of Packages per Shipment	28	320	4	250	100	various
Number of Annual Shipments	1,075	94	104	100	240	52

Table 8.3: Products and Output Materials for the LTSMF

	Output Material 1	Output Material 2	Output Material 3	Output Material 4	Output Material 5
Type/Chemical	DUCRETE™ Shield	Empty UO2 containers	Empty UO2 containers	Empty UO2 containers	Radwaste
Physical Form	solid, ambient	solid, ambient	solid, ambient	solid, ambient	solid, ambient
Packaging Type	as is	30-gal drum	30-gal drum	30-gal drum	55-gal drum
Container weight, kg	~90,000 (varies)	45	45	45	34
Material weight, kg	same	~0 (clean)	~0 (clean)	~0 (contaminated)	454 kg
Chemical content/ composition	~50% UO_2	steel	steel	steel, 100 ppm UO_2	Radwaste
Annual quantity, te/yr	43,200	151	151	16	383
Packaging Containers, no./yr	480	15,271	15,271	1,608	534
Transportation Mode	rail	truck	rail	truck	truck
Number of packages per shipment	40	100	300	~100	40
Number of Annual Shipments	12	153	38	16	13

Table 8.4: Products and Output Materials for the HTSMF

	Output Material 1	Output Material 2	Output Material 3	Output Material 4	Output Material 5
Type/Chemical	Metal shield	Empty Billet container	Empty Billet container	Empty Billet container	Radwaste
Physical Form	solid, ambient	solid, ambient	solid, ambient	solid, ambient	solid, ambient
Packaging Type	as is	Box	Box	Box	
Container weight, kg	~91,000	~23	~23	~23	~34
Material weight, kg	same	~0 (clean)	~0 (clean)	~0 (contaminated)	454 kg
Chemical content/ composition	~50% U	steel	steel	steel, 100 ppm U_3O_8	Radwaste
Annual quantity, te/yr	41,200	329	329	35	1,875
Packaging Containers, no./yr	453	14,298	14,298	1,505	3,300
Transportation mode	rail	truck	rail	truck	truck
Number of packages per shipment	38	100	300	~100	40
Number of annual shipments	12	143	48	15	83

9.0 PERMITTING AND REGULATORY COMPLIANCE

This section identifies and briefly discusses the more relevant requirements and regulations that impact construction and operation of a shielding and cask manufacturing facility. Many of these regulations and requirements require a specific site for analysis and evaluation. A specific site is beyond the scope of this report, and thus, only general effects are noted. Some of these requirements have already been discussed in section 2.3, General Design and Safety Criteria. Although the requirements and net effects are essentially the same for either DOE or commercial facilities, the approaches differ. Thus, this section is split into three separate parts covering the cask and the manufacturing facility as either a DOE-owned or a commercially owned facility. Some regulations impact construction more than operations, and this is used as the major divider of the last two sections. Table 9.1 summarizes regulations impacting shielding and cask requirements. Table 9.2 summarizes the major DOE requirements and their effects. Table 9.3 summarizes the regulations and their effects for a commercial, depleted uranium shielding manufacturing plant.

While a DOE-constructed facility for depleted uranium shielding would not be subject to NRC requirements, depleted uranium is still regarded by DOE as source material, and if it were planned to dispose of any process wastes containing depleted uranium as LLW, it would be subject to DOE orders at DOE disposal sites and to NRC licensing criteria at commercial disposal sites. On the other hand, a depleted uranium shielding manufacturing facility constructed for commercial use would be subject to NRC requirements as defined in Title 10, Part 40, of the Code of Federal Regulations (CFR), "Domestic Licensing of Source Material." Reference is made in Part 40 to only one type of facility for processing source material ("Appendix A, Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes by the Extraction or Concentration of Source Material from Ores Processed Primarily from their Source Material Content"). Nevertheless, depleted uranium falls under the definition of source material as stated in Part 40 (as its U-235 isotopic content exceeds 0.05 percent), and so it is highly probable that a commercial depleted uranium shielding manufacturing facility would have to be designed to meet the siting and operational requirements of appendix A.

9.1 NRC Commercial Regulatory Compliance for Shielded Casks

Currently, the NRC provides the majority of regulations and licensing requirements for shielded casks. Thus, commercial SNF storage casks are licensed by the NRC and are subject to a wide range of laws, regulations, standards, and guidance. DUCRETE™ and depleted uranium metal shielding containers for either storage or disposal would require licensing by the NRC. The NRC licensing hierarchy specifies that the most important compliance must be with the CFR, which is considered the law regarding Independent Spent Fuel Storage Installations (ISFSI). NRC regulatory guides (R.G.), industry standards, and NRC NUREG reports are significant guides used in the licensing process, but there may be variations by the cask designer when sufficient technical justification is provided. Table 9.1 delineates the specific sections of the CFR, NRC R.G.s, NRC NUREGs, and industry standards that are typically used in the licensing of commercial casks. Some of these provide methodology guidance for safety analyses or cask design limits for such parameters as concrete temperature, fuel cladding temperature, and component stresses. This table contains 4 parts from the CFR, 15 NRC regulatory guides, 5 NRC NUREG and/or NRC/Contractor Reports (NUREG/CR), and 11 industry standards or reports used in cask licensing.

The four CFR parts with legal requirements for licensing casks each encompass a different aspect of cask design or operation. The 10CFR72 is the principal cask licensing law consisting of the following 12 subparts: general provisions; licensing application, form, and contents; issuance and conditions of license; records, reports, inspections, and enforcement; citing evaluation factors; general design criteria; quality assurance; physical protection; training and certification of personnel; provision of storage information to state governments and Indian tribes; general license for storage of spent fuel at power reactor sites; and approval of spent fuel storage casks. The 10CFR20 provides occupational dose standards for onsite workers. The 10CFR50 is the basis for the nuclear power plant license, thereby covering the cask operational phase in which spent fuel is loaded into the cask in the spent fuel building that is part of the nuclear power plant. The 10CFR71 is used in evaluating movement of SNF to/from the cask storage site.

No SNF cask containing depleted uranium has been licensed or proposed for licensing. It is anticipated that a design containing depleted uranium would have to meet these same regulations as existing casks plus additional requirements of confinement and durability of the uranium material. As noted previously, this implies sandwiching the uranium shielding between metal shells (i.e., the annulus) and minimizing dispersion during handling and accident scenarios.

9.2 Major Regulations Affecting Construction of a Cask Manufacturing Facility

9.2.1 Regulatory Requirements for DOE Facility Construction

Construction of a depleted uranium shielding manufacturing facility constitutes a Major Systems Acquisition (MSA) for DOE. Therefore, the DOE project management system, as defined by DOE Order 4700.1 (U.S. DOE, 1991), becomes the major requirement. This order defines the process for DOE's execution, construction, and completion of the MSA. It identifies key decisions (KDs), management roles, documents, estimating bases, and project control methods. Construction of the shielding manufacturing facility would initially require two new documents: Justification of New Start (JNS) and Justification of Mission Need (JMN). Both of these would be relatively short. After approval (usually designated as "KD-0"), DOE would prepare a Project Plan (PP) and a more detailed Project Management Plan that defines roles, provides organization [both management and as a Work Breakdown Structure (WBS)], identifies additional documentation, and estimates schedules and costs. The additional documentation requirements would include a Conceptual Design Report (CDR), detailed design reports (usually Title 1 for preliminary, and Title 2 for final), an environmental impact statement (EIS), permit applications, laboratory program documents, and a SAR.

The general design requirements for the construction of a DOE facility for manufacturing cask shielding are stated in DOE Order 6430.1A (U.S. DOE, 1989). Division 13 of this Order pertains to "Special Facilities," (as defined in DOE 5480.5, Safety of Nuclear Facilities). Subdivision 1319 of DOE 6430.1A refers to "Uranium Processing and Handling Facilities (UPHF)," which appears to include a shielding manufacturing facility, although it states, "This section is not process specific. It is principally directed at facilities that process and handle uranium enriched in U-235." Thus, portions of this order, such as 1319-3, "Nuclear Criticality Safety," clearly are not applicable to the design of the plant.

9.2.2 Regulatory Requirements for Commercial Facility Construction

The laws and regulations that pertain to the construction and operation of a cask shielding manufacturing plant have been established by several Federal agencies with no single regulation specifically addressing all aspects of plant design. Many of these regulations apply to the cask plant because they generally encompass nuclear fuel cycle facilities that handle uranium. In the hierarchy of Federal regulations, acts and sections of the CFR constitute the law that must be met unless the government grants an exception. Other regulatory documents such as NRC R.G.s, industry standards, and NRC NUREG or NUREG/CR reports may be deviated from provided sufficient technical justification is supplied by the applicant and is accepted by the NRC.

Federal laws, in the form of acts, set general goals, standards, bases, and authority that relate to a depleted uranium shielding cask plant. These acts and a brief summary are delineated below.

National Environmental Policy Act (NEPA) of 1970 - NEPA sets national environmental policy and goals by requiring Federal government agencies to evaluate the environmental effects of major Federal actions in a detailed report.

Noise Control Act (NCA) of 1972 - The NCA sets noise control responsibility at the state and local levels with specific requirements on the noise level that a facility must meet.

Atomic Energy Act (AEA) of 1954 - This act gives the NRC licensing and regulatory authority for commercial nuclear energy applications. Its applicability to a DOE cask shielding plant will depend on a decision by DOE to comply with NRC regulations.

Parts of the CFR establish more specific standards for the design and operation of a depleted uranium shielding manufacturing plant. Sections of the CFR that are potentially applicable to this plant are discussed below.

10CFR51 - For nuclear facilities regulated by the NRC, this regulation establishes environmental protection requirements and documentation to comply with NEPA.

NUREG/CR-3058 - "A Methodology for Tornado Hazard Probability Assessment," October, 1983. This document describes how to calculate the probability of a specified severe tornado at a given specific site for safety analysis.

NRC R.G.1.145 - "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," November, 1982. This guide delineates the methodology for calculating doses due to the atmospheric release of radioactive materials. It is directly applicable to the release of uranium to the atmosphere.

NRC R.G. 3.12 - "General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants," August 1973. This document provides criteria for the design of ventilation systems to ensure that no releases of radioactive material to the environment occur. Although not specifically designated for a cask shielding plant, many of the principles and criteria are directly applicable to the U and UO_2/UC part of the plant.

NRC R.G. 3.16 - "General Fire Protection Guide for Plutonium Processing and Fuel Fabrication Plants," January 1974. This document provides criteria for the design of a fire protection program to ensure that no releases of radioactive material to the environment occur. Although not specifically designated for a cask shielding plant, many of the principles and criteria are directly applicable to the uranium handling parts of the plant.

NRC R.G. 3.39 - "Standard Format and Content of License Application for Plutonium Processing and Fuel Fabrication Plants," January 1976. This document prescribes a format for license applications to the NRC that is generally applicable to a cask shielding plant with the exception that criticality accidents need not be considered for the shielding plant.

NRC R.G. 3.40 - "Design Basis Floods for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Fabrication Plants," Revision 1, December 1977. This document provides criteria for the determination of site-specific design basis floods to ensure that a facility is designed for these events without releasing any radioactive material to the environment. Although not specifically designated for a cask shielding plant, many of the principles and criteria are directly applicable to the uranium handling parts of the plant.

9.3 Major Regulations Affecting Operations of a Cask Manufacturing Facility

9.3.1 Regulatory Requirements for DOE Facility Operations

DOE is committed to the operation of its facilities in accordance with its own orders, and in accordance with Federal environmental statutes, including the AEA, NEPA, RCRA, the Clean Air Act (CAA), and the Clean Water Act (CWA).

Key DOE orders include 5400.5, "Radiation Protection of the Public and the Environment". This order specifically requires the application of the ALARA process for radiation protection of the public and the environment. The radiation protection system used in DOE 5400.5 is based on recommendations of the International Commission on Radiological Protection (ICRP). In its Publication No. 26 (1977), the ICRP recommended a system of dose limitations consisting of three basic principles:

(1) No practice shall be adopted unless its introduction produces a positive net benefit ("justification").

(2) All exposures shall be kept as low as is reasonable achievable, economic and social factors being taken into account ("ALARA" or "optimization").

(3) The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission ("individual dose limits").

DOE dose limits are being codified in 10CFR935. Other important DOE orders include 5400.3 (the Hazardous and Radioactive Mixed Waste Program), 5440.1E (NEPA Compliance Program), 5480.4 (Environmental Protection, Safety, and Health Protection Standards), 5480.5 (Safety of Nuclear Facilities), and 5820.2A (Waste Management).

9.3.2 Regulatory Requirements for Commercial Facility Operations

EPA and NRC regulations are the principal requirements for commercial facilities, and these are summarized in the next two pages. State and local regulations generally follow EPA and NRC requirements, but can be more stringent.

CAA - The CAA requires that the EPA set air quality standards for specific chemical pollutants. This act applies to normal emissions from a shielding manufacturing plant.

CWA - The CWA requires that the EPA establish specific limits on chemical pollutants in water. The state certifies that permitted discharge from a plant meets all standards.

RCRA - The RCRA is under the auspices of the EPA and encompasses the entire life-cycle of hazardous waste. RCRA regulates hazardous waste during its generation, transport, use, storage, and disposal. RCRA-listed materials are not used at the shielding manufacturing facility. However, it is possible for a waste exhibiting hazardous characteristics (i.e., corrosivity, reactivity, ignitability, and EP toxicity) to be generated during a plant accident. Also, uranium is not currently regulated as a hazardous material. Uranium dioxide and uranium carbide are not and are unlikely to become RCRA-regulated materials.

NCA of 1972 - The NCA sets noise control responsibility at the state and local levels with specific requirements on the noise level that a facility must meet.

10 CFR 20 - Issued by the NRC, this regulation sets standards for radiation protection for nuclear facilities under the auspices of the NRC, with the primary emphasis being on radiation dose standards from normal operation of these facilities.

40 CFR 190, Subpart B - Sets public maximum radiation doses from normal operational releases.

40 CFR 61, Subpart I - Air emission of radioisotopes from normal operation of an NRC licensed facility is limited so that the annual public effective dose equivalent does not exceed 10 mrem (0.1 milli Sievert).

10 CFR 40 - Sets requirements for domestic licensing of nuclear source material. This regulation may not apply to the low Uranium-235 enrichment of depleted uranium.

10 CFR 71 - Under the authority of both the NRC and the Department of Transportation (DOT), this regulation provides specific criteria for the safe packaging and transport of radioactive material. This regulation would pertain to the shipment of depleted uranium into the cask shielding manufacturing plant and the shipment out of this plant of its uranium-bearing product (i.e., the shielding cask containing uranium metal, uranium dioxide, or uranium carbide).

29 CFR 1900-1999 - This regulation enacts the Occupational Safety and Health Act (OSHA) of 1990, which sets standards for the safety of workers under the auspices of the Department of Labor (DOL).

10 CFR 75 - In accordance with an agreement between the United States and the International Atomic Energy Agency (IAEA), this regulation provides for a system of accounting and control of nuclear material. The proposed shielding manufacturing plant may be eligible for exemption from this regulation because of the low uranium-235 enrichment involved in this facility.

Industry standards, NRC R.G.s and NUREG or NUREG/CR reports provide guidance and a framework for the regulating government agencies to review designs and license applications. These documents do not carry the power of the law, but are respected as representing good technical practices. Deviations from such relevant documents usually require a detailed technical explanation and justification. These documents are summarized below.

NUREG-1140 - "A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees," by S.A. McGuire, January 1988. This report evaluates historical data on accidents at fuel cycle and radioactive material plants. Analyses are performed for accidental releases of uranium in different meteorology, and the results are related to toxic chemical and radiation dosage limits. Recommended emergency actions for accidental releases of uranium are discussed in this document. A 1-mile emergency response zone is recommended for uranium releases with respirable particles. This document influences site size and potential evacuation distances.

NUREG-1391 - "Chemical Toxicity of Uranium Hexafluoride Compared to Acute Effects of Radiation," Stephen A. McGuire, February 1991. This report evaluates the comparative toxicological and radiation effects of UF_6. It concludes that the equivalent health effects of a 25 rem whole body dose is the ingestion of 10 mg of uranium.

NRC R.G. 3.42 - "Emergency Planning for Fuel Cycle Facilities and Plants Licensed under 10 CFR Parts 50 and 70," Revision 1, September 1979. This document provides guidance in the design and development of emergency plans for facilities containing radioactive materials.

NRC R.G. 3.67 - "Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities," January 1992. This document specifies the required format and contents of emergency plans that would be applicable to a uranium shielding manufacturing plant.

Draft Guide - 8013 - "ALARA Levels for Effluents from Materials Facilities," U.S. NRC, October 1992. This draft guide presents information on radionuclide effluent quantities that would comply with ALARA dose goals.

These requirements also invoke certain standards and codes. For the cask manufacturing facility, the two most important ones are ANSI and ASME. ANSI provides standards and specifications for chemical processing equipment, flanges, valves, pumps, etc. The ASME establishes standards and estimating protocols for pipes and vessels. For the shielding manufacturing facility (non-nuclear reactor, non-direct fired), section 8, division 1 applies. Building code requirements specific to the site would also have to be met.

Table 9.1: Typical Commercial Spent Nuclear Fuel Storage Cask Licensing Regulations

Office of the Federal Register, Code of Federal Regulations Title 10 - Energy, Chapter I - Nuclear Regulatory Commission (10 CFR)
1. 10 CFR Part 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation." 2. 10 CFR Part 20, "Standards for Protection Against Radiation." 3. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities." 4. 10 CFR Part 71, "Packaging and Transportation of Radioactive Material."
U.S. Nuclear Regulatory Commission Regulatory Guides
1. R.G. 3.61, "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask," 1989. 2. R.G. 3.60, "Design of an Independent Spent Fuel Storage Installation (Dry Storage)," March 1987. 3. R.G. 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be as Low as Reasonably Achievable," Revision 3, 1978. 4. R.G. 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures As Low as Reasonably Achievable," May 1977. 5. R.G. 7.8, "Load Combinations for the Structural Analysis of Shipping Casks," May 1977. 6. R.G. 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Revision 1, March 1978. 7. R.G. 1.76, "Design Basis Tornado for Nuclear Power Plant," April 1974. 8. R.G. 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Revision 1, December 1973. 9. R.G. 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October 1983.

Table 9.1: Typical Commercial Spent Nuclear Fuel Storage Cask Licensing Regulations, (continued)

U.S. Nuclear Regulatory Commission Regulatory Guides (cont'd)

10. R.G. 3.62, "Standard Format and Content for the Safety Analysis Report for Onsite Storage of Spent Fuel Storage Casks," 1989.
11. R.G. 1.25, "Assumptions used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors," March 1972.
12. R.G. 1.4, " Assumptions used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors," June 1974.
13. R.G. 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)," August 1989.
14. R.G. 1.28, "Quality Assurance Program Requirements (Design and Construction)," February 1979.
15. R.G. 1.92, "Combining Model Responses and Spatial Components in Seismic Response Analysis," February 1976.

U.S. Nuclear Regulatory Commission NUREG and NUREG/CR Reports

1. NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants," July, 1980.
2. NUREG/CR-3019, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials," March 1985.
3. NUREG-0800, "Standard Review Plan", Revision 2
4. NUREG/CR-3332, "Radiological Assessment - A Textbook on Environmental Dose Analysis," September 1983.
5. NUREG/CR-1815, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers up to Four Inches Thick," August 1981.

Table 9.1: Typical Commercial Spent Nuclear Fuel Storage Cask Licensing Regulations (continued)

Industry Standards and References

1. ANSI/ANS 57.9, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," American Nuclear Society, 1984.
2. ACI-349-85, "Code Requirements for Nuclear Safety Related Concrete Structures and Commentary," American Concrete Institute, 1985.
3. ASME, "Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC," American Society of Mechanical Engineers, 1981.
4. ANSI A58.1, "Minimum Design Loads for Buildings and Other Structures," American National Standards Institute, 1982.
5. ACI-318-83, "Building Code Requirements for Reinforced Concrete," American Concrete Institute, 1983.
6. PNL-6364, "Control of Degradation of Spent LWR Fuel during Dry Storage in an Inert Atmosphere," M.E. Cunningham, et al., Pacific Northwest Laboratory, October 1987.
7. PNL-6189, "Recommended Temperature Limits for Dry Storage of Spent Light Water Reactor Zircaloy-Clad Fuel Rods in Inert Gas," I.S. Levy, et al., Pacific Northwest Laboratory, May 1987.
8. PNL-4835, "Technical Basis for Storage of Zircaloy-Clad Spent Fuel In Inert Gases," A.B. Johnson and E.R. Gilbert, September 1983.
9. ANSI N14.6-1986, "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More," American National Standards Institute, 1987.
10. NFPA 78, "Lightning Protection Code," National Fire Protection Association Codes.
11. ANSI/ASME NOG-1-1983, "Rules for Construction of Overhead and Gantry Cranes," American National Standards Institute and American Society of Mechanical Engineers, 1983.

Table 9.2: Effect of DOE Requirements on the Shielding and Cask Manufacturing Plant

Requirement	Effect
DOE Order 4700.1	Defines project management and requirements
DOE Order 6430.1A	Identifies general design requirements
DOE Order 5400.5	Establishes ALARA and radiation limits for DOE facilities
DOE Order 5820.2A	Identifies waste management responsibilities and requirements
DOE Order 5400.3	Identifies hazardous and mixed waste requirements
DOE Order 5480.4	Establishes environmental protection, safety, and health standards

Table 9.3: Effect of Commercial Regulations on the Shielding and Cask Manufacturing Plant

Regulation	Effect
NEPA	Evaluate Environmental Impact
CAA	Normal Operational Chemical Emission Air Quality Standards
CWA	Normal Operational Water Chemical Pollutant Standards
RCRA	Life Cycle of all Plant Hazardous Waste
NCA	Normal Operational Noise Level Standards
AEA	NRC Authority for all Commercial Nuclear Energy Applications
10CFR20	Specific Detailed Worker Occupational Dose Limits for organs and whole body (e.g., 5 rem whole body per year); allowable air and water radionuclide concentrations; worker radiological protection; dose calculation methodology; radwaste handling; public dose limits from normal operation; license requirements; recordkeeping.
40CFR190(B)	Public Annual Dose Cannot Exceed 25 mrem (whole body), 75 mrem (thyroid), and 25 mrem (other organs) from all discharges associated with normal operation of any nuclear fuel cycle facility.
40CFR61(I)	Radionuclide air emissions from operation will not cause any individual annual dose to exceed 10 mrem; reporting; recordkeeping.
10CFR40	Licensing requirements for handling and storing source material such as UF_6.
10CFR71	Design standards for packages that transport radioactive materials such as UF_6 and uranium end products; license conditions; operating controls; quality assurance.
29CFR1900	Nonnuclear safety and health standards for workers.

Table 9.3: Effect of Commercial Regulations on the Shielding and Cask Manufacturing Plant (continued)

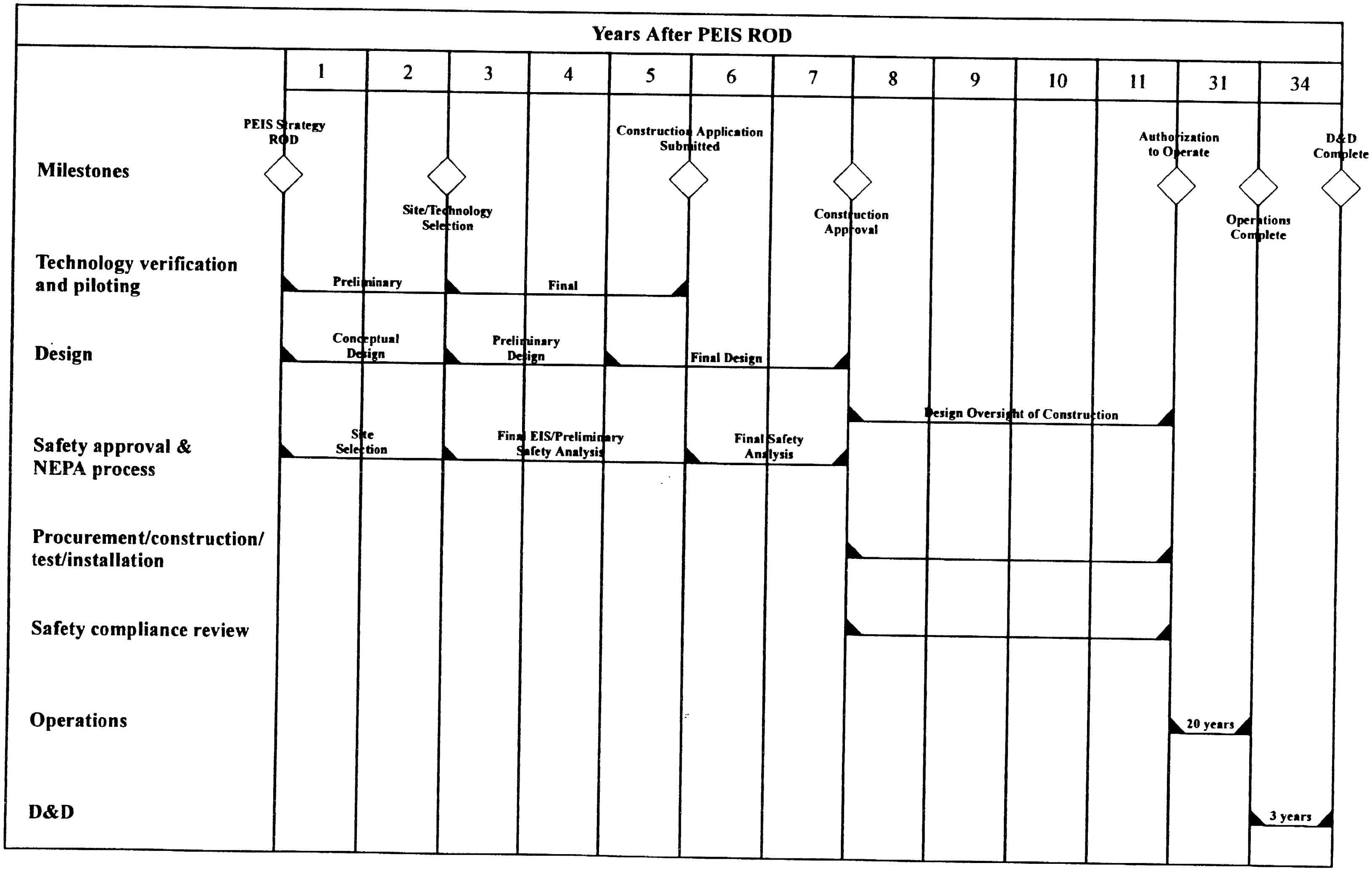
Regulation	Effect
10CFR51	Application of NEPA to NRC-regulated facilities; EIS requirements.
10CFR75	Nuclear material accountability and control for uranium.
NUREG-1140	One mile emergency evacuation zone protects against worst case, low probability uranium fire accident.
NUREG-1391	Chemical toxicity of UF_6 is greater than the radiation dose with appropriate limits of 10 mg uranium intake.
NUREG/CR-3058	Site-specific tornado probability calculation method.
R.G.1.145	Method to calculate atmospheric dispersion of uranium releases.
R.G.3.12	Ventilation system design for radioactive material.
R.G.3.16	Fire protection program for radioactive material.
R.G.3.39	License application format and content.
R.G.3.40	Method to calculate design basis floods.
R.G.3.42	Development of Emergency Plans.
R.C.3.67	Format and Content of Emergency Plans.
D.G.-8013	Radionuclide effluent levels for ALARA.

10.0 SCHEDULE ESTIMATE

A preliminary schedule to deploy, operate, and decommission a representative depleted UF_6 conversion facility is illustrated in figure 10.1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting allocated 3 years following preliminary assessments. Design activities include both Preliminary and Final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installationare assumed to require 4 years. Plant startup occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

Figure 10.1: Estimate of Overall Schedule for the Shielding Manufacturing Program



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12.0 GLOSSARY

Administrative and Technical Support Building - a building in the SMF containing office space for administration and technical support, security and visitor control, health physics center, analytical support and laboratory services, first aid and a cafeteria

Adsorbent - a substance which has the ability to condense or hold molecules of other substances on its surface

ANISN discrete ordinates method - calculation method for surface neutron dose rate by solving Boltzmann transport equation in a slab, sphere, or cylinder geometry

anhydrous - without water

asphyxiants - gases which have little or no toxic effects except that in very large air concentrations they displace enough oxygen to cause death by lack of oxygen

calcining - heating to a high temperature, but below the melting or fusing point, causing loss of moisture, reduction, or oxidation

Cost Analysis Report - This Report will analyze the total costs for each management option to provide a sound basis which can be used to estimate the life-cycle costs associated with the alternatives

crystallographic-systems - a categorization of crystals according to their degree of symmetry

cyclone separators & filters - equipment that separates solid particles from fluids by centrifugal force

dense uranium compounds - uranium compounds with a density greater than 5 g/cm

Depleted Uranium Dioxide Receiving Area - within the LTSMF MPB, contains truck and rail bays for receiving UO_2 shipments

Depleted Uranium Dioxide Storage Area - within the LTSMF MPB, provides storage for UO_2 in the original shipping containers, up to 30 days

depleted uranium hexafluoride - uranium hexafluoride which has been fed through the "enrichment" process and is depleted in the U-235 isotope.

Depleted Uranium Metal Receiving Area - within the HTSMF MPB, contains truck and rail bays for receiving DU metal ingot shipments

Depleted Uranium Metal Shielding Casting Area - within the HTSMF MPB, area where the non-radioactive shielding annulus from the SCAB is heated, the depleted uranium metal is melted, then poured into the annulus and transferred to a cooling stand to solidify

Depleted Uranium Metal Shielding Cooling Area - within the HTSMF MPB, area where the cast depleted uranium metal shielding casks are cooled by natural convection and held in interim storage

Depleted Uranium Metal Storage Area - within the HTSMF MPB, provides storage for depleted uranium metal ingots in the original shipping containers, up to 30 days

double confinement - having at least two barriers between the compound and the environment. This is a required by DOE and NRC regulations for radioactive materials

DUCRETE™ - concrete made using depleted uranium sand and/or pellets (UO_2) as the aggregate

DUCRETE™9 - DUCRETE™ made using a 1:2:9 ratio of cement, sand and UO_2 aggregate

DUCRETE™18 - DUCRETE™ made using a 1:2:18 ratio of cement, sand and UO_2 aggregate

DUCRETE™ Curing Area - within the LTSMF MPB, the area where cast shielding casks cure for one month to allow the DUCRETE™ to achieve 90% strength

DUCRETE™ Mixing and Casting Area - within the LTSMF MPB, area where UO_2 is mixed with cement and sand, cast in the non-radioactive shielding annulus and allowed to set to form the shielding cask

Emergency Services Building - building in the SMF which provides space for firefighters and paramedics, communications equipment, and emergency vehicles

endothermic - reaction or chemical change in which heat is absorbed

enthalpy - the heat content per unit mass of a substance

eversafe cylinder geometrics - geometrics that will not achieve criticality under any combination of uranium enrichment and moderation

external hazards - extremes of naturally occurring environmental conditions, i.e., tornado, flood, earthquake, lightning, and extremely high temperatures

Final Assembly and Quality Control Area - within the MPB, where any voids in the shielding are filled, the seal, cover and draining features are added to the shielding cask, and QC is performed

Finished Cask Interim Storage and Shipping Area - within MPB, provides short, lag storage space for finished shielding cask awaiting shipment to SCPSB

General Warehouse and Storage Building - building in the plant containing loading/unloading bays, an office area and storage cribs for supplies and chemicals. This building supplies receiving and storage capabilities for most of the items received at the site

Health Physics and RCA Access Control Building - a building in the SMF that functions as the main portal to the shielding manufacture and depleted uranium handling facilities

High Temperature Shielding Manufacturing Facilities - SMF that manufactures shielding from depleted uranium metal by melting it at high temperatures (about 1,100 °C) and casting in an annulus to form a shielding cask

hydrodynamics - forces that water and other fluids in motion exert

irradiated - treated with some form of radiant energy

K-effective - measure of criticality, where a value of 1.0 indicates critical condition and values less than 1.0 indicate subcriticality

light water reactor (LWR) - principle type of nuclear reactor currently in use. LWRs are powered by uranium dioxide fuel with zirconium allow cladding and use ordinary (or light) water for cooling and moderating

Main Processing Building - building in the RCA of the SMF where the depleted uranium shielding is manufactured. This building houses most of the radioactive material processing

mixed oxide - mixture of compounds of oxygen and other elements or radicals

non-mechanistic accidents - incredible scenarios with no believable means of occurring that are assumed to occur to demonstrate design safety

off-gases - byproduct gases from a reaction chamber

operational errors - accidents caused by serious error, malfunction, or failure during loading, transport or emplacement of casks

pressurized swing absorption system - system which provides pressurized nitrogen to the SMF for inerting mixers and casting areas

Public Participation Plan - this plan lays out DOE's strategy for ensuring effective, two-way communication with the public throughout its decision-making process. The Public Participation Project consists of a variety of activities and methods for the public and stakeholders to participate in the projects from which DOE will gather information to make its decision

pyrolytic - chemically changed due to heat

radioactive mixed waste - a waste that contains both radioactive isotopes as defined by the Atomic Energy Act and hazardous substances as defined by RCRA or TSCA

Radiological Control Area - restricted area on the plant site which contains those facilities responsible for handing depleted uranium

Radwaste Storage Building - storage building located in the RCA for temporarily storage of packaged and/or solidified low level waste until its shipment offsite to disposal facilities. Storage areas are separated by concrete block partitions

Record of Decision (ROD) - this document will select the optimum strategy for a long-term management plan for the Depleted Uranium Hexafluoride Management Program

Shielding Cask Assembly Building - building in the SMF which receives, inspects and assembles the non-radioactive shielding components

Shielding Cask Product Storage Building - building in the SMF for storage of completed shielding casks prior to shipment to a user site

Shielding Manufacturing Facility - a plant where depleted uranium shielding is generated and assembled with non-radioactive shield components to produce shielding casks

sinter - to form a homogeneous mass by heating without melting

supercompaction - applying high compressive forces to material reducing volume and increasing density

technetium - a silver-gray, radioactive metallic element, often used as a tracer and to eliminate corrosion in steel

Technology Assessment Report - This report identifies and evaluates the available long-term management options, including those suggested by the public, industry, national laboratories and other government agencies. The evaluation was conducted by a panel of independent technical experts to determine the merits and reasonableness of each option

terminal velocity - the maximum velocity of a falling body, attained when the resistance of air, water or their surrounding fluid has become equal to the force of gravity acting upon the body

transuranic isotope - an isotope having an atomic number greater than 92

triuranium octaoxide - U_3O_8 - an oxide form of uranium, which is very stable. This is the form of "yellowcake", or mined uranium which has been refined

uranium dioxide - UO_2 - a black, crystalline powder, which is widely used in the manufacture of fuel pellets for nuclear reactors. Pressed and sintered, it is stable when exposed to water or air below 300 °C

uranium hexafluoride - UF_6 - a white crystalline solid at atmospheric conditions. This form is used as feed for almost all enrichment plants

Uranium Processing and Handling Facility - facilities which process and handle uranium enriched in U-235 (see DOE Order 6430.1 Section 1319)

Utility Supply Building - a building in the SMF which provides the utility functions for the site, supplying pressurized nitrogen, deionized water, steam and spare power

Waste Management Building - a building in the RCA responsible for general waste management, including solidification and decontamination

ZYLIND computer code - computer code using point kernal method to predict gamma dose rates from cylindrical sources and shielding

Appendix A

Analysis of Radiation Shielding Using Depleted Uranium Forms

Appendix A: Analysis of Radiation Shielding Using Depleted Uranium Forms

This appendix quantifies the efficacy of depleted uranium as a shielding material, using existing NRC-licensed designs with standard source terms based upon commercial SNF. Various chemical and physical combinations of depleted uranium are considered. Over 80 percent of current SNF is stored using horizontal designs, and this is the focus of the analysis of section A.1. This appendix also discusses the MPC program for commercial SNF, and summarizes INEL evaluations. Finally, this section estimates depleted uranium consumption by individual design and by potential market.

A.1 Analysis of Depleted Uranium Forms for Radiation Shielding in Horizontal Designs

The purpose of this analysis is to evaluate the effectiveness of different chemical forms of UF_6 as the neutron and gamma shield for the VECTRA NUHOMS-24P HSM. Currently, the NUHOMS-24P HSM shielding consists primarily of a 3-foot-thick reinforced concrete rectangular box around the cylindrical stainless steel dry storage canister (DSC), which contains 24 pressurized water reactor (PWR) SNF assemblies. Figure A.1 displays a representative module. The availability of approximately 560,000 te of UF_6 at uranium enrichment plants owned by the DOE represents a significant source of potential uranium shielding materials.

This shielding analysis used the actual design source term for 24 PWR fuel assemblies, which is delineated in the NUHOMS-24P Topical Report (NUTECH, Inc., 1988). This source term was calculated in this reference by assuming that the fuel had an average burnup of 40,000 MWD/MTU, a maximum initial U-235 enrichment of 4.0 wt %, and a post-irradiation cooldown or decay time of 5 years. The total gamma and neutron source for the 24 PWR spent fuel assemblies in the NUHOMS-24P HSM was 1.79E+17 photons/second and 5.4E+9 neutrons/second, respectively. The topical report also provided a specific energy spectrum distribution for the gamma and neutron sources.

For this preliminary shielding analysis, the SNF source is assumed to be evenly distributed on the inner surface of the DSC, which has a radius of 84 cm and a height of 365.8 cm. For one-dimensional radial shielding calculations, the shielding from this source is 1.58 cm of stainless steel, 16.07 cm of air, followed by the primary shield itself, which in the NUHOMS-24P design is 91.44 cm (36 in.) of reinforced concrete.

A total of seven different chemical forms of depleted UF_6 were evaluated in this analysis. These shields were U; UC; UO_2; uranium dioxide aggregate concrete with ratios of 1:2:9 and 1:2:18, the last numeral being the relative UO_2 content (DUCRETE™ 9 or DUCRETE™18); and high-temperature cured graphite matrix containing 85 percent of either UC or UO_2 and 15 percent carbon (UC-C or UO_2-C). The density and elemental composition of these shield materials along with the standard NUHOMS-24P materials (i.e., fuel, steel, air, and reinforced concrete) were obtained from several sources and are presented in table A.1.

Gamma ray dose shielding analyses were performed using the ZYLIND computer code (ORNL, 1990) and point checked using textbook methods (Schaeffer, 1973). ZYLIND uses the point kernel method to predict gamma dose rates assuming cylindrical sources and shielding. ZYLIND can model up to 20 energy groups, 8 shield layers, and has data for 24 elements as well as 3 materials.

ZYLIND has been extensively validated by comparison to several hundred containers with radioactive material and has predicted dose rates with 10 to 20 percent accuracy. The ZYLIND analysis of the NUHOMS-24P HSM was performed by first calculating the surface dose of the standard HSM with 36 in. of concrete and the design basis bounding 24 PWR spent fuel assembly gamma source term. The gamma source term from the NUHOMS topical report (NUTECH, Inc., 1988) is presented in table A.2.

The ZYLIND calculated surface gamma dose rate on the HSM, with its standard 36-in. concrete shield, was 40.8 mrem/hr. The NUHOMS-24P topical report (NUTECH, Inc., 1988) reported a calculated surface gamma dose rate of 11.2 mrem/hr using different dose calculation methods and a different computer code. ZYLIND was used to calculate the thickness of each depleted uranium shield material delineated in table A.1, which resulted in the same gamma 40.8 mrem/hr dose rate as the 36-in. concrete shield. Shield thickness was determined by iteratively running the ZYLIND model for each shield until the calculated dose rate was approximately 40.8 mrem/hr. For all shields, the identical design basis 24 PWR source term and shield geometry were used with the exception of the HSM shield composition and thickness. Results of the ZYLIND gamma dose rate analysis for depleted uranium shield wall thickness are presented in table A.3. These results are presented in terms of an Equivalent Dose Rate Shielding Thickness (EDRST), which is defined as the shield thickness necessary to provide the same surface dose rate as another shield.

Neutron surface dose rates on the HSM were calculated using the one-dimensional discrete ordinates computer code ANISN (ORNL, 1990 & ORNL, 1994) with the P3-S16 scatter and quadrature solution approximation, which was coupled with the CASK-81 (ORNL, 1987) 22 neutron group, 18 gamma group cross section data file. ANISN solves the Boltzmann transport equation in a slab, sphere, or cylinder geometry. The ANISN discrete ordinates method is widely recognized and used in the nuclear power industry and accepted by the NRC. The bounding 24 PWR spent nuclear fuel assembly neutron source term is presented in table A.4.

The ANISN discrete ordinates method calculated an HSM surface neutron dose rate with the standard 36-in. thick concrete wall of 2 mrem/hr. The NUHOMS-24P topical report (NUTECH, Inc., 1988) reported a calculated surface neutron dose rate of 0.11 mrem/hr. This method was used to calculate the depleted uranium shielding thickness necessary to achieve an HSM surface neutron dose rate of 2 mrem/hr. The same design basis 24 PWR neutron source term and shield geometry was used with the exception of HSM shield wall composition and thickness. Results of this neutron dose rate analysis in terms of shield wall thickness are presented in table A.5.

A comparison of tables A.3 and A.5 shows that the required shielding thickness for depleted uranium materials is greater to achieve the NUHOMS neutron dose rate limit than for its gamma dose rate limit. The dominating effect of the neutron dose rate limit is due to the fact that it is much lower than the corresponding gamma dose rate limit; coupled with the fact that with the exception of DUCRETE™, all depleted uranium shield materials lack hydrogen, which is the best neutron shield material. The uranium shield materials with significant concentrations of carbon provide good neutron shielding because of the relatively low atomic weight of carbon. Using the neutron EDRST as the determinant for shield thickness, the depleted uranium-based shielding varies from 11.5 in. to 19.3 in. as compared to the standard concrete shield of 36 in.

Using the neutron EDRST results in a shield that is about two to four times the gamma EDRST. The resulting shield design meets the same neutron dose rate limit as the original NUHOMS-24P design, but results in much lower gamma dose rates. An analysis was performed to optimize the shield wall thickness so as to meet the total dose rate (i.e., sum of gamma and neutron) limit of the NUHOMS-24P design. The goal of this analysis was to select a shield wall thickness that resulted in a total (i.e., gamma and neutron) NUHOMS HSM wall surface dose rate of approximately 11 mrem/hr. Figure A.2 presents a set of curves for the neutron and gamma dose rate as a function of shield wall thickness for four selected depleted uranium shield materials: uranium metal (or Uranium-4% Iron alloy), DUCRETE™ 1:2:18, uranium dioxide-carbon, and uranium carbide-carbon. The optimized shield wall thickness for 11 mrem/hr total dose rate for these four shields rounded up to the nearest inch is:

DUCRETE™ 1:2:18	16.0 in.
Uranium/Uranium-Iron	17.0 in.
Uranium Dioxide-Carbon	12.0 in.
Uranium Carbide-Carbon	10.0 in.

These optimized shield thicknesses could be further reduced by:

- including the shielding effect of inner and outer steel liners, which would encapsulate the depleted uranium shield once the liner thickness has been set by structural requirements;
- allowing a higher surface contact total dose rate than the 11 mrem/hr, and
- performing multidimensional detailed shielding analyses once a more complete design has been formulated.

Using the dimensions of the NUHOMS HSM shield walls and excluding the basemat (which is assumed to be normal concrete), the mass of depleted uranium used for shielding in each HSM was calculated with the above delineated optimized shield wall thicknesses. The results are tabulated below for each of the four shields in terms of depleted uranium used per HSM.

DUCRETE™ 1:2:18	139 te UO_2 per HSM

Uranium Metal/Alloy	437 te U per HSM
Uranium Dioxide-Carbon	132 te UO_2 per HSM
Uranium Carbide-Carbon	136 te UC per HSM

Along with neutron and gamma dose shielding, the depleted uranium-based HSM walls function as heat conduction paths for some of the decay heat generated by the spent fuel within the NUHOMS-24P, which is designed for a maximum decay heat of 24 kW. The standard NUHOMS-24P design with its 36-in. thick concrete HSM walls has thermal limits both on the zircaloy cladding of the spent PWR fuel and the concrete. The bulk concrete thermal limit of about 250 °F requires the inclusion of an air flow labyrinth inside the HSM to provide natural convection air flow for heat removal. Detailed heat transfer analyses of the concrete cask designs have indicated that approximately two-thirds of the decay heat is removed by natural convection through the internal air flow pathways and that as much as the remaining one-third of the decay heat is transferred by conduction through the concrete HSM walls. The need for natural convection air flow heat removal within the HSM is further demonstrated by the thermal analysis results of a postulated accident in which all the air flow inlets and outlets are completely blocked. For this scenario, the NUHOMS Topical Report's (NUTECH, Inc., 1988) thermal analysis shows that the concrete bulk temperature limit would be exceeded in less than 2 days.

In cartesian coordinates, the conduction heat transfer through the HSM walls is directly proportional to the temperature difference across the walls, wall area, and the ratio of wall thermal conductivity to wall thickness (K/t) (Kreith, 1961). The HSM inner wall area facing the spent fuel DSC would be identical for all shield materials. The ratio K/t, however, is a direct function of the shield material conduction and shielding properties because thermal conductivity is a measure of conduction ability, and wall thickness reflects radiation shielding capability. Thus, K/t is denoted the Heat Conduction Factor (HCF), which is a measure of the shield wall's ability to conduct heat. The HCF can be interpreted as an indicator of two different thermal performance measures: (1) for a constant heat source, a larger HCF will result in a lower shield material temperature rise (or a lower maximum shield wall temperature), or (2) for a desired shield wall temperature rise, a larger HCF will allow a greater amount of heat to be transferred by conduction through the shield wall. The HCF must be evaluated in terms of material temperature limits of the shield material(s). Table A.6 presents values of thermal conductivity and material temperature limits for the standard NUHOMS-24P HSM concrete and potential uranium materials.

Using the bounding neutron EDRST values from table A.5 and the values of thermal conductivity from table A.6, the HCF was calculated for potential uranium shielding materials and normalized to the HCF for the standard NUHOMS-24P HSM. The four depleted uranium shield optimized thicknesses were also used to calculate optimized shield HCF and are presented in table A.7. This table shows that all the potential uranium shield materials have superior heat conduction capabilities as compared to the standard NUHOMS-24P HSM concrete shield wall. Furthermore, the largest improvement in HCF from concrete, by a factor of 5.8 to 16.3, is evident in the uranium metal (U), uranium carbide (UC), 85% UO_2 - 15% C, and 85% UC - 15% C shields.

As previously mentioned, some heat transfer analyses indicate that only one-third of decay heat is transferred through the shield wall while the other two-thirds is carried out by natural convection air flow from internal labyrinth air passages. It would be possible to eliminate the internal air passages of the HSM if the shield wall could provide sufficient conduction heat transfer from direct contact with the DSC while maintaining both the fuel and the shield itself below any temperature limits. This eliminates the need for air passage flow obstruction surveillance and reduces the size of the HSM. As a first approximation, shield wall HCFs greater than 3.0 relative to the concrete wall should be capable of adequately conducting heat without an air passage. This presumes that the shield itself does not have a temperature limit below about 300 °F since the DSC outside wall can approach 300 °F without exceeding the fuel cladding storage temperature limit.

Table A.6 shows that only concrete and DUCRETE™ have temperature limits of less than 300 °F. Table A.7 indicates that the following depleted UF_6 shields have HCFs greater than 3.0 with a corresponding material temperature limit above 300 °F: uranium (U), uranium carbide (UC), 85% UC-15% C, and 85% UO_2-15%. One disadvantage of uranium metal is its inherent pyrophoricity and general propensity for chemical reactions. This undesirable chemical behavior may preclude the consideration of uranium metal as a shield. The remaining high HCF shields are: UC, UC-C, and UO_2-C.

The following conclusions can be made from the current evaluation of depleted uranium forms as potential shield material in the NUHOMS-24P HSM:

1. All seven chemical forms or composite shields using depleted uranium had superior neutron and gamma shielding performance when compared to the concrete currently used in the HSM.

2. All seven depleted uranium shield materials had superior heat conduction capability as compared to concrete.

3. Use of depleted uranium materials results in a significant reduction in shield wall thickness for equivalent or reduced dose rates and enhanced conduction heat transfer for the NUHOMS-24P design.

4. Some uranium shields have the potential for accommodating a revised NUHOMS-24P design in which all heat transfer is by direct shield wall conduction without the additional space, cost, and operational restrictions associated with internal air passage concrete cask designs.

A.2 The Multi-Purpose Canister (MPC) Approach

A.2.1 Introduction

The DOE Office of Civilian Radioactive Waste Management (OCRWM) has been evaluating a number of different systems for handling, transporting, storing, and disposing commercial nuclear power plant SNF. The systems being evaluated can be classified into three categories: multi-purpose canister (MPC), multi-purpose unit (MPU), and transportable storage cask (TSC). Information on these conceptual designs was obtained from three DOE sources (U.S. DOE, 1994a, U.S. DOE, 1994b, and CFR, 1994).

A.2.2 Multi-Purpose Canister (MPC)

The MPC concept consists of a triple-purpose, sealed, metallic container that provides confinement for SNF assemblies during handling, transport, interim storage, and disposal without repackaging or further handling of the SNF. The MPC would be placed inside specialized casks or overpacks for transfer, storage, transport and waste repository disposal. The casks or overpacks provide chemical, mechanical, radiological, and thermal protection while dissipating SNF decay heat during handling, transport, and storage. Once loaded with SNF at commercial nuclear power plant spent fuel storage pools, the MPC eliminates the need for handling the bare SNF for all steps in the process leading to its ultimate disposal into the repository.

The conceptual design of the MPC uses commonly applied materials and existing technology to construct a cylindrical stainless steel 316L shell with both inner and outer lids, an SNF basket, and a shield plug. The basket is made of an aluminum-boron alloy that is sandwiched between stainless steel plates. The basket provides SNF assembly structural support and criticality control by assembly-to-assembly spacing and the incorporation of neutron absorbing material between adjacent SNF assemblies. The shell supports the basket, maintains geometric stability, and with the welded lids, constitutes the primary confinement boundary for radioactive material within the SNF. The shield plug, made of layers of steel and depleted uranium, provides radiation shielding in the axial direction from the MPC.

The MPC design was developed for two different sizes, 125 tons and 75 tons, to accommodate the capabilities of all commercial nuclear power plant sites while minimizing the number of MPC needed for all projected commercial SNF. The large MPC can hold 21 pressurized water reactor (PWR) fuel assemblies or 40 boiling water reactor (BWR) fuel assemblies, while the small MPC can hold 12 PWR assemblies or 24 BWR assemblies. Figures A.3 through A.6 show basic design details and dimensions of the two MPC designs with the PWR basket in place. Overall outside dimensions of the two casks are: 60.3-in. outer diameter and 193-in. height for the large MPC; 49.62-in. outer diameter and 191.625-in. height for the small MPC.

The MPC design specifies parameters for SNF assemblies that can be placed inside the basket. These design parameters, based on thermal, shielding, structural, and criticality analyses are summarized below.

SNF Assembly Design Parameter	PWR Fuel	BWR Fuel
Length (in.)	180	180
Outer Square Dimensions (in.)	9 x 9	6 x 6
Weight (lbs)	1,720	730
Decay Time After Reactor Core Discharge		
• Storage (yrs)	5	5
• Transportation (yrs)	10	10
• Disposal (yrs)	20	20

SNF Assembly Design Parameter	PWR Fuel	BWR Fuel
Initial Enrichment (wt % U-235)	3.75	3.75
Limiting Burnup (MWD/MTU)	37,000	37,000

The dimension and weight parameters will probably encompass all current and projected future commercial SNF designs, but the enrichment and burnup limits are lower than most modern and projected future SNF designs. DOE has estimated that 80 percent of all SNF meets the aforementioned limits and that the remaining 20 percent will be accommodated by changes in MPC system operations. One possible change could be the loading of fewer SNF assemblies into the basket and showing, by appropriate analyses, the partially filled MPC meets all design criteria.

Criticality analyses of the two MPC sizes with either PWR or BWR fuel assemblies assume that only 75 percent of the Boron-10 in the basket is present and that the MPC has been breached with concomitant water intrusion during the long term disposal time period. With the exception of the large MPC containing PWR fuel, all the MPC designs meet criticality limits under current NRC regulations. The large MPC with PWR fuel must rely on burnup credit to demonstrate criticality safety. Without burnup credit, the large MPC-PWR criticality analyses for fresh 3.75% U-235 result in a value of k-effective of about 1.2. K-effective is a measure of the neutron multiplication, chain reaction capability of a mass of fissionable material. A safe value of k-effective is less than 1.0, preferably 0.95. Burnup credit allows for modeling of the SNF with a reduced U-235 enrichment and the presence of neutron absorbing fission products that is characteristic of nuclear fuel that has been burned in a nuclear reactor core to produce heat for electric power generation. The NRC has not approved the use of burnup credit for criticality analyses, but has been studying this issue for several years.

Thermal analysis of the maximum SNF cladding surface temperature is necessary to ensure that the confinement integrity of the cladding is maintained. A typical cladding temperature limit for safe long-term storage of commercial zircaloy clad SNF is about 340 °C. For the MPC, the limiting conditions for maximum cladding surface temperature are when the MPC is inside a transportation cask. Thermal analyses for this condition with both large and small MPCs carrying either PWR or BWR fuel results in a maximum cladding temperature of 301 °C, which is below the limit.

The limiting structural analysis for the MPC is for a hypothetical 9-m drop during transportation, which causes a 60 g acceleration. Structural analyses have shown that the 1.0-inch shell thickness of the large MPC and the 0.875-inch shell thickness of the small MPC are sufficient to maintain structural integrity for this drop accident. Another structural design aspect is the capacity of the MPC to withstand internal over pressurization due to failure of 100 percent of all its fuel rods, which releases fission gases to the free volume within the MPC. Analyses show that the MPC can withstand such an event with a maximum internal pressure of 100 pig. Finally, the basket wall thickness was shown to adequately maintain its structural integrity in the case of a postulated MPC drop while being transported.

Because the MPC is encased in either a cask or overpack for all its functions, the only shielding dose analysis that must be performed is for the MPC top lid. The top lid requires welding and inspection. Calculated total (neutron and gamma) dose rates outside the inner lid are 93.7 mrem/hr for the small MPC and 117.3 mrem/hr for the large MPC.

A.2.3 MPC Transportation Cask

The transportation cask is used to encapsulate the MPC for transport to the waste repository or interim storage. To accommodate the two MPC sizes, there are two transportation casks sizes for 125 tons and 75 tons. Both of these casks consist of a cylindrical shell with an open inner cavity, which is slightly larger than the outer diameter of the MPC. The shell is made up of layers of stainless steel Types 316L and 304, depleted uranium, lead, and a neutron shield. The integral lower lid is a combination of layers of stainless steel Type 316L and neutron shielding. The upper lid is steel.

Depleted uranium is an effective gamma radiation shield because of its high density. Neutron shielding material requires a high density of low atomic weight elements (e.g., hydrogen) to slow down neutrons that can then be more easily absorbed. The lead is used to withstand the 1-m pin puncture test that is required by 10 CFR 71 for transportation casks. The cask inner stainless steel thickness is determined by the 10 CFR 71 required 9-m drop test.

Figures A.7 through A.10 present basic drawings of the large and small transportation casks. The large MPC cask allows a 0.35-inch radial clearance and a 0.25-inch axial clearance between the MPC and the cask cavity wall. Similar clearances for the small MPC are 0.315-inch radial and 0.25-inch axial. While the MPC has two removable eyebolts for lifting, the transportation cask has four trunnions. Overall outside diameter and height dimensions for the large and small transportation casks are: 85.5 inches and 208.25 inches for the large cask, 69.25 in. and 204.875 in. for the small cask.

As with the MPC, the transportation cask structural analysis evaluates the 9-m drop and 60g acceleration load. In addition, the effects of a 1-m pin puncture were evaluated for the cask. All structural analyses showed sufficient design margin for these postulated accidents.

Thermal analyses were performed to determine the maximum cladding temperature inside the transportation cask with a limit of 340 °C for cladding integrity. The highest calculated cladding temperature was 301 °C for the large cask with PWR fuel. Analysis of a 10 CFR 71 required half-hour 800 °C fire resulted in clad temperatures less than 340 °C and a lead temperature of 186 °C, which is substantially less than the 327 °C melting point of lead.

Shielding dose analyses were performed for the cask design to demonstrate compliance with 10 CFR 71, which specifies a limit of 200 mrem/hr contact and 10 mrem/hr at 2 m from the cask boundary. The peak calculated surface and 2-m dose rates, respectively, for both casks are: 111.5 mrem/hr and 7.5 mrem/hr for the large cask, and 172.4 mrem/hr and 9.5 mrem/hr for the small cask.

A.2.4 MPC Storage Cask

One preconceptual design of a storage cask to hold an MPC has been presented by the INEL (INEL, 1994). The cask, called a Ventilated Storage Vessel (VSV), is modeled after the Sierra Nuclear Corporation's (SNC) Ventilated Storage Cask (VSC-24), which is a vertical concrete cask with internal air passages and an internal steel cylindrical container holding SNF (U.S. DOE, 1995). The VSV would be designed to both meet the requirements of 10 CFR 72 and hold the MPC. Its radial and axial shielding would be made of DUCRETE™, a concrete that uses depleted uranium as its aggregate. Two different VSV sizes would be available to accommodate both MPC sizes. Design parameters for the VSV include: peak surface dose rate of 200 mrem/hr, average surface dose rate of 20 mrem/hr, maximum normal operating public annual dose of 25 mrem, fuel cladding surface temperature limits between 340 and 420 °C depending on the type of SNF, seismic ground accelerations of 0.25 g horizontal and 0.17 g vertical, and an 80-in. drop height. This design has not been fully analyzed and is still in the early stages of development.

A.2.5 Transportation Storage Cask (TSC)

The transportation storage cask (TSC) system is an alternative to the MPC, which uses a dual-purpose cask or canister that is designed for storage and transportation, but must be unloaded for disposal. The two types of TSC systems are: (1) dual purpose cask with integral basket, called a TSC metal cask, and (2) a canister that is inserted into a dual purpose cask, called a TSC canister.

Two TSC metal cask conceptual designs have been developed. The large 100-ton cask can hold 21 PWR or 40 BWR SNF assemblies, while the small 75-ton cask has a capacity of 12 PWR or 24 BWR SNF assemblies. These two TSC metal cask designs are presented in figures A.11 through A.14. Outside diameter and overall height dimensions for the large and small casks are 83.25 in.

and 209 in. for the large cask, and 72.32 in. and 209 in. for the small cask. The basket is composed of square stainless steel boxes that include an aluminum-boron poison alloy. The cask shell consists of alternating layers of stainless steel, lead, stainless steel, neutron shielding material, and stainless steel. The top and bottom lids are made of a sandwich of stainless steel around neutron shielding material.

The TSC metal cask design is similar to the design of the transportation casks for the MPC. Principal differences include the fact that the TSC metal cask uses lead but no depleted uranium for radial gamma shielding, and the top lid of the TSC metal cask has more shielding than the transportation cask, which relies somewhat on the MPC top lid integral shielding. It is also interesting to note that the storage and transportation functions for the same number of PWR/BWR fuel assemblies are accomplished with 100- and 75-ton TSC metal casks as compared to 125- and 75-ton MPC transportation casks.

The TSC metal cask design is subject to licensing approval in accordance with both 10CFR71 and 10CFR72. One actual TSC metal cask design has been submitted to the NRC for licensing approval, the Nuclear Assurance Corporation's Storable Transport Cask (NAC-STC). This stainless steel cask can hold 26 PWR SNF assemblies with a minimum decay time of 6.5 years and a maximum U-235 enrichment and burnup of 4.2 wt % and 40,000 MWD/MTU, respectively. The top of this cask is sealed with two bolted lids and O-ring seals. Borated aluminum neutron absorber panels are incorporated in the basket design. Overall dimensions are 98.2 in. in outer diameter and 193.02 in. in length. In October 1994, the NRC issued a Certificate of Compliance (COC) for the transportation function of the NAC-STC. Typically, the transportation function licensing requirements are more stringent than those for storage. A storage COC is expected shortly.

The TSC canister is similar to the MPC, but only serves the two functions of transportation and storage whereas the MPC also serves the function of disposal. The TSC canister has a basket for maintaining SNF geometry and criticality control. The canister is placed inside either a storage or transportation overpack. Neither the canister nor the overpack are designed for emplacement in a waste repository.

The TSC canister is subject to licensing approval in accordance with 10 CFR 71 and 10 CFR 72. One actual TSC canister design has been submitted to the NRC for licensing approval, the Pacific Nuclear System's NUHOMS MP-187. The MP-187 weighs 117 tons loaded, can hold 24 SNF PWR assemblies, and is made of a stainless steel shell with carbon steel end plugs. The MP-187's outer dimensions are a diameter of 91.50 in. and a length of 201.50 in. Its basket includes the use of borated aluminum composite for criticality control. The MP-187 is designed to hold fuel with a minimum decay time of 8 years and a maximum U-235 enrichment and burnup of 3.43 wt % and 38,268 MWD/MTU, respectively. The specific licensing application for the MP-187 is for use at the Rancho Seco nuclear power plant site. The MP-187 design submittal is currently being reviewed by the NRC.

Another TSC concept developed by INEL is the Transportable Storage Vessel System (TSVS), which uses a DUCRETE™ storage cask surrounded by a steel transportation overpack (U.S. DOE, 1995). Three possible SNF assembly basket configurations can hold either 17, 21, or 25 PWR assemblies, respectively. Impact limiters are placed on each axial end of the TSVS to absorb crush forces. The weight of the TSVS would range from 135.9 tons to 168.0 tons depending on the number of SNF assemblies being held within. Thermal analyses of this design have shown that the DUCRETE™ temperature limits would not be exceeded if 20-year decay fuel is used with full solar heat flux considered or 10-year decay fuel with a solar heat flux shield. This design has not been fully evaluated and is still in the early stages of development.

A.2.6 Multi-Purpose Unit (MPU) System

The multi-purpose unit (MPU) system consists of a cask with an inner sealed canister that is designed to perform the three functions of storage, transportation, and disposal. As such, the MPU must meet the licensing requirements of 10 CFR 60, 10 CFR 71, and 10 CFR 72. Like the MPC, the MPU conceptual design includes two different sizes: the large 125-ton MPU that can hold either 21 PWR or 40 BWR SNF assemblies, and the small 90-ton MPU that has a capacity of either 12 PWR or 24 BWR SNF assemblies.

Figures A.15 through A.20 present design details of the two MPU sizes. The large MPU has an outer diameter of 88.50 in. and a length of 214 in., while the small MPU has an outer diameter of 76.50 in. and a length of 212.25 in. The MPU radial shielding and confinement is provided by a composite of stainless steel, Alloy 825 steel, thick carbon steel, and removable neutron shielding material. Axial shielding is provided by thick carbon steel, stainless steel, depleted uranium, and neutron shielding material.

One distinguishing design feature of the MPU related to its direct disposal function is that it uses a layer of Alloy 825 and a carbon steel radial shell of either 7.75 in. or 8.375 in., depending on the size of the MPC. Apparently, these materials were included to ensure substantially complete containment of the SNF for about 1,000 years while in the repository. In comparison, single purpose storage and/or transportation cask designs are generally licensed and useful for about 40 to 50 years.

Another MPU-like concept evaluated is a 21 PWR/52 BWR package similar to the BR-100 transport cask configuration (Hertzler and Nishimoto, 1994). The internal cavity is 58.5 in. in diameter and 181 in. long. The base of the vessel is connected to the cylindrical bodies of the package with full penetration welds. The inner containment barrier is a 0.5-in.-thick high nickel alloy (i.e., Alloy 825) cylinder with a lid that is weld-sealed closed after SNF loading. Alloy 825 has very good corrosion resistance properties, which are high priority for a repository waste package. The photon shielding portion of the waste package is a 3.5-in.-thick cylindrical vessel made of depleted uranium metal immediately surrounding the inner vessel. The outer wall providing the structural component of the package is a 2-in.-thick cylinder of 304L stainless steel. Finally, a 3.75-in. borated polyethylene neutron shield with a 0.25-in. stainless steel skin surrounds the metal package. The polyethylene neutron shield would be removable, similar to the OCRWM's MPC shipping container overpack. The internal fuel basket assembly is assumed to be the same as the BR-100 design, which is made from alloy 6061 aluminum extrusions with T6511 temper. Ceramic-metallic plates, made from B_4C and aluminum powder, are included for criticality control. No assessment of the selection of basket material in the BR-100 report is made as part of this study. Figures A.21 and A.22 show the longitudinal and radial cross sections of the package geometry.

Regulatory Guide 7.9 requires that a listing be provided of the weights of individual subassemblies of the SNF package and the total weight of the package contents. This section identifies the subassemblies and the estimated wights. The estimated weights of package components are listed in table A.8 and the total operational package weights are given in table A.9. These component weights are dictated primarily by radiation shielding and preliminary structural analysis. Significantly more design detail and analysis is required to accurately define these parameters. Those identified here are preconceptual only.

A.2.7 Summary of the MPC Approach

A number of multipurpose conceptual designs for commercial SNF storage, transportation, and in some instances, disposal have been developed by DOE's OCRWM. These designs reduce the number of steps and operational radiation exposure associated with all the expected steps involved in removing SNF and placing it in a waste repository.

Two concepts, the MPC and MPU, are designed for all three functions of storage, transport, and disposal. The MPC requires specialized overpacks or casks, while the MPU is a complete unit requiring no additional structures. It should be noted that the DOE has determined that the MPC is the preferred design and has sought bids by contractors for the design and construction of the MPC. The TSC is designed to fulfill the storage and transportation functions, but requires fuel transfer to a separate structure for disposal. Two actual TSC designs, the NAC-STC and MP-187 have been submitted for licensing approval by the NRC and the NAC-STC has received licensing certification for its transportation function.

All the multipurpose designs are basically cylindrically shaped metal casks with radial and axial layers of different materials that provide gamma and neutron shielding as well as confinement of radioactive materials and structural strength to withstand accidents postulated by applicable regulations. The SNF is supported in baskets consisting of an array of hollow square support channels made of a sandwich of stainless steel around a neutron-absorbing boron-aluminum alloy.

With the exception of lids and the preconceptual INEL designs, most multipurpose conceptual and actual submitted designs use steel, lead, and neutron-shielding materials for shielding. The MPC incorporates a 2-in.-thick depleted uranium layer inside its top lid. The MPC TSC incorporates a

166-in.-high, 1.50-in.-thick depleted uranium layer in its radial shielding shell. The MPU inner canister design uses a 2.0-inch-thick depleted uranium shield layer in its top lid like the MPC.

It may be possible to replace most of the neutron and gamma shielding in these designs with some chemical form of UF_6.

The following matrix presents a comparison of the functional design of currently licensed, licensing submittal, conceptual design, and preconceptual design commercial SNF containers.

SNF Container	Function(s)	Licensing Status
Dry Storage Cask	Storage	NRC Licensed and Operating
Transportation Cask	Transportation	NRC Licensed and Operating
TSC	Transportation & Storage	License submittal under NRC Review for two designs (NAC-STC and MP-187), NAC-STC has transport license
MPC	Storage, Transport, & Disposal Requires Cask/Overpack	Conceptual Design
MPC Storage Cask	Storage Cask for MPC	Conceptual Design
MPC Transport Cask	Transport Cask for MPC	Conceptual Design
MPU	Storage, Transport, & Disposal	Conceptual Design

A.3 Analyses by INEL

INEL contracted with SNC, a vendor of commercial SNF vertical concrete casks in the United States, to analyze conceptual spent fuel storage cask designs using DUCRETE™ (Lessing, 1995) as the primary shielding in lieu of concrete. This study, documented in February 1995 (Hopf, 1995), examined shielding, thermal, structural, and radiological issues as they pertain to the use of DUCRETE™. Several different DUCRETE™ mixtures were evaluated using the basic SNC VSC system design (U.S. DOE, 1995).

The SNC VSC system consists of a welded steel cylindrical multi-purpose sealed basket (MSB) that encloses a support rack that holds 24 PWR commercial SNF assemblies. Figure A.23 displays the standard system. Figure A.24 compares the cross sections of the DUCRETE™ and standard VSC (Lessing, 1995). The MSB is encased in a vertical cylinder of steel-lined reinforced concrete with an air gap between the MSB and the inner diameter of the concrete cask. A labyrinth set of air passages is provided at the bottom and top of the cask to allow air flow through the space around the MSB so as to provide natural convection air cooling to remove the spent fuel decay heat. The standard VSC uses a 29-in.-thick concrete cask wall for shielding. The VSC MSB can also be configured to store BWR SNF.

Several radiation source terms are used in the conceptual design study for DUCRETE™ casks. The standard source from the NRC-approved VSC-24 cask is based on 5-year cooled PWR fuel with a burnup of 35,000 MWD/MTU and an initial uranium loading of 0.467 MTU/assembly. Alternate source studies use PWR fuel with a burnup of 55,000 MWD/MTU and 12.5-year cooling period; BWR fuel with a burnup of 33,000 MWD/MTU and 5-year cooling period; and 40,000 MWD/MTU PWR fuel cooled for 5 years (MPC source term). Shielding calculations use an axial power peaking factor of 1.2 to account for the axial variation in burnup (and therefore radiation source) of SNF. The total cask gamma and neutron source terms for each of the four aforementioned fuel burnup and decay time combinations are presented below.

Specifications of SNF	Gamma Source	Neutron Source
PWR, 35,000 MWD/MTU, 5-YEAR	1.644 E+17	2.64 E+9
PWR, 55,000 MWD/MTU, 12.5-YEAR	1.270 E+17	1.10 E+10
BWR, 33,000 MWD/MTU, 5-YEAR	1.697 E+17	5.88 E+9
PWR, 40,000 MWD/MTU, 5-YEAR	2.376 E+17	1.30 E+10

The PWR cask source term is based on 24 PWR SNF assemblies in a cask while the BWR cask is based on 65 BWR SNF assemblies in a cask.

The standard concrete VSC system has a design limit of 24 kW of decay heat per cask. This same limit is applied to the DUCRETE™ cask with the exception of the MPC case, which allows for a total MPC decay heat of 27.36 kW. SNC has shown that different combinations of SNF burnup and cooldown time will result in the same decay heat (i.e., a larger burnup SNF will meet the same decay heat limit by requiring a longer cooldown time).

The DUCRETE™ cask system is modeled in shielding analyses as a series of concentric, infinite height cylindrical shells of different materials. The MSB is modeled as the central cylinder with a smeared homogeneous mixture of its fuel, helium gas, and structural steel contents. This cylinder is surrounded by cylinders of, in descending order of their proximity to the MSB, MSB steel shell, air flow passage, DUCRETE™ inner steel liner, DUCRETE™ shield, DUCRETE™ shield outer steel liner, air of the atmosphere. The cask internal labyrinth air flow passages and details within the MSB are not modeled because of their relative complexity and the goal of calculating a surface cask contact dose rate only in this study. Aside from the substitution of DUCRETE™ for concrete, this study reduced the cylindrical internal air passage around the MSB from 4 in. in the standard concrete VSC to 2.25 in. and the thickness of the inner steel liner of the DUCRETE™ from 1.75 in. the standard VSC to 0.5 in. These changes were made to reduce the size and weight of the loaded DUCRETE™ cask to 100 tons, which is a crane limit at some nuclear power plants and a specification of the MPC.

The material composition of the DUCRETE™ used for shielding in the VSC system was varied over a range of UO_2 volume fractions, sand types, and UO_2 rock densities for a total of 34 different DUCRETE™ shields. A shield thickness for each of these types of DUCRETE™ that would result in a 100-ton cask was determined. The UO_2 volume fractions varied from 0.25 to 0.75, while the UO_2 rock density varied from 50 percent of theoretical density to 95 percent of theoretical density. Two different sands were used: silica and colemanite. For silica sand DUCRETE™, 1% boron was added to the mixture for enhanced neutron absorption. Since colemanite sand has a significant hydrogen component, DUCRETE™ with colemanite sand was not doped with boron for neutron absorption. Total density of the 34 DUCRETE™ compositions encompassed a range of from 3.46 gm/cubic cm to 8.5 gm/cubic cm. The maximum allowable DUCRETE™ shield thickness for a 100-ton cask was a range of from 6.72 in. to 14.689 in. depending on the specific DUCRETE™ composition.

The shielding calculations were performed using the MCNP monte carlo three-dimensional computer code, developed by Los Alamos National Laboratory (LANL), which has been used by SNC for its standard VSC system. MCNP is used with the CASK cross sections and corresponding flux-to-dose conversion factors for both gamma and neutron dose rate calculations of the DUCRETE™ VSC system. Benchmarking of MCNP-calculated dose rates for the standard VSC system with actual measured dose rates have showed that MCNP over predicts dose rate by about a factor of three. Therefore, this study reduced MCNP calculated dose rates for the DUCRETE™ casks by a factor of three.

The shielding analysis investigated the effect of different DUCRETE™ shield material components on dose rate for each source term. For both silica and colemanite sand, the gamma dose rate was found to increase with smaller UO_2 aggregate volume, which is expected because of the effect on density and the superior gamma shielding inherent in higher density materials. The neutron dose rates decreased with decreasing UO_2 aggregate volume because the smaller amount of UO_2 allowed for a higher density of hydrogen in the DUCRETE™, which is a superior neutron shield. It was also found that the colemanite sand DUCRETE™ was a better neutron shield because of its higher hydrogen content.

The lowest total (neutron and gamma) dose rate for both silica and colemanite sand for each source term is delineated below.

Source Term	Sand	UO_2-%TD	UO_2-Fraction	Dose Rate
PWR-35,000-5YR	SILICA	73	0.45	73 mrem/hr
PWR-35,000-5YR	COLEMANITE	73	0.55	53 mrem/hr
PWR-35,000-5YR	COLEMANITE	50	0.60	62 mrem/hr
PWR-35,000-5YR	COLEMANITE	95	0.55	55 mrem/hr
PWR-55,000-12.5YR	SILICA	73	0.25	105 mrem/hr
PWR-55,000-12.5YR	COLEMANITE	73	0.35	62 mrem/hr
BWR-33,000-5YR	SILICA	73	0.40	100 mrem/hr
BWR-33,000-5YR	COLEMANITE	73	0.45	65 mrem/hr
PWR-40,000-5YR	SILICA	73	0.35	138 mrem/hr
PWR-40,000-5YR	COLEMANITE	73	0.45	85 mrem/hr

The above results show that colemanite sand DUCRETE™ provides a significant total dose rate reduction as compared to silica sand even with 1% boron added. Also, the UO_2 density does not significantly affect cask total dose rate since a lower density UO_2 just allows a thicker shield for the same cask weight limit. Furthermore, the study shows that an optimum 100-ton cask DUCRETE™ shield would have a DUCRETE™ shield thickness of about 10.5 in. using DUCRETE™ with colemanite sand, 73% TD UO_2, and a UO_2 fraction of between 45 and 50 percent. This shield will ensure VSC cask surface contact dose rates of between 50 and 100 mrem/hr for all four source terms.

Additional shielding calculations were performed to investigate other DUCRETE™ cask design variations. It was found that allowing the VSC cask weight to be 125 tons instead of 100 tons reduced the cask surface dose rates by about a factor of 10. Another design variation was to allow the steel liner thickness to increase from 0.5 in. to 1.5 in., which may be required for cask transport structural requirements. Without changing the overall 100-ton cask weight or outer diameter, the additional steel replaced some DUCRETE™ that had a slightly reduced density. The resulting cask surface dose rate from a 1-in. increase in the steel liner thickness would increase the cask surface dose rate by about 10 percent, which would still keep the dose rates within the 50 to 100 mrem/hr range.

The thermal performance of the DUCRETE™ VSC cask was calculated by focusing on the effect of the smaller air flow passage around the MSB (i.e., 2-inch-wide vs. 4-inch-wide for the standard VSC). The natural convection air flow into the VSC and around the MSB is dictated by two forces acting against each other. They are (1) the air buoyancy effect from the temperature difference between the VSC air inlet and outlet, and (2) air drag forces associated with the labyrinth flow passage inside the VSC and friction. The first force is responsible for creating an air flow through the VSC while the second force reduces this air flow. An adequate air flow will remove the SNF decay heat without exceeding fuel storage cladding and/or shielding temperature limits.

A simplified spreadsheet calculation of the two forces and their effect on air flow and exit air temperature was performed for the standard and DUCRETE™ VSC with a 24-kW decay heat load. The smaller air flow passage around the MSB in the DUCRETE™ cask increased air flow resistance by about 20 percent which resulted in a 7 °F increase in the exit air temperature, from 175 °F in the standard VSC to 182 °F in the DUCRETE™ VSC. This increase, reflected in a 7 °F increase in the fuel clad temperature, is deemed to be insignificant. The higher decay heat (i.e., 27.36 kW) of the MPC system would increase fuel temperatures, but is expected to be offset by the presence of borated aluminum plates in the MPC SNF basket which, along with criticality control, will enhance heat conduction from the fuel to the basket walls. Therefore, the thermal performance of the DUCRETE™ VSC cask is expected to be similar to the standard VSC system.

A qualitative structural evaluation of the DUCRETE™ VSC system concludes that the higher density and smaller shield wall thickness of the DUCRETE™ cask (10.5 in. thick as compared to 29 in. for the standard concrete cask) will make it as strong as the standard cask and will not require the use of rebar in the DUCRETE™.

Radiological evaluation of DUCRETE™ showed that even if all the neutrons released by the SNF were absorbed in the U-238 present in DUCRETE™, the total Pu-239 produced over 40 years would be 10 to 100 microcuries. This corresponds to a concentration which is 100,000 times smaller than the Class-A LLW limit. The estimated DUCRETE™ surface neuron and gamma dose rate is about 0.21 mrem/hr, which would be greatly reduced by the presence of an outer cask steel shell. Measured surface dose rates from samples of DUCRETE™ were 12 to 16 mrem/hr composed mostly of charged particles that are absorbed in the steel shell.

This conceptual design study of a DUCRETE™ VSC cask presented results of shielding and thermal calculations and structural and radiological evaluations. The study determined that all structural, thermal, and radiological design criteria could be met using DUCRETE™ shielding. For a 100-ton cask weight limit, the optimum DUCRETE™ shield used colemanite sand, 45%-50% fraction of UO_2, 73% TD UO_2, and was 10.5 in. thick with a resulting cask surface dose rate of from 50 to 100 mrem/hr depending on the specific SNF source term.

A.4 Shielding Designs and Depleted Uranium Consumption

Tables A.10 - A.12 summarize shielding designs and their consumption of depleted uranium. The cylindrical designs use less depleted uranium than the HSMs. Also, uranium metal shielding requires around three times the weight of uranium dioxide or carbide shielding. However, use of a

3-in. or so polyethylene neutron shield with uranium metal reduces uranium usage to approximately the same value for all of the designs.

Table A.1: Material Shielding Properties

Shield Material	Total Density (gram/cc)	Elemental Composition
Uranium Metal	19.05	100%U
Uranium Carbide	13.6	95%U; 4%C
Uranium Dioxide	10.96	88%U; 12%O
DUCRETE™ 1:2:9	6.25	0.12%H; 21.34%O; 0.11%Mg; 0.27%Al; 8.55%Si; 0.05%S; 3.29%Ca; 0.15%Fe; 66.11%U
DUCRETE™ 1:2:18	7.53	0.07%H; 17.28%O; 0.06%Mg; 0.15%Al; 4.8%Si; 0.03%S; 1.88%Ca; 0.09%Fe; 75.56%U
85%UO2-15%C	9.6	15%C; 10%O; 75%U
85%UC-15%C	11.8	19%C; 81%U
Concrete	2.3	Built into Computer Codes
Stainless Steel	7.87	Built into Computer Codes
Air	0.001	80%N; 20%O or Built into Codes
Fuel-Air-Basket	2.13	9%O; 22%Fe; 69%U

Table A.2: Standardized NUHOMS-24P Gamma Source Term

Energy (Mev) Maximum	Energy (Mev) Average	Source (Photons/Second)
10	9.0	1.951 E+6
8.0	7.25	1.706 E+7
6.5	5.75	1.480 E+8
4.0	3.5	2.041 E+11
3.0	2.75	1.597 E+12
2.5	2.25	5.173 E+13
2.0	1.83	1.040 E+14
1.33	1.17	6.372 E+15
1.0	0.9	1.557 E+16
0.6	0.5	6.892 E+16
0.4	0.35	2.596 E+15
0.3	0.25	4.475 E+15
0.2	0.15	5.442 E+15
0.15	0.10	6.312 E+16

Table A.3: NUHOMS-24P HSM Gamma Equivalent Dose Rate Shielding Thickness (EDRST)

NUHOMS-24P HSM Shield Material	Gamma EDRST (in.)
Uranium (U)	3.4
Uranium Carbide (UC)	4.8
85% Uranium Carbide - 15% Carbon	5.9
Uranium Dioxide (UO_2)	6.2
85% Uranium Dioxide - 15% Carbon	7.4
Uranium + 6 Inches of Concrete	8.9 (2.9 + 6.0)
DUCRETE™ 1:2:18 (UO_2 Aggregate)	9.4
Uranium Carbide + 6 Inches Concrete	10.2 (4.2 + 6.0)
DUCRETE™ 1:2:9 (UO_2 Aggregate)	11.6
DUCRETE™ 1:2:18 + 6 Inches Concrete	13.9 (7.9 + 6.0)
DUCRETE™ 1:2:9 + 6 Inches Concrete	15.8 (9.8 + 6.0)
Concrete	36.0

Table A.4: Standardized NUHOMS-24P Neutron Source Term

Energy (Mev)		Source (Neutrons/Seconds)
Maximum	Average	
14.92	13.56	2.513 E+6
12.2	11.1	1.017 E+7
10.0	9.09	3.108 E+7
8.18	7.27	1.039 E+8
6.36	7.06	2.160 E+8
4.96	4.51	2.794 E+8
4.06	3.535	5.908 E+8
3.01	2.735	4.754 E+8
2.465	2.405	1.128 E+8
2.35	2.09	6.242 E+8
1.83	1.47	1.128 E+9
1.11	0.83	1.037 E+9
0.55	0.3305	7.166 E+8
0.111	0.0555	7.263 E+7

Table A.5: NUHOMS-24P HSM Neutron Equivalent Dose Rate Shielding Thickness

NUHOMS-24P HSM Shield Material	**Neutron EDRST (in.)**
Uranium (U)	18.9
Uranium Carbide (UC)	18.3
85% Uranium Carbide - 15% Carbon	11.5
Uranium Dioxide (UO_2)	19.3
85% Uranium Dioxide - 15% Carbon	13.3
DUCRETE™ 1:2:18 (UO_2 Aggregate)	18.5
DUCRETE™ 1:2:9 (UO_2 Aggregate)	18.7
Concrete	36.0

Table A.6: Shield Material Thermal Conductivity and Temperature Limits

Shield Material	Thermal Conductivity (BTU/Hr-FT-F)	Temperature Limit (°F)
Concrete	3.64 (with 10% rebar)	250
Uranium (U)	15.8 @ 200F	>1000
Uranium Carbide (UC)	14.8 @ 200F	>>1000
Uranium Dioxide (UO_2)	4.5 @ 200F	>>1000
DUCRETE™ 1:2:9	5.8 (with 10% rebar)	~250
DUCRETE™ 1:2:18	6.2 (with 10% rebar)	~250
Carbon (c)	26.6 @ 70F	>>1000
85% UC - 15% C	16.5	>>1000
85% UO_2 - 15% C	7.8	>>1000

Table A.7: NUHOMS-24P HSM Depleted Uranium Shielding Heat Conduction Factors (HCFs)

Shield Material	Heat Conduction Factor (HCF) (BTU/Hr-F)	Relative HCF
Concrete	1.213	1.00
Uranium (U)	10.03	8.27
Uranium Carbide (UC)	9.70	8.00
Uranium Dioxide (UO_2)	2.80	2.31
DUCRETE™ 1:2:18	4.02	3.32
DUCRETE™ 1:2:9	3.72	3.07
85% UC - 15% C	17.22	14.19
85% UO_2 - 15% C	7.04	5.80
Optimized DUCRETE™	4.65	3.83
Optimized Uranium Metal/Alloy	11.15	9.19
Optimized 85% UC - 15% C	19.8	16.32
Optimized 85% UO_2 - 15% C	7.8	6.43

Table A.8: Weights of the Major Components in the Depleted Uranium MPU

Component	Estimated Weight (lb)
Cask Body	126,000
- U Metal	94,700
- Alloy 825	5,650
- 304 L SST	25,650
Main Lid (Incl. Depleted Uranium Shield Plug)	11,000
Polyethylene Shield	6,200
Basket Assembly	9,000
Impact Limiters	8,000
Payload of SNF	32,300 (33,500 BWR)
Handling Equipment	2,500
Railcar	45,000
Skid	11,500
Water	10,000

Table A.9: Total Estimated Operational Weights for the Depleted Uranium MPU

Operation Function	Total Weight - lb (tons)
Crane Hook Load	192,000 (96)
Dry Storage Weight	185,700 (93)
Gross Vehicle Weight	290,000 (125)

Table A.10: Material Usage by HSM Designs

Material	Standard HSM	HSM-DUCRETE™	HSM-Depleted UO_2/C	HSM-Depleted UC/C
depleted uranium Component	None	139 te UO2	132 te UO2	136 te UC
Cement	In Concrete	8 te	None	None
Concrete	153 te (1)	25 te (2)	25 te	25 te
Steel	18 te	< 18 te (3)	< 18 te	< 18 te
Total (4)	171 te	<190 te	< 175 te	< 179 te

1. Concrete weight for the Standard NUHOMS includes the weight of the basemat.
2. Concrete weight for the HSM-DUCRETE™, HSM-depleted UO2/C, and HSM-depleted UC-C is estimated for the basemat only.
3. Steel weight includes rebar, which may not be necessary for the DUCRETE™ cask and will not be used for the depleted UO2/C and depleted UC/C HSMs, but is bounding since the outer and inner steel liner thickness is not yet known.
4. Total weight is only for the HSM and does not include a loaded DSC, which is the cylindrical steel basket encapsulating the SNF that is placed inside the HSM. The loaded weight of the DSC is approximately 30 te.

Table A.11: Depleted Uranium Metal Usage by Various Designs

Material	HSM-Depleted Uranium Metal/Alloy	MPC (2)	MPU (2)	Depleted Uranium MPU (2) (Large Only)
Uranium Metal	437 te	1.8 te (Large) 1.2 te (Small)	1.8 te (Large) 1.2 te (Small)	43 te
Concrete	25 te (Basement)	None	None	None
Steel	not included	97 te (Large) 59 te (Small)	97 te (Large) 59 te (Small)	19 te
Total	462 te (1)	114 te (Large) 68 te (Small)	114 te (Large) 82 te (Small)	90 te

1. Total weight of HSM-depleted uranium Metal/Alloy does not include weight of loaded DSC canister which encapsulates the SNF and is placed inside the HSM. The loaded DSC weighs approximately 30 te.

2. MPC and MPU weights include basket, SNF, impact limiters, etc.

Table A.12: Material Usage by VSC Designs

Material	Standard VSC	VSC - DUCRETE™ (1)
Depleted UO_2	None	44 te
Cement	In Concrete	5.5 te
Concrete	69 te	None
Steel	22 te	< 22 te (1)
Colemanite Sand	None	7 te
Total (2)	92 te	< 64.5 te

1. Steel weight will depend on whether rebar is needed for the DUCRETE™ shield, since it will be encased in steel liners and has a much smaller thickness than the standard VSC concrete shield wall.

2. Total is only for the shield enclosure (VCC) component of the VSC; the total weight of the VSC includes the fuel encapsulating MSB basket cylinder, which weighs approximately 20 te with its SNF contents.

Figure A.1: The NUHOMS-24P Horizontal Storage Module Components

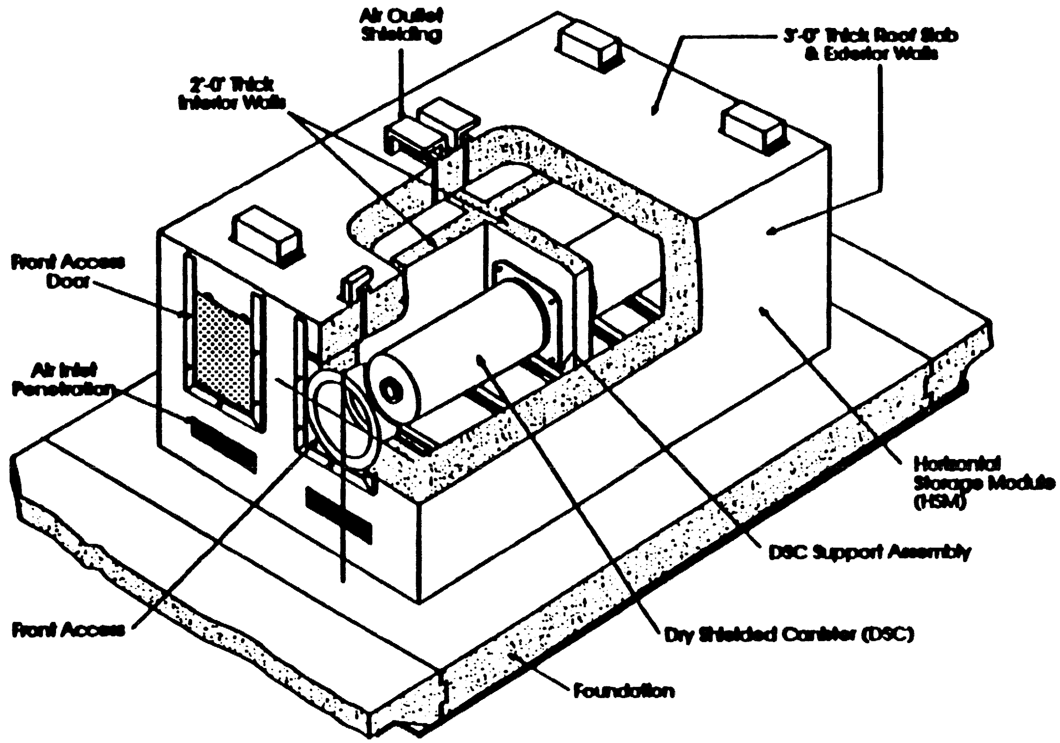


Figure A.2: Depleted Uranium Shielding Dose Rate for NUHOMS-24P Source Term

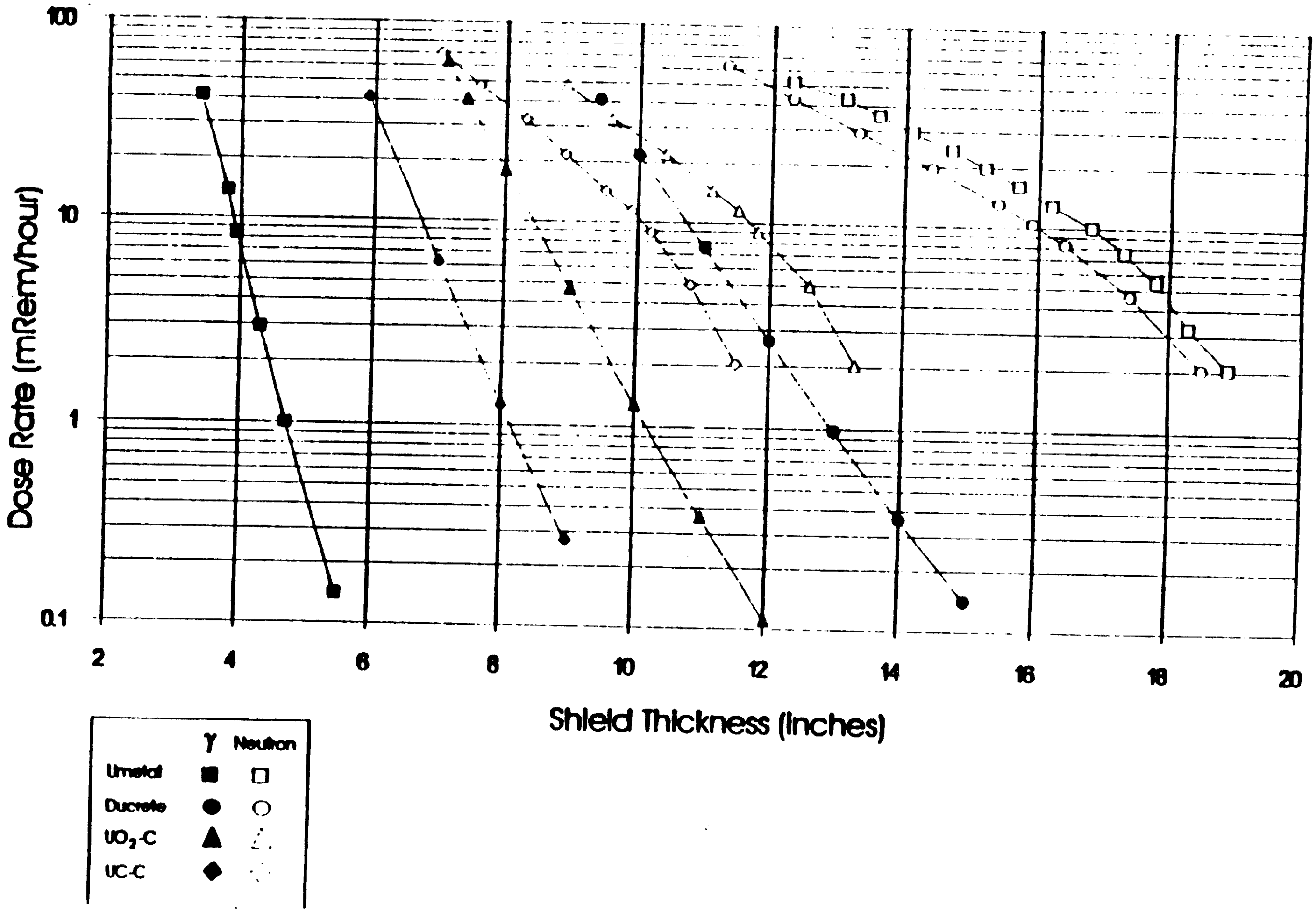


Figure A.3: Large 21 PWR MPC (End Section View - U.S. DOE, 1994)

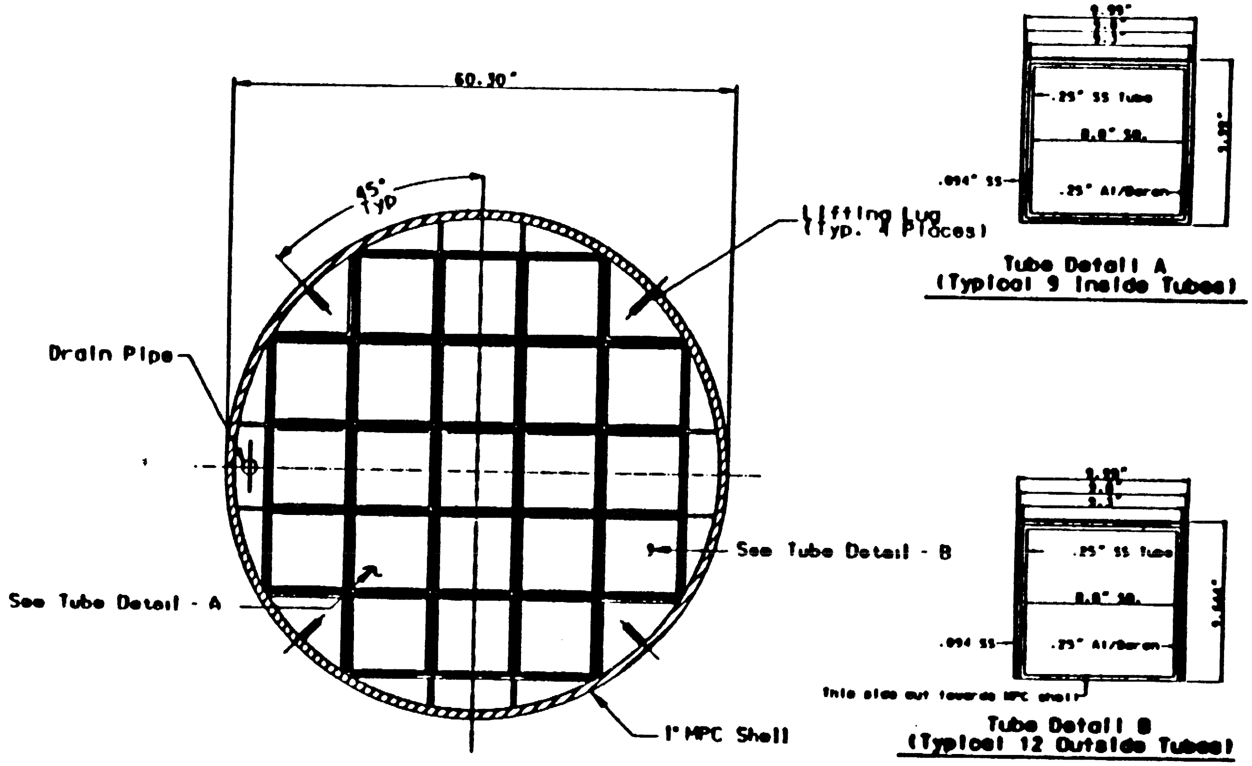


Figure A.4: Large 21 PWR MPC (Side Section View - U.S. DOE, 1994)

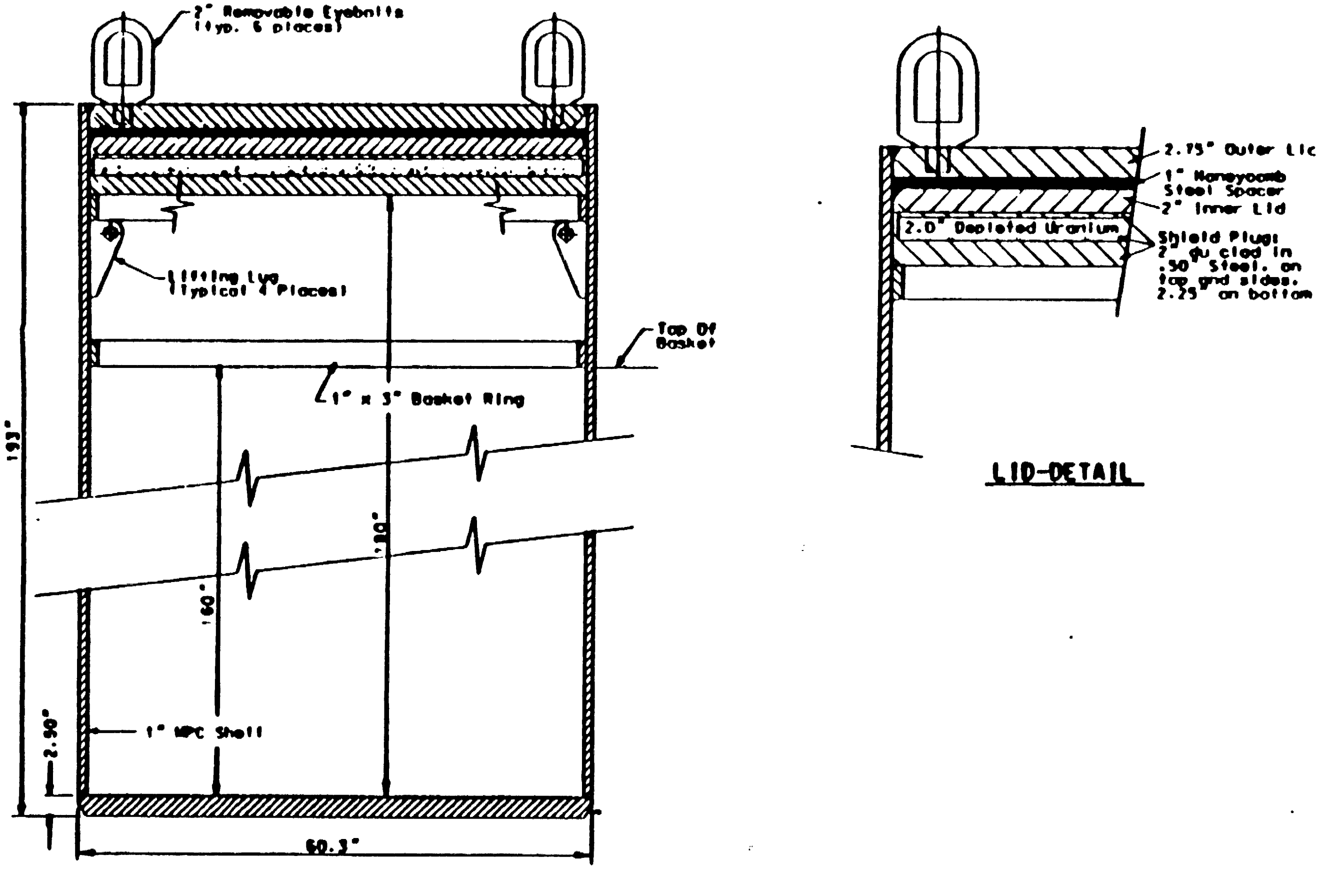


Figure A.5: Small 12 PWR MPC (End Section View - U.S. DOE, 1994)

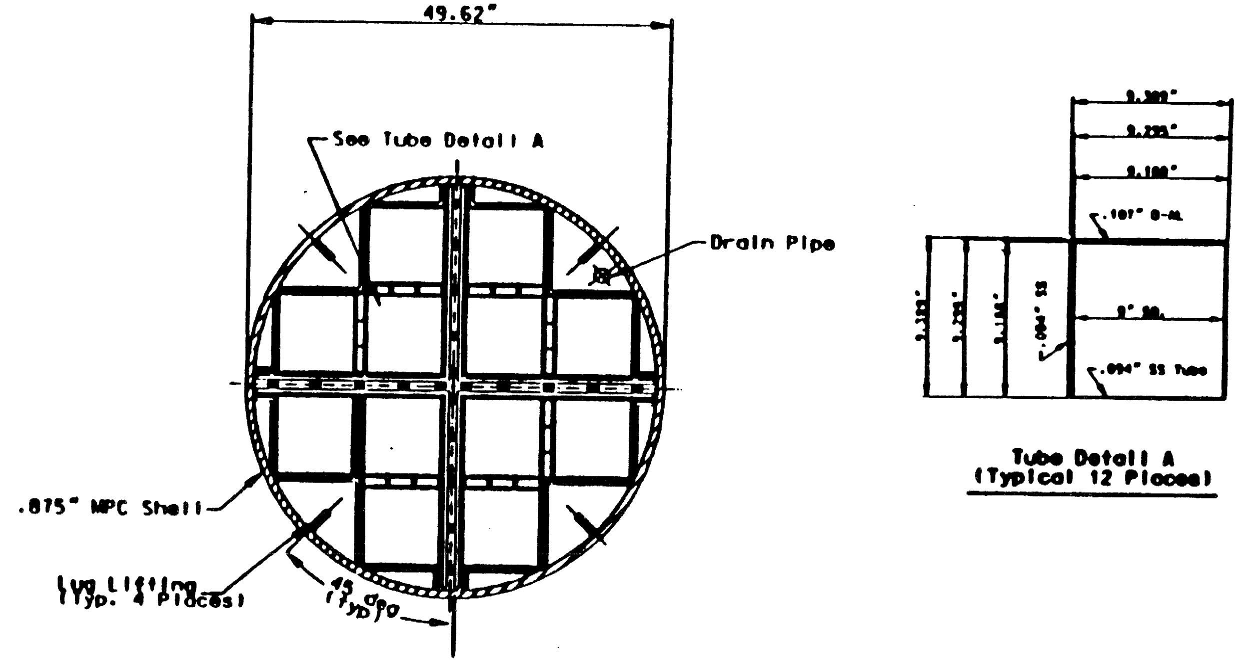


Figure A.6: Small 12 PWR MPC (Side Section View - U.S. DOE, 1994)

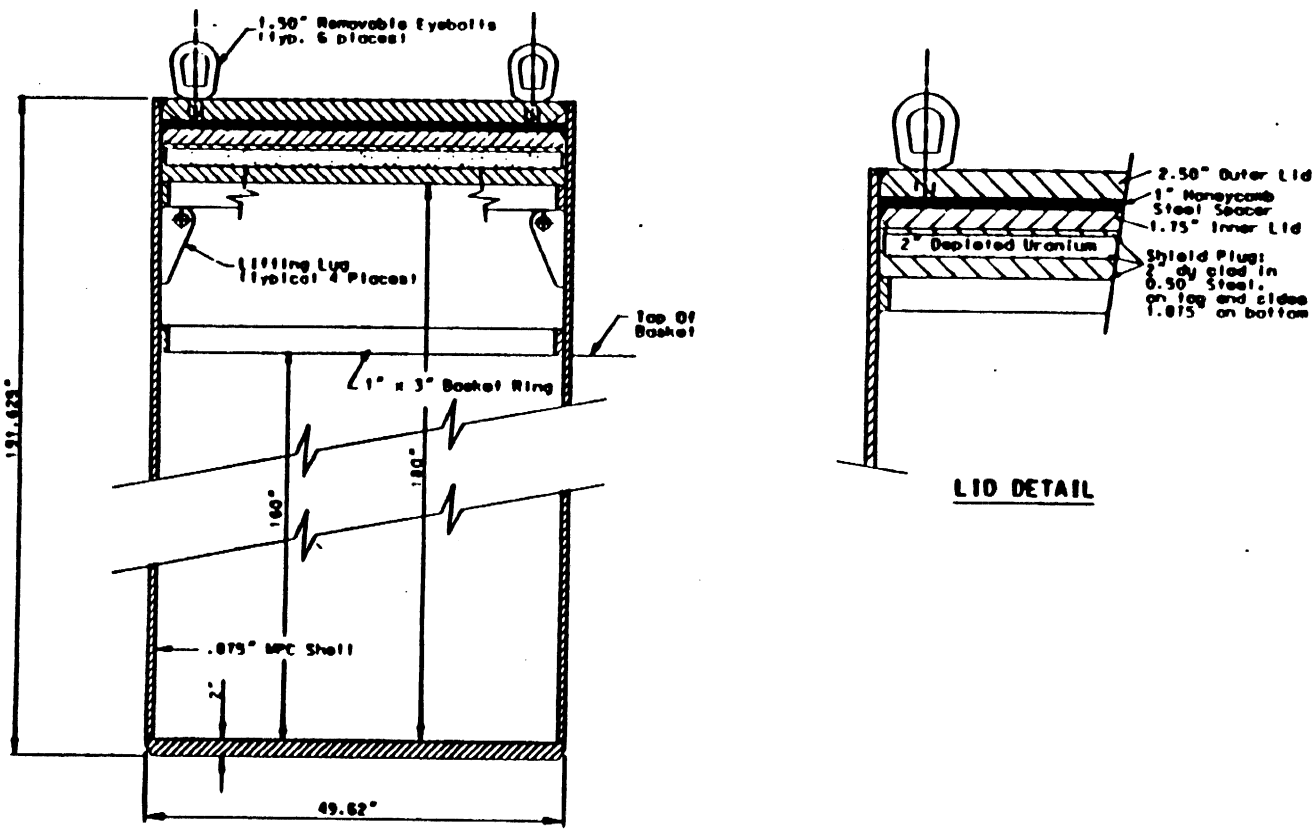


Figure A.7: Large Transportation Cask (Side Section View - U.S. DOE, 1994)

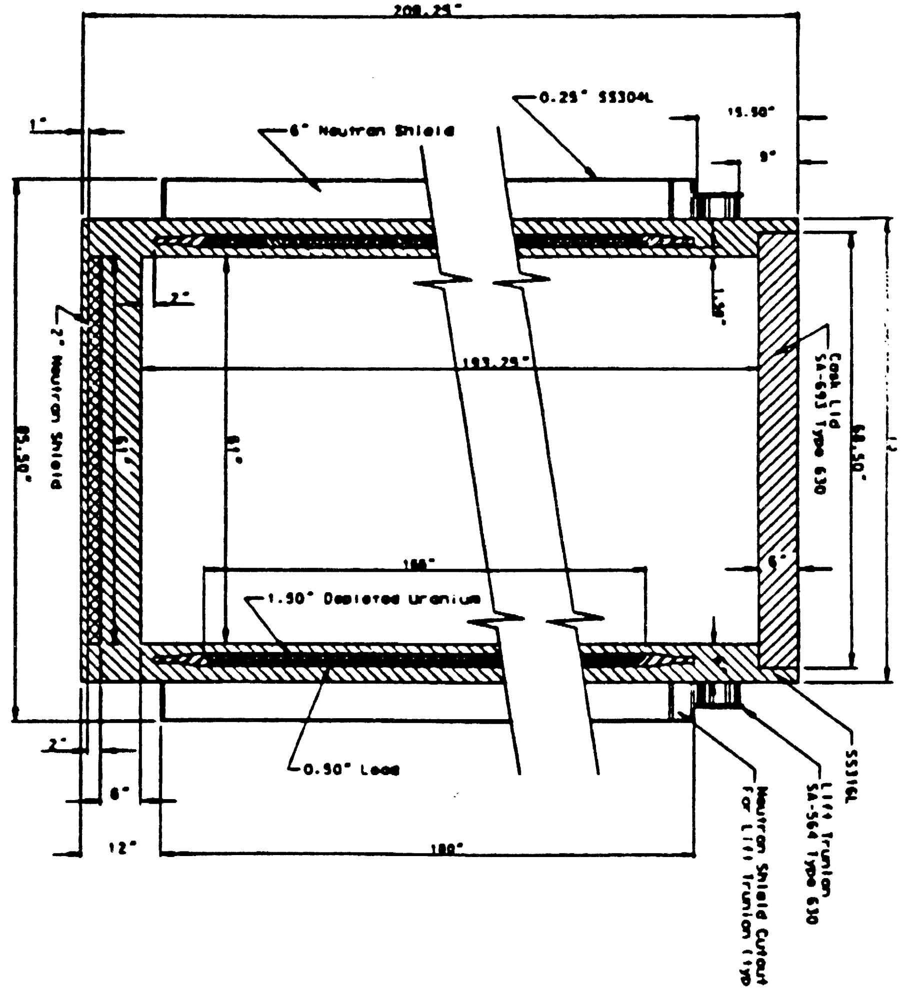


Figure A.8: Large Transportation Cask (Top Section View - U.S. DOE, 1994)

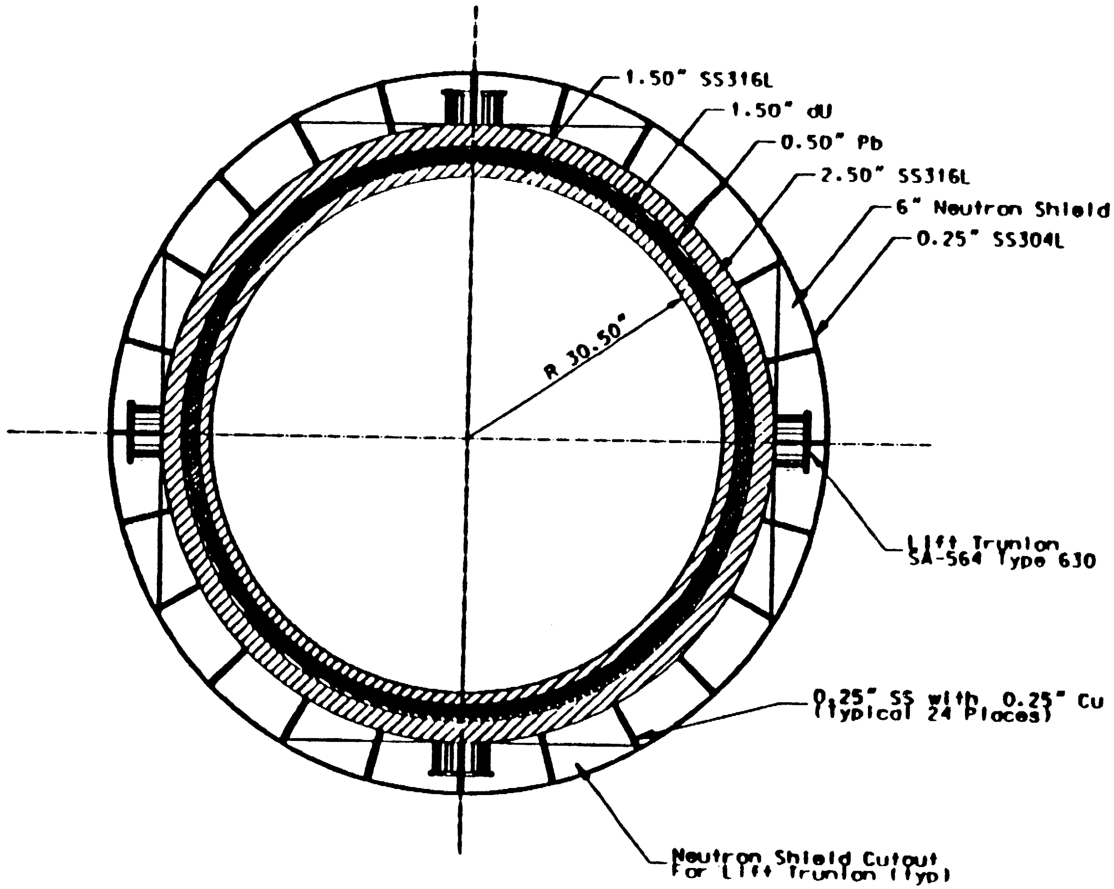


Figure A.9: Small Transportation Cask (Side Section View - U.S. DOE, 1994)

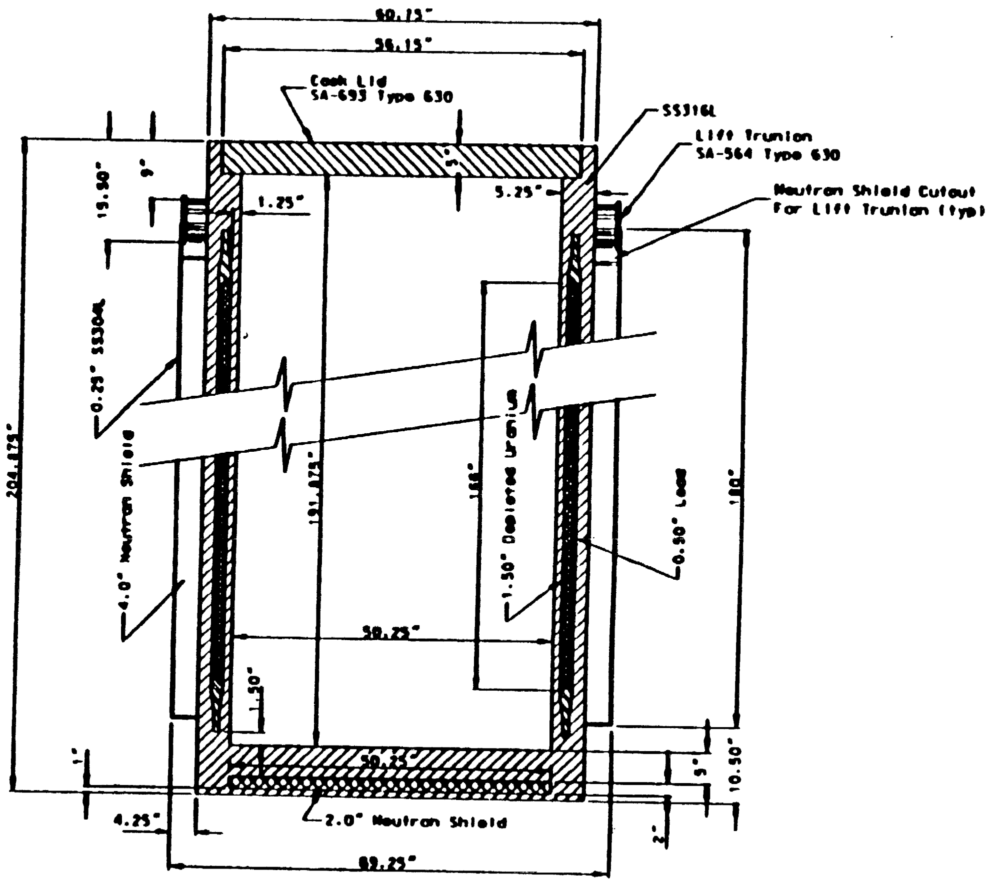


Figure A.10: Small Transportation Cask (Top Section View - U.S. DOE, 1994)

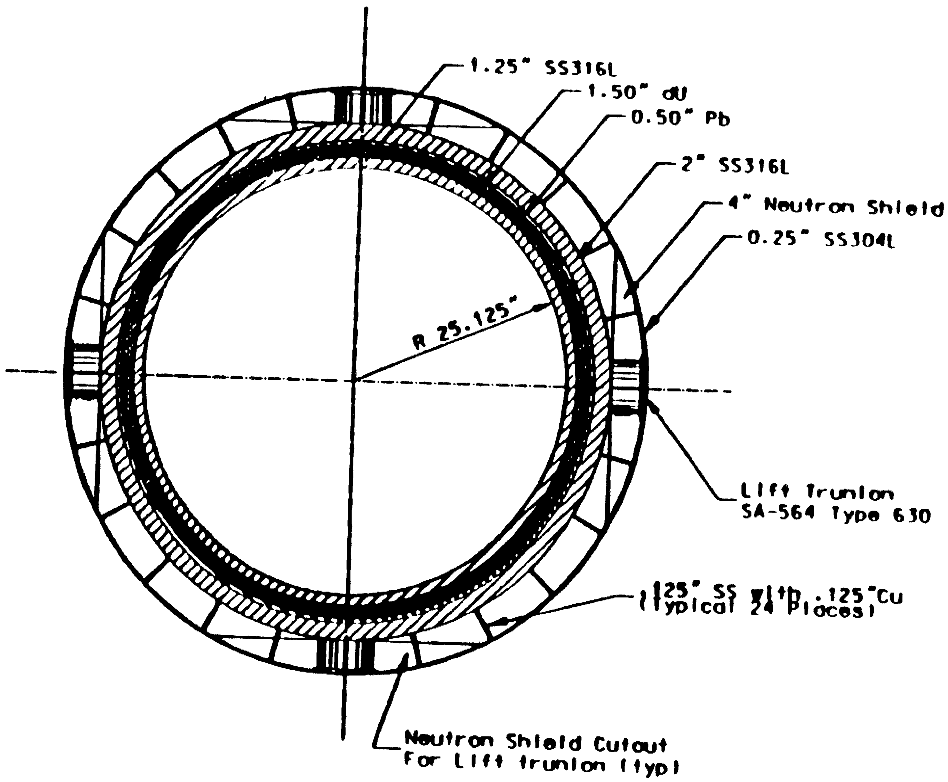


Figure A.11: 100-Ton TSC Metal Cask for 21 PWR Fuel Assemblies (End Section View - U.S. DOE, 1994)

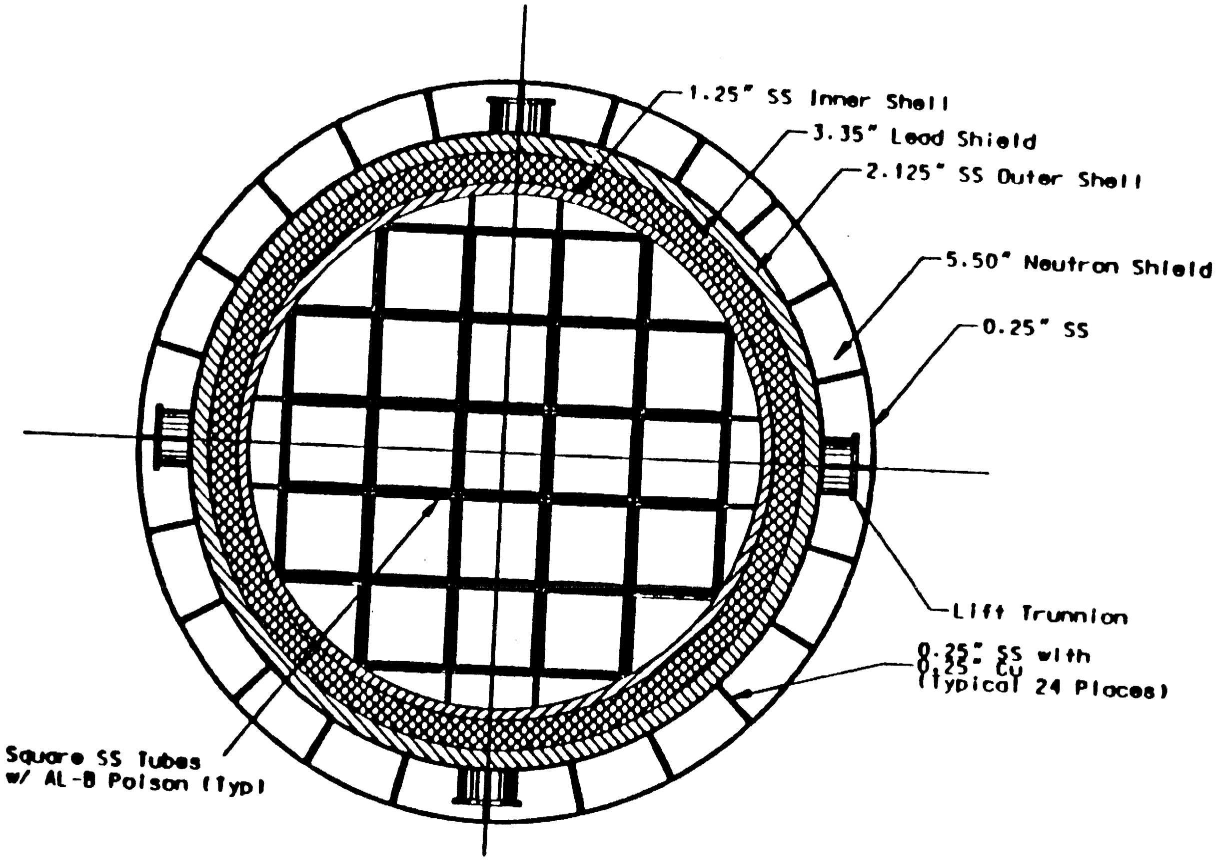


Figure A.12: 100-Ton TSC Metal Cask (Side Section View -U.S. DOE, 1994)

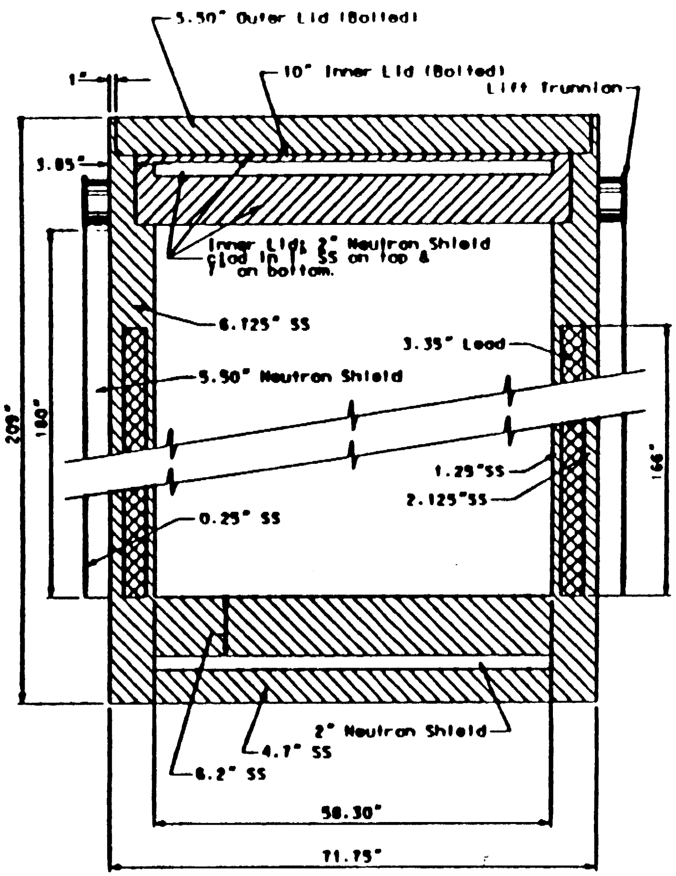


Figure A.13: 75-Ton TSC Metal Cask For 12 PWR Fuel Assemblies (End Section View - U.S. DOE, 1994)

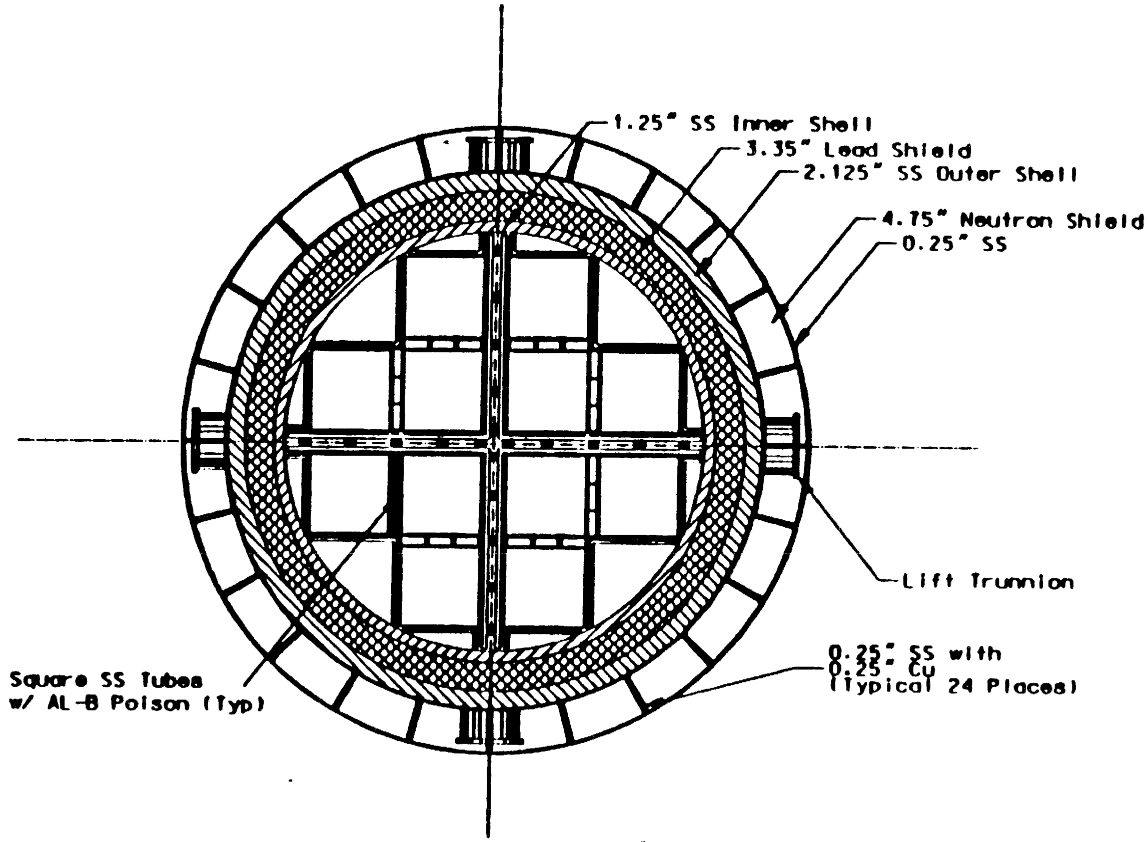


Figure A.14: 75-Ton TSC Metal Cask (Side Section View -U.S. DOE, 1994)

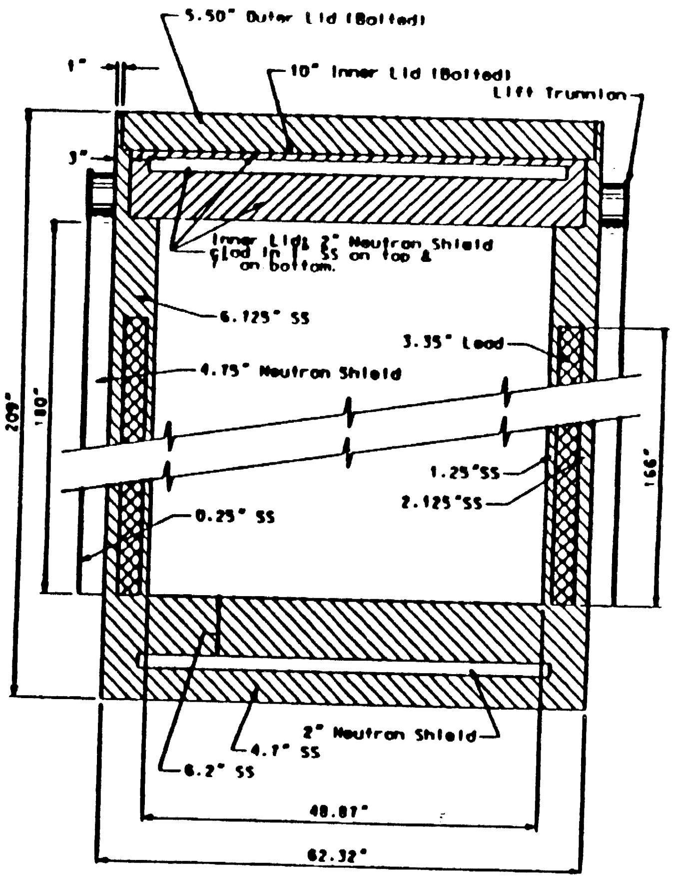


Figure A.15: 125-Ton MPU For 21 PWR Fuel Assemblies (End Section View - U.S. DOE, 1994)

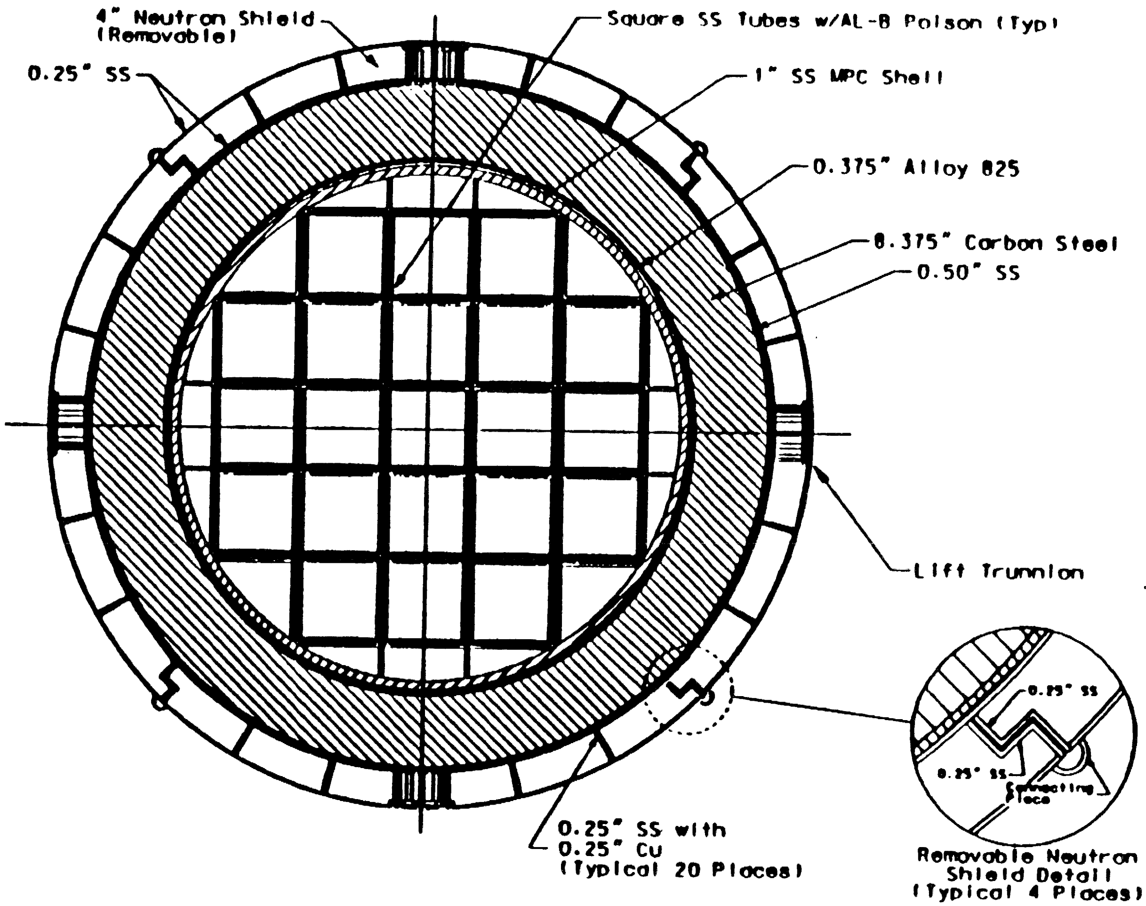


Figure A.16: 125-Ton MPU Outer Body (Side Section View -U.S. DOE, 1994)

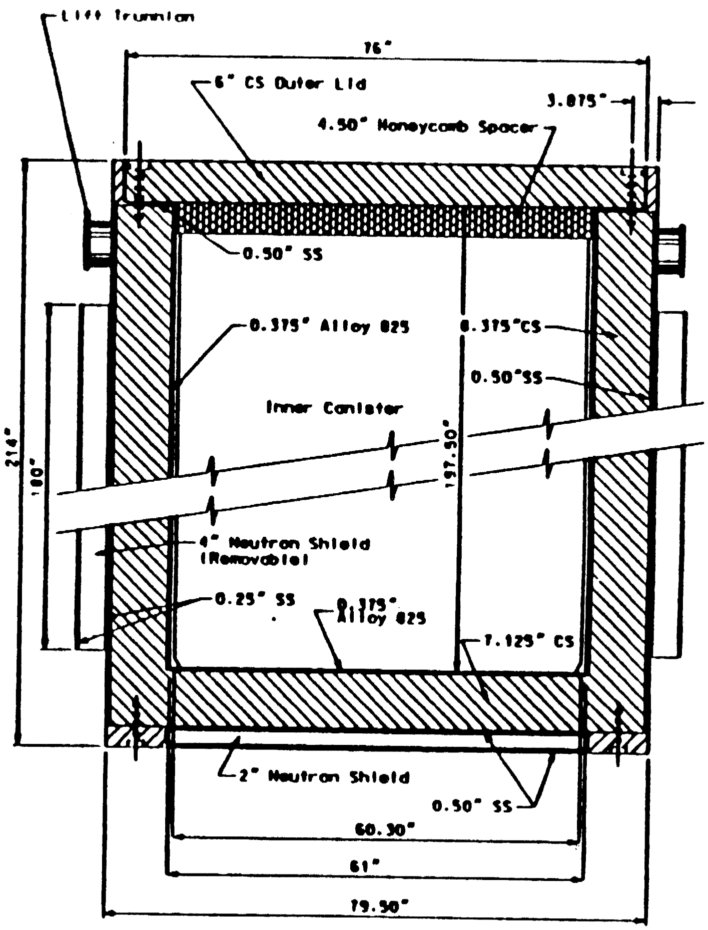


Figure A.17: 125-Ton MPU Inner Canister (Side Section View -U.S. DOE, 1994)

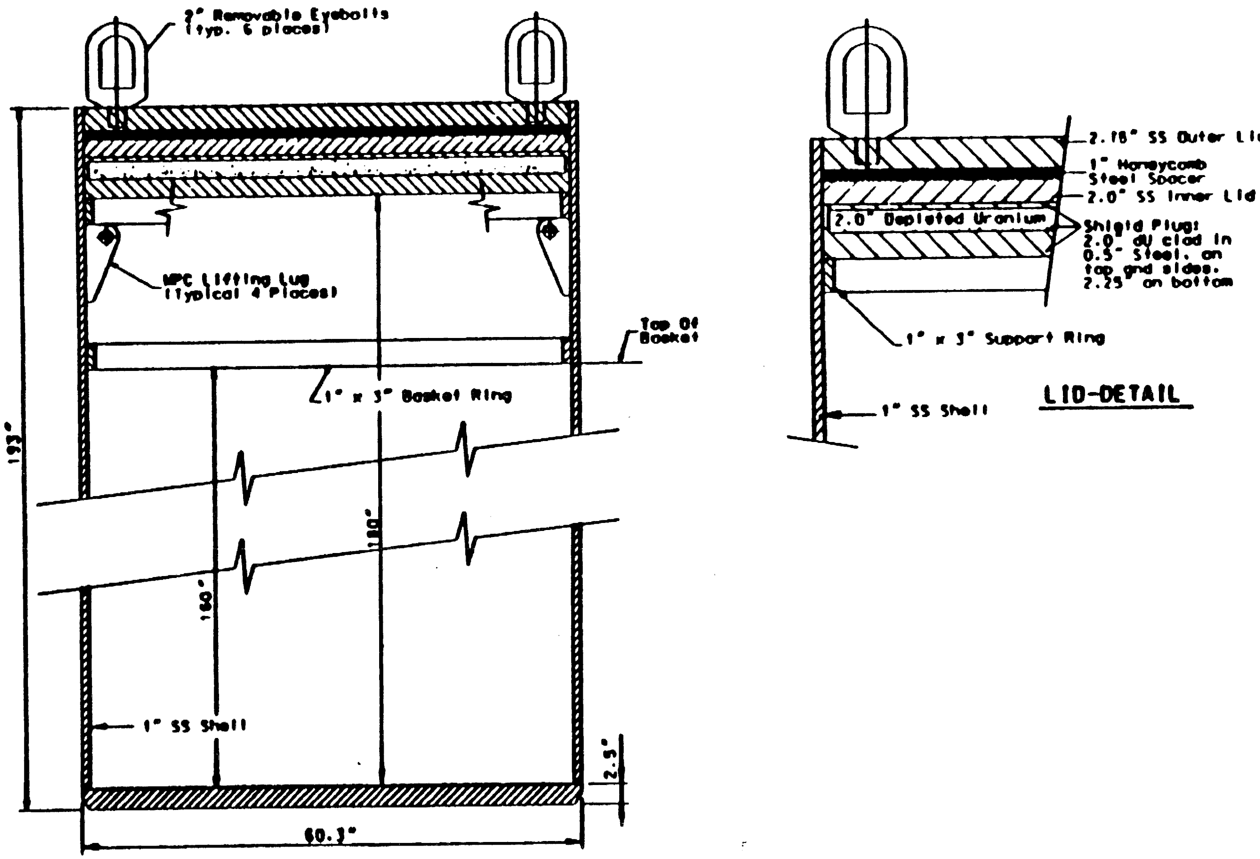


Figure A.18: 90-Ton MPU For 12 PWR Fuel Assemblies (End Section View -U.S. DOE, 1994)

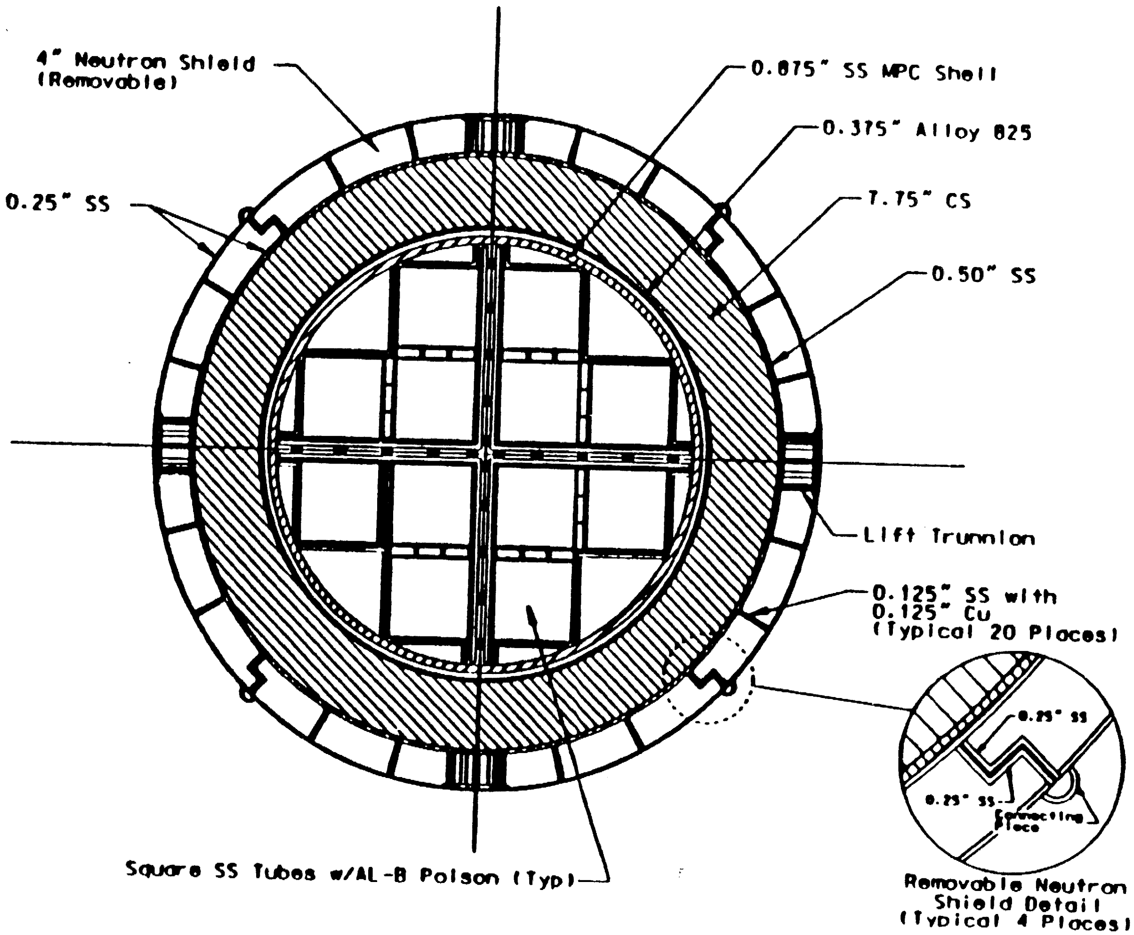


Figure A.19: 90-Ton MPU Outer Body (Side Section View -U.S. DOE, 1994)

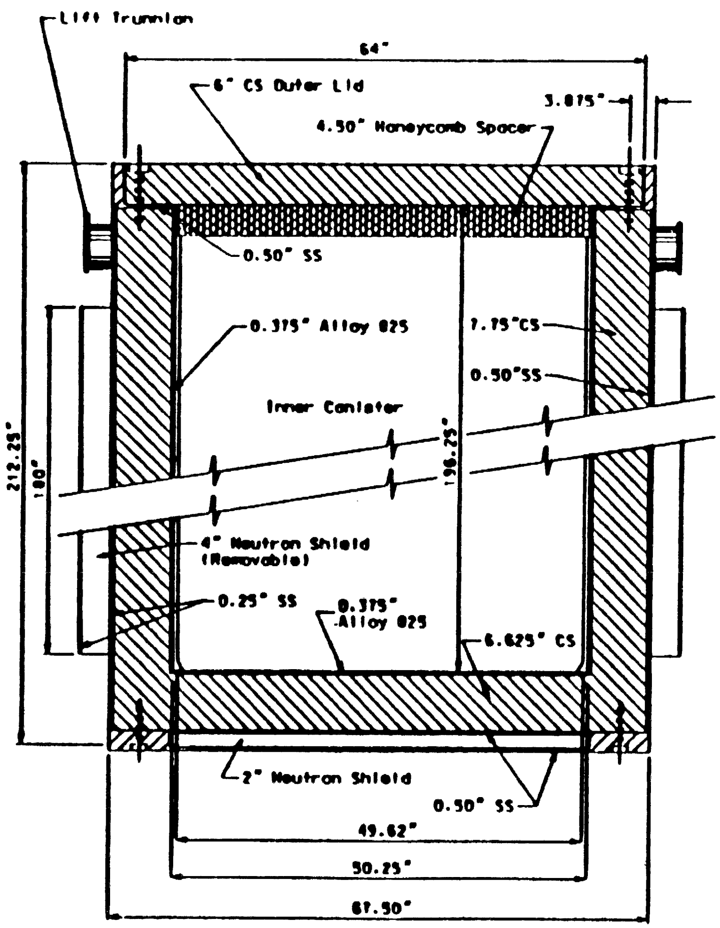


Figure A.20: 90-Ton MPU Inner Canister (Side Section View -U.S. DOE, 1994)

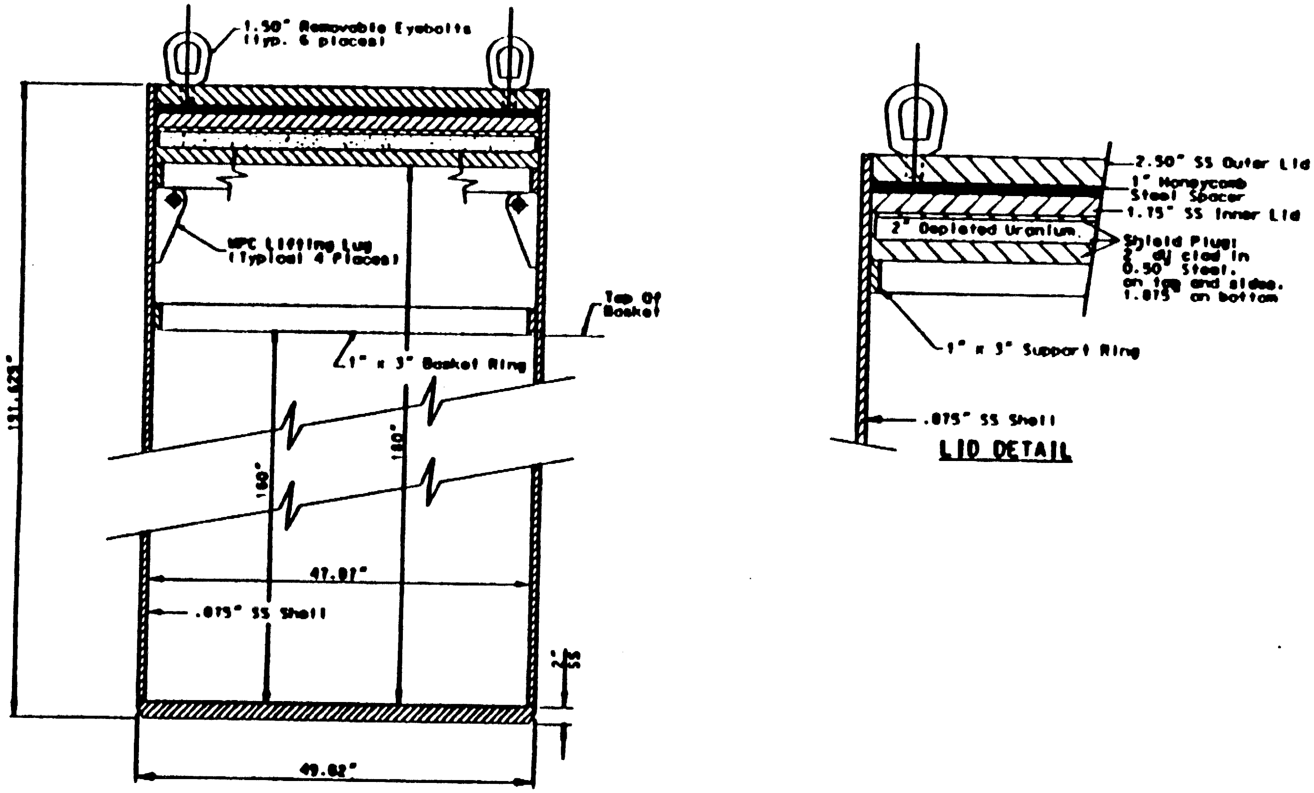


Figure A.21: Longitudinal Cross Section of Depleted Uranium Metal Shielded MPC ("Depleted Uranium MPU")

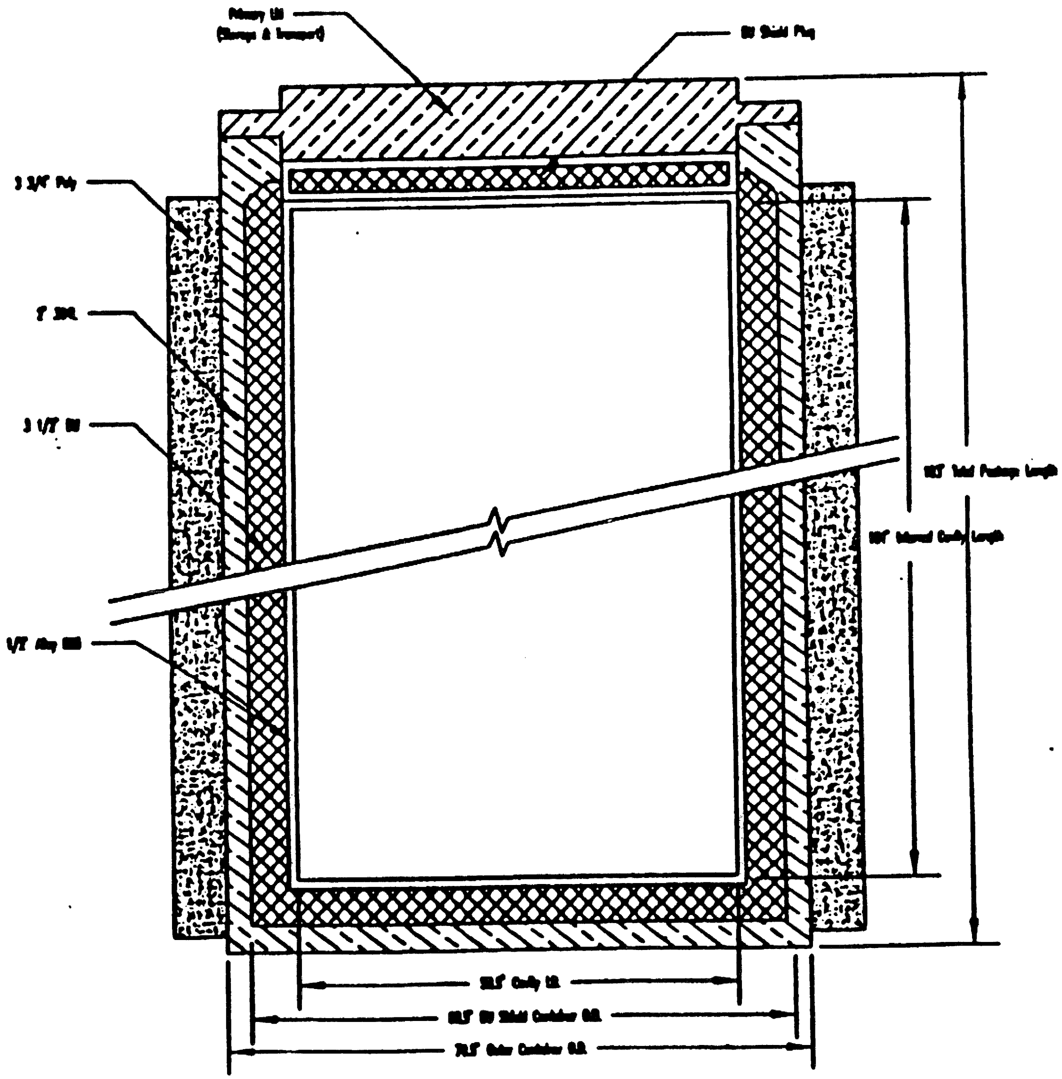


Figure A.22: Radial Cross Section of Depleted Uranium Metal Shielded MPC ("Depleted Uranium MPU")

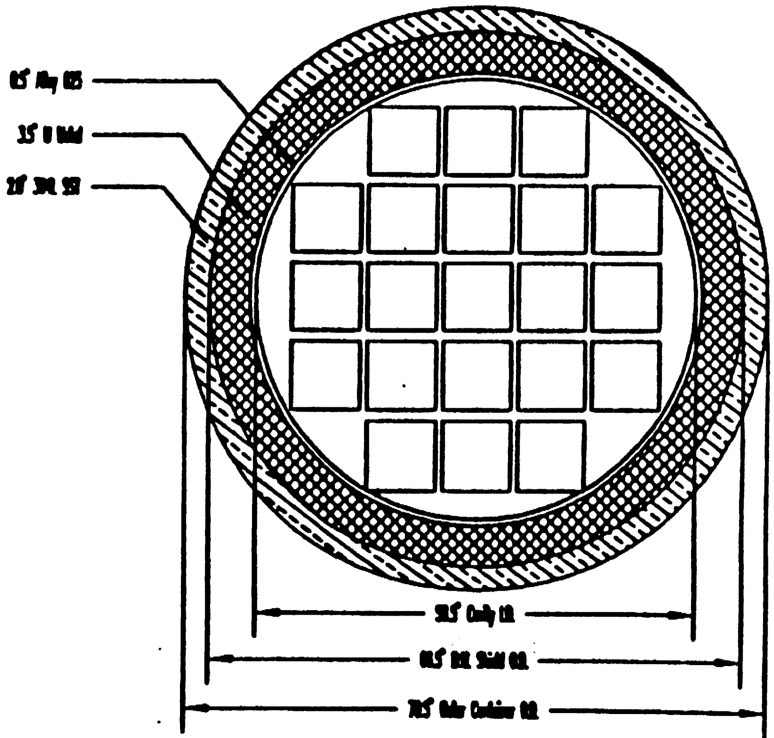


Figure A.23: Standard Ventilated Storage Cask System (VSC) Evaluated by INEL (Hopf, 1995)

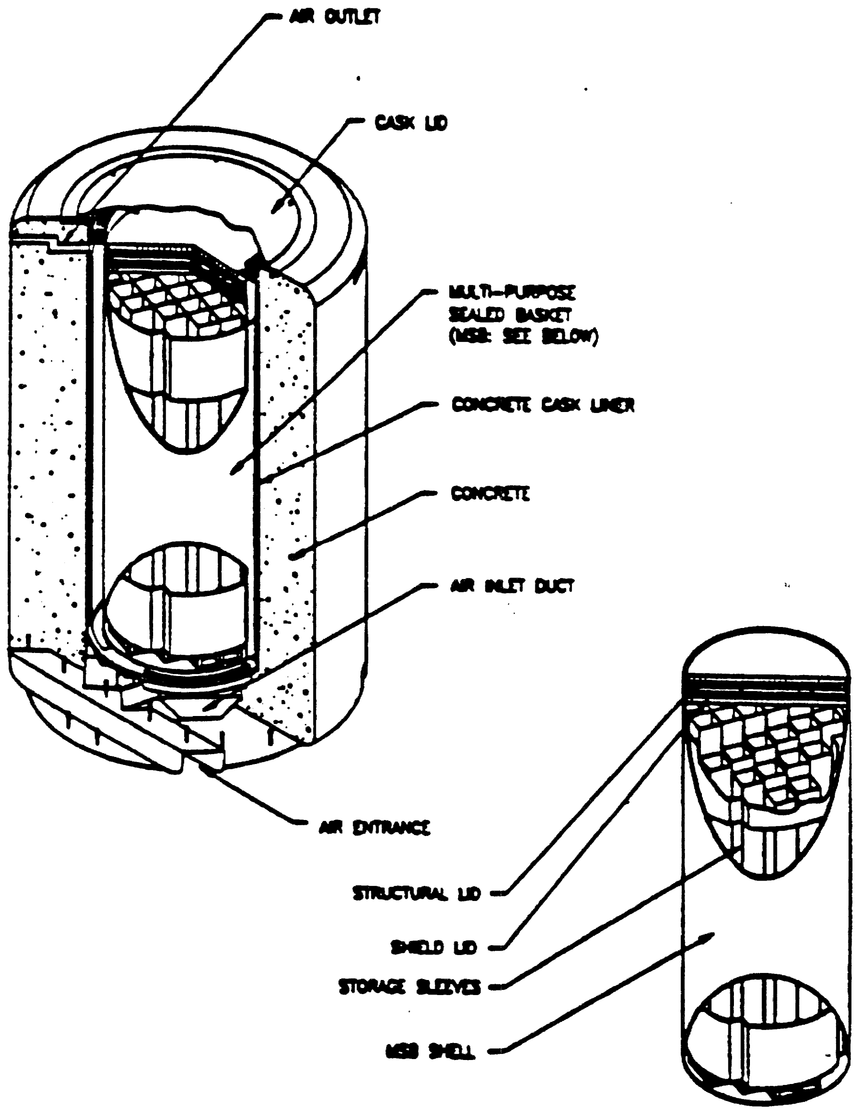
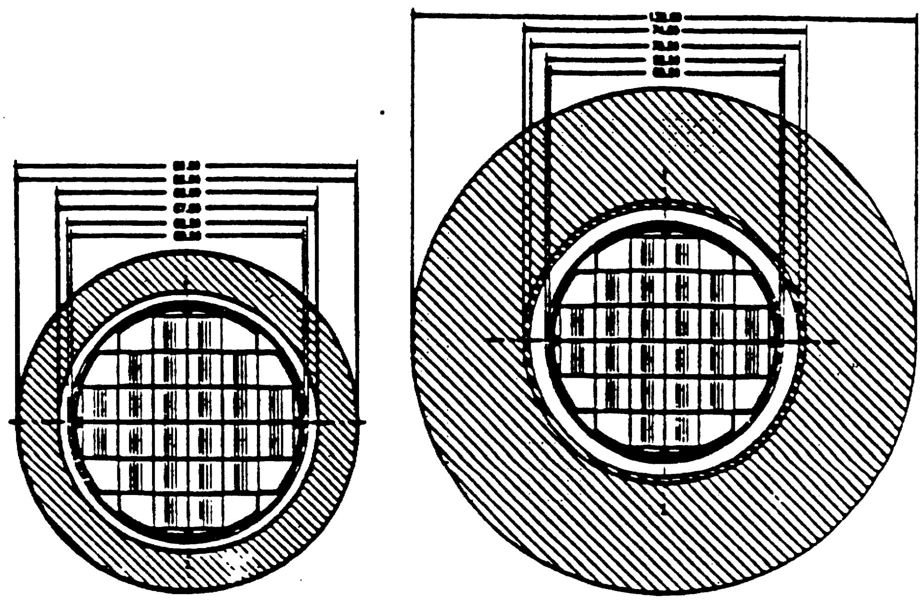


Figure A.24: **Horizontal Cross Sections of DUCRETE™ Cask (left) and the Standard VSC Storage Cask (right) (Hopf, 1995)**



Appendix B

Equipment Lists for the Low Temperature Shielding Manufacturing Facility (LTSMF)

Appendix B: Equipment Lists for the Low Temperature Shielding Manufacturing Facility (LTSMF)

Table B.1: Equipment List for the Shielding Cask Assembly Building (SCAB)

Item/Description	Number
150-te Bridge Crane	3
Tool Cart/Supplies	1 Lot
Shielding Cask Assembly Stations	21
Computers/LAN	10
12.6 kW UPS/UBS	1
Miscellaneous Installation	1 Lot
Total Building Charge	50,106 ft^2

Table B.2: Equipment List for the Main Processing Building (MPB)

Item/Description	Number
150-te Bridge Crane	4
High Shear Mixers	4
Cement Hoppers	6
Vibratory Feeders	12
Ultrasonic Equipment	4
Total Building Charge	98,027 ft^2

Table B.3: Equipment List for the Shielding Cask Product Storage Building (SCPSB)

Item/Description	Number
150-te Bridge Crane	1
12.6 kW UPS/UBS	1
Computers/LAN	2
Miscellaneous Installation	1 Lot
Total Building Charge	53,777 ft^2

Table B.4: Equipment List for the General Warehouse and Storage Building (GWSB)

Item/Description	Number
20-te Bridge Cranes	2
Computers/LAN	10
Barcode Readers	6
12.6 kW UPS/UBS	1
Installation Estimate for Above	1 Lot
Building Charge	72,226 ft^2

Table B.5: Equipment List for the Waste Management Building (WMB)

Item/Description	Number
Tanks, FRP/Propylene, 5,000 gal	4
Pumps, Propylene, 100 gpm, 50 psig	4
Tanks, SS316L, 5,000 gal	8
Pumps, SS316L, 100 gpm, 50 psig	8
Ion Exchange Vessels, 6 ft each	18
Piping, Propylene, 2 in., Sch., 40	300
Piping, SS316L weld, 2 in., Sch., 40	600
Building Charge	62,022 ft^2

Table B.6: Equipment List for the Waste Management Building (WMB)

Item/Description	Number
20-te Bridge Crane	2
Computer/LAN	2
Barcode Readers	6
12.6 kW UPS/UBS	1
Installation Estimate	1 Lot
Building Charge	61,720 ft^2

Table B.7: Equipment List for the Utility Supply Building (USB)

Item/Description	Number
PSA Nitrogen Package, 700 SCFM @ 99%, 80 psig [362 kW(e)]	2
Installation	2
DI Water Systems, 15 gpm capacity, SS, 75 ft^3 vessels, 4 filters, 15,000-gal tank, 2 100-gpm pumps [2 kW(e) in operation]	5
Computer Stations	1
HP Instrumentation, hand held	10
Portal Monitors	2
7 kW UPS/UBS	1
12.6 kW UPS/UBS	1
Maintenance Area Equipment/Tools	1
100 kW Diesel Electric Generators (SPS)	2
Building Charge, ft^2	39,073 ft^2

Table B.8: Equipment List for the Health Physics and RCA Access Control Building (HPRACB)

Item/Description	Number
Computers/LAN	22
HP Portal Monitors	10
Assay/Counting Instrumentation	4
HP Hand held Instruments	50
12.6 kW UPS/UBS	2
Miscellaneous Installation Estimate	1 Lot
Building Charge	4,069 ft^2

Table B.9: Equipment List for the Emergency Services Building (ESB)

Item/Description	Number
Fire truck with extension ladder	2
Ambulances	2
Computer Stations, Installed	20
Building Charge, Low Hazard Facility	4,069 ft^2
12.6 kW UPS/UBS	1

Table B.10 Equipment List for the Administration and Technical Support Building (ATSB)

Item/Description	Number
Laboratory Instrumentation	1 Lot
Cafeteria Equipment	1
Computers Installed	62
5 kW UPS/UBS	1
12.6 kW UPS/UBS	1
Elevator	1
Site Telephone System	1
Building Charge, Standard Construction	20,441 ft^2

Appendix C

Equipment Lists for the High Temperature Shielding Manufacturing Facility (HTSMF)

Appendix C: Equipment Lists for the High Temperature Shielding Manufacturing Facility (HTSMF)

Table C.1: Equipment List for the Shielding Cask Assembly Building (SCAB)

Item/Description	Number
150-te Bridge Crane	3
Tool Cart/Supplies	1 Lot
Shielding Cask Assembly Stations	21
Computers/LAN	10
12.6 kW UPS/UBS	1
Miscellaneous Installation	1 Lot
Total Building Charge	50,106 ft^2

Table C.2: Equipment List for the Main Processing Building (MPB)

Item/Description	Number
150-te Bridge Crane	4
Vacuum Melting Furnaces	16
Soaking Pit	2
Vibratory Feeders	16
Ultrasonic Equipment	4
Total Building Charge	109,200 ft^2

Table C.3: Equipment List for the Shielding Cask Product Storage Building (SCPSB)

Item/Description	Number
150-te Bridge Cranes	1
12.6 kW UPS/UBS	1
Computers/LAN	2
Miscellaneous Installation	1 Lot
Total Building Charge	53,777 ft^2

Table C.4: Equipment List for the General Warehouse and Storage Building (GWSB)

Item/Description	Number
20-te Bridge Cranes	2
Computers/LAN	10
Barcode Readers	6
12.6 kW UPS/UBS	1
Installation Estimate for Above	1 Lot
Building Charge	72,226 ft^2

Table C.5: Equipment List for the Waste Management Building (WMB)

Item/Description	Number
Tanks, FRP/Propylene, 5,000 gal	4
Pumps, Propylene, 100 gpm, 50 psig	4
Tanks, SS316L, 5,000 gal	8
Pumps, SS316L, 100 gpm, 50 psig	8
Ion Exchange Vessels, 6 ft each	18
Piping, Propylene, 2 in., Sch., 40	300
Piping, SS316L weld, 2 in., Sch., 40	600
Building Charge	62,022 ft^2

Table C.6: Equipment List for the Radwaste/Storage Building (RSB)

Item/Description	Number
20-te Bridge Crane	2
Computers/LAN	2
Barcode Readers	6
12.6 kW UPS/UBS	1
Installation Estimate	1 Lot
Building Charge	61,720 ft^2

Table C.7: Equipment List for the Utility Supply Building (USB)

Item/Description	Number
PSA Nitrogen Package, 700 SCFM @ 99%, 80 psig [362 kWe)]	2
Installation	2
DI Water Systems, 15 gpm capacity, SS, 75 ft^3 vessels, 4 filters, 15,000-gal tank, 2 100-gpm pumps [kW(e) in operation]	5
Computer Stations	1
HP Instrumentation, hand held	10
Portal Monitors	2
7 kW UPS/UBS	1
12.6 kW UPS/UBS	1
Maintenance Area Equipment/Tools	1
100 kW Diesel Electric Generators (SPS)	2
Building Charge	39,073 ft^2

Table C.8: Equipment List for the Health Physics and RCA Access Control Building (HPRACB)

Item/Description	Number
Computers/LAN	22
HP Portal Monitors	10
Assay/Counting Instrumentation	4
HP Hand held Instruments	50
12.6 kW UPS/UBS	2
Miscellaneous Installation Estimate	1 Lot
Building Charge	4,069 ft^2

Table C.9: Equipment List for the Emergency Services Building (ESB)

Item/Description	Number
Fire truck with extension ladder	2
Ambulances	2
Computer Stations, Installed	20
Building Charge, Low Hazard Facility	4,069 ft^2
12.6 kW UPS/UBS	1

Table C.10 Equipment List for the Administration and Technical Support Building (ATSB)

Item/Description	Number
Laboratory Instrumentation	1 Lot
Cafeteria Equipment	1
Computers Installed	62
5 kW UPS/UBS	1
12.6 kW UPS/UBS	1
Elevator	1
Site Telephone System	1
Building Charge, Standard Construction	20,435 ft^2

Appendix D

Facility Wastes and Emissions

Appendix D: Facility Wastes And Emissions

Enriched or depleted uranium can be produced in the form of metallic uranium by converting depleted uranium hexafluoride (UF_6) to uranium tetrafluoride (UF_4). The Ames process has been the standard industrial method for producing uranium metal. Developed in 1956 at Iowa State College, this process is comprised of a UF_6 reduction step using hydrogen and a UF_4 reduction step using magnesium:

$$UF_6 + H_2 \rightarrow UF_4 + 2\ HF$$

$$UF_4 + 2\ Mg \rightarrow U + MgF_4$$

Because the heat of reaction is small, additional heat is needed to melt the products. A charge of UF_4 and magnesium are gradually heated in a reactor vessel, which consists of a steel tube lined with an insulating layer of specially purified dolomitic lime.[1] The resulting spontaneous exothermic reaction reduces the reactants to molten uranium metal and magnesium fluoride (MgF_2) (Benedict, et al., 1981).

Once produced, the uranium metal is then machined and manufactured into products such as armor, penetrators, and shielding. The MgF_2 byproduct slag, which contains appreciable quantities of uranium (typically 4-8 wt. %), is processed to recover the uranium content (SAIC, 1995).

There are two commercial facilities in the United States that produce uranium metal from depleted UF_4 - Aerojet Ordnance Tennessee operated by GenCorp Aerojet in Jonesborough, Tennessee, and Carolina Metals in Barnwell, South Carolina. The uranium metal is subsequently machined. A third non-commercial facility, the DOE Y-12 Plant in Oak Ridge, Tennessee, performs similar operations.

D.1 Background on Existing Uranium Metal Fabrication Plants

<u>Carolina Metal</u>

The two primary operations at Carolina Metal are UF_6 to UF_4 conversion and UF_4 reduction. In 1992, Carolina Metals processed 20 14-ton cylinders. Each cylinder yields 16,000 lbs of depleted uranium metal. Therefore, the throughput for Carolina Metals was 320,000 lbs/yr. This

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[1]Lime is one of the few oxides that does not react with and contaminate molten uranium.

throughput provides the basis for the effluent release rates and waste generation rates presented later in this section.

GenCorp Aerojet

The primary operation at GenCorp Aerojet is UF_4 reduction. At the Jonesborough facility, UF_4 drums are unloaded, inspected, and stored in an enclosed warehouse. The UF_4 is reduced by the following batch process: the depleted UF_4 is weighed and then blended with high grade chipped magnesium. The blended mixture is charged into a steel vessel lined with graphite, sealed with a graphite lid, dolomite cap, and a steel lid, and placed into an electrically heated furnace. Once loaded into the furnace, the reaction vessel is heated to the reaction-ignition temperature (nominally 1,080 °F). The resulting spontaneous exothermic reaction reduces the reactants to molten uranium metal and magnesium fluoride (MgF_2). The higher density molten uranium collects in the bottom of the vessel, and the lighter MgF_2 accumulates at the top. The entire process is electronically monitored and logged to ensure product quality. After cooling, the vessel is opened, transferred to an automated manipulator, upended, and jolted to remove the uranium and MgF_2 (Monteford, 1995a).

The uranium is weighed, tagged, and sent either to packaging for storage or to subsequent operations, depending on the end use. The MgF_2 is processed to remove the uranium and daughter products, then either sold or disposed of in a local landfill (Monteford, 1995a).

The average throughput for GenCorp Aerojet from 1992 to 1994 was around 150 te/yr. This quantity provides the basis for the effluent release rates and waste generation rates presented later in this section.

Y-12

The primary operations at the Y-12 plant include vacuum induction casting, rolling, forming, machining, and certification for depleted uranium parts production, and those processes plus additional vacuum are remelting (VAR) for producing high quality depleted uranium alloy parts. Production of depleted uranium/depleted uranium alloy for radiation shielding uses would not require the VAR processing for a high quality depleted uranium alloy.

Because Y-12 is a laboratory, actual throughputs vary greatly. The effluent release rates and waste generation rates presented later in this section represent processing about 150,000 kg/yr depleted uranium at start of the stream (Derrington, 1995).

D.2 Estimates of Emissions to the Atmosphere

Atmospheric releases from the facilities are regulated by federal and state permits. The commercial facilities use continuous monitoring systems to ensure that stack emissions are within the limits established by the permits.

Carolina Metal

In 1992, Carolina Metal released 216μCi (as alpha) and 248 μCi (as beta) to the atmosphere from UF_6 conversion activities. The values from UF_4 reduction activities were 201 μCi (as alpha) and 291 μCi/yr (as beta + gamma).

GenCorp Aerojet

In 1993, GenCorp Aerojet released 0.58 lbs total uranium to the atmosphere. In 1994, the release increased to 0.656 lbs total uranium.

D.3 Estimates of Effluents to Surface Waters

The commercial facilities either have eliminated or will eliminate the liquid effluent releases by redesigning their processing operations. This involves a recycle step to reuse the liquid effluents. Once accomplished, the only remaining liquid effluents are sanitary and storm water runoff.

Carolina Metals

No liquid effluents from processing operations are released to the environment. Liquid effluents from laboratory operations and sanitation are routed to covered evaporation ponds.

GenCorp Aerojet

In 1992, GenCorp Aerojet released 20.7 lbs total uranium in its liquid effluent streams. In 1993 and 1994, the annual quantities were 26.6 lbs and 24.0 lbs total uranium, respectively.

Y-12

The estimated liquid effluent release rates for the Y-12 plant are shown in table D.1.

D.4 Waste Generation Estimates

Carolina Metal

In 1992, Carolina Metal generated approximately 3,500 ft^3 HF from UF_6 conversion activities. From UF_4 reduction activities, approximately 1,560 ft^3 HF (as MgF_2) were generated.

GenCorp Aerojet

GenCorp Aerojet has developed methods to treat or dispose of mixed wastes. Nonhazardous/nonradiological waste streams are handled through local landfills. Although special approval is required for industrial wastes, attaining such approvals has not posed a problem in the past. GenCorp Aerojet has developed several effective waste minimization systems, such as solid waste decontamination and reuse of process support products, which has greatly reduced waste streams. For example, MgF_2 decontamination uses dry mill, chemical, and proprietary separation technologies to remove the uranium with a minimal amount of byproduct.

GenCorp Aerojet recycles as much of the uranium as is cost effective. The uranium is recovered through both chemical and solid waste processing to be reused in the product streams, which reduces raw material costs and radioactive burial (Benedict, et al., 1981).

Waste treatment facilities process as much waste as possible for secondary uses. For example, in the treatment of liquid waste streams, the acid from pickling operations and the hydroxides from scrubbing operations are used to manipulate pH. This reduces the cost of secondary process chemicals for waste operations and eliminates the need to treat additional waste streams.

In 1992, GenCorp Aerojet generated 22,707 ft^3 of disposable waste. In 1993 and 1994, the facility generated 8,744 and 5,070 ft^3 of disposable waste, respectively.

Y-12

The estimated waste generation rates for the Y-12 plant are shown in table D.2. Table D.3 summarizes the existing plant data for uranium metal manufacturing and machining plants.

Table D.1 Estimated Liquid Effluent Release Rates for the Y-12 Plant

Effluent Type	Quantity	Unit
Industrial	7,300	gal
Mixed Waste	158,200	gal
LLW	29,900	gal
RCRA[a]	22,500	gal

a. Resource Conservation and Recovery Act.
(Derrington, 1995)

Table D.2 Estimated Waste Generation Rates for the Y-12 Plant

Waste Type	Quantity	Unit
Industrial	138,100	ft^3
Mixed Waste	200	ft^3
LLW	7,340	ft^3
RCRA[a]	600	ft^3

a. Resource Conservation and Recovery Act.
(Derrington, 1995)

Table D.3: Summary of Existing Plant Data

Waste Type	Liquid Effluents (gal)			Airborne Emissions (lb)			Wastes (ft^3)		
	GenCorp Aerojet	Y-12	Carolina Metal	GenCorp Aerojet	Y-12	Carolina Metal	GenCorp Aerojet	Y-12	Carolina Metal
Industrial		7,300				0		138,000	175 78 (b)
Mixed Waste		158,020				0		200	
LLW	23.8 (c)	29,900		0.6 (d)		0		7,340	
RCRA (a)		22,500				0		600	

a. Resource Conservation and Recovery Act.
b. From MgF.
c. Three-year average.
d. Two-year average.

NOTE 1: Blanks represent unavailable data.
NOTE 2: Data based on an approximate throughput of 150 tons/year.

Appendix E

Radiation Exposure and Manpower Distribution Estimating Data

Appendix E: Radiation Exposure and Manpower Distribution Estimating Data

Table E.1 Low Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 17)	Source	Distance (ft)	Material (Note 18)	Thickness	Person Hours per year
SHIELDING CASK ASSEMBLY BUILDING								
Building Operations	45	8	520	1	100	Steel	0.095"	187200
Building Management	3	8	520	1	100	Steel	0.095"	12480
Security	1	2	1095	1	100	Steel	0.095"	2190
MAIN PROCESSING BUILDING								
Control Room Operations	10	8	260	2,3	40,80	Steel	0.095",0.25"	20800
Building Management	1	8	520	2,3	20,80	Steel	0.095",0.25"	4160
Security	1	8	1095	2,3	20,80	Steel	0.095",0.25"	8760
Depleted Uranium Dioxide Receiving Area								
Unload/inspect UO2 drum pallets	2	0.25	8038	4	3	Steel	0.095"	4019
Transfer pallet to storage unit position	2	0.25	8038	4	6	Steel	0.095"	4019
Area surveillance	1	2	260	2	10	Steel	0.095"	520
Security	1	1	1095	2	15	Steel	0.095"	1095
Depleted Uranium Dioxide Storage Area								
Transfer pallet to ducrete mixing conveyor area	2	0.25	8038	4	6	Steel	0.095"	4019
Area management	1	8	260	5	10	Steel	0.095"	2080
Area surveillance/engineer	1	4	260	5	10	Steel	0.095"	1040
Security	1	1	1095	5	15	Steel	0.095"	1095

Table E.1 Low Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

Ducrete Mixing and Casting Area								
Load cement/additives into hopper	1	0.2	31488	3	50	Steel	0.25"	6297.6
Load colemanite sand into hopper	1	0.2	33600	3	40	Steel	0.25"	6720
Load drum onto conveyor	2	0.1	32150	6	3	Steel	0.095"	6430
Unload empty drum from conveyor onto drum bay pallets	2	0.1	32150	3,7	60,25	Steel	0.25",0.25"	6430
Load empty drum pallets onto truck for WMB	2	0.2	8038	3,7	60,25	Steel	0.25",0.25"	3215.2
Remove failed mixer	4	8	6	8	3	Steel	0.5"	192
Place new mixer in position	4	8	6	3	10	Steel	0.25"	192
Unload empty cask	2	0.3	480	9	30	Steel	0.25"	288
Transfer cask to pour stand	2	0.3	480	9	10	Steel	0.25"	288
Remove ducreted cask from pour stand to setting stand	2	0.5	480	10	3	Steel	0.25"	480
Install temporary seal for top	1	0.5	480	10	1	Steel	0.25"	240
Transfer ducreted cask to curing area	2	0.3	480	10	6	Steel	0.25"	288
Cement/sand hopper operations	1	8	520	3	40	Steel	0.25"	4160
DUO hopper operations	1	8	520	3	5	Steel	0.25"	4160
Pour stand operations	4	8	520	10	5	Steel	0.25"	16640
Area Management	1	8	520	2	15	Steel	0.095"	4160
Area Surveillance/engineer	1	8	520	2	10	Steel	0.095"	4160
Security	1	1	1095	9	15	Steel	0.25"	1095
Ducrete Curing Area								
Load cask into curing position	2	0.2	480	10	3	Steel	0.25"	192
Transfer cask to final assembly	2	0.2	480	10	6	Steel	0.25"	192
Cask surveillance/testing	1	8	260	10	3	Steel	0.25"	2080
Security	1	1	1095	7	15	Steel	0.25"	1095

Table E.1 Low Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

Final Assembly and Quality Control Area								
Load cask into assembly stand	2	0.2	480	10	3	Steel	0.25"	192
Transfer cask to test stand	2	0.2	480	10	6	Steel	0.25"	192
Transfer cask to finished interim storage	2	0.25	480	10	6	Steel	0.25"	240
Assembly/test operations	12	8	260	10	6	Steel	0.25"	24960
Area Management	1	8	260	10	40	Steel	0.25"	2080
Area surveillance/engineer	1	8	260	10	10	Steel	0.25"	2080
Security	1	1	1095	11	15	Steel	0.25"	1095
Finished Cask Interim Storage and Shipping Area								
Unload cask into storage position	2	0.2	480	10	3	Steel	0.25"	192
Transfer cask to shipping bay	2	0.25	480	10	6	Steel	0.25"	240
Load cask onto transport	2	0.25	480	10	3	Steel	0.25"	240
Area surveillance/engineer	1	4	260	10	10	Steel	0.25"	1040
Security	1	1	1095	12	15	Steel	0.25"	1095
SHIELDING CASK PRODUCT STORAGE BUILDING (4 Buildings)								
Unload cask from rail	2	1	480	10	3	Steel	0.25"	960
Transfer cask to storage position	2	1	480	10	6	Steel	0.25"	960
Transfer from storage position to rail	2	1	480	10	6	Steel	0.25"	960
Load cask onto rail	2	6	480	10	3	Steel	0.25"	5760
Surveillance	1	8	520	13	6	Steel	0.25"	4160
Building Management	1	8	260	13	6	Steel	0.25"	2080
Security	1	2	1095	13	30	Steel	0.25"	2190

Table E.1 Low Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

GENERAL WAREHOUSE AND STORAGE BUILDING								
Building Operations	16	8	260	1	600	Steel	0.095"	33280
Building Management	2	8	260	1	600	Steel	0.095"	4160
Security	1	2	1095	1	600	Steel	0.095"	2190
WASTE MANAGEMENT BUILDING								
Building Operations	18	8	260	14	3	Steel	0.053"	37440
Compactor Operations	19	8	365	16	10	Steel	1.0"	55480
Building Management	2	8	260	14	10	Steel	0.053"	4160
Security	1	2	1095	14	30	Steel	0.053"	2190
RADWASTE STORAGE BUILDING								
Building Operations	7	8	260	15	3	Steel	0.053"	14560
Building Management	1	8	260	15	10	Steel	0.053"	2080
Security	1	2	1095	15	30	Steel	0.053"	2190
UTILITY SUPPLY BUILDING								
Building/Power Stations Operations	20	8	260	1	200	Steel	0.095"	41600
N2 and DI Water Operations	7	8	365	1	200	Steel	0.095"	20440
Security	1	2	1095	1	200	Steel	0.095"	2190
HEALTH PHYSICS AND RCA ACCESS CONTROL BUILDING								
Building Operations	27	8	260	1	200	Steel	0.095"	56160
Building Management	1	8	520	1	200	Steel	0.095"	4160
Security	1	2	1095	1	200	Steel	0.095"	2190
EMERGENCY SERVICES BUILDING								
Building Operations	6	8	1095	1	500	Steel	0.095"	52560
Building Management	2	8	260	1	500	Steel	0.095"	4160
Security	1	2	1095	1	500	Steel	0.095"	2190

Table E.1 Low Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

ADMINISTRATIVE AND TECHNICAL SERVICES BUILDING								
Building Operations	44	8	260	1	500	Steel	0.095"	91520
Management/Staff	4	8	520	1	500	Steel	0.095"	16640
Security	3	8	1095	1	500	Steel	0.095"	26280
								851007.80
								409.14

1) Cumulative inventory of MPB.
2) Cumulative inventory of DUO storage area.
3) Six DUO hoppers.
4) Single pallet of four UO2 drums.
5) Cumulative inventory of DUO receiving area.
6) Single UO2 drum.
7) Cumulative inventory of ducrete curing area.
8) Shear mixer content.
9) Cumulative inventory of mixing/casting area.
10) Single large ducreted cask.
11) Cumulative inventory of final assembly and quality control area.
12) Cumulative inventory of finished cask interim storage and shipping area.
13) Cumulative inventory of a single SCPSB.
14) LLW bundles in WMB.
15) Cumulative inventory of LLW bundles in RSB.
16) Inventory of Compactor.
17) 32150 UO2 drums received per year.
    8038 UO2 drum pallets received per year (32150 UO2 drums / 4 drums per pallet).
    31488 containers of cement and additives received per year.
    33600 containers of colemanite sand received per year.
    260 days per year X 2 shifts per day = 520 shifts per year.
    365 days per year X 3 shifts per day = 1095 shifts per year.
18) Materials do not include walls between operating areas.

Table E.2 Low Temperature Shielding Manufacturing Facility: MaintenanceActivities: 100% Throughput

Equipment	Number of Workers per station	Hours per Component per year (Note 14)	Number of Components	Source	Distance (ft)	Material (Note 15)	Thickness	Person Hours per year
SHIELDING CASK ASSEMBLY BUILDING								
Overhead Crane	2	52	3	1	100	Steel	0.095"	312
UPS/UBS	2	26	2	1	100	Steel	0.095"	104
HVAC	2	520	1	1	100	Steel	0.095"	1040
MAIN PROCESSING BUILDING								
UPS/UBS (Control Room)	2	26	2	2,3	40,80	Steel	0.095",0.25"	104
HVAC (Control Room)	2	520	1	2,3	40,80	Steel	0.095",0.25"	1040
Depleted Uranium Dioxide Receiving/Storage Area								
Overhead crane	2	52	1	2	20	Steel	0.095"	104
Ducrete Mixing and Casting Area								
Overhead crane	2	52	1	4	20	Steel	0.25"	104
Cement/additive conveyor	2	104	8	3	30	Steel	0.25"	1664
Sand conveyor	2	104	4	3	20	Steel	0.25"	832
DUO conveyor	2	104	4	5	3	Steel	0.25"	832
Drum conveyor	2	104	2	6	3	Steel	0.095"	416
Drum tipper	2	52	4	5,6	3,3	Steel	0.25",0.095"	416
Shear mixer	2	52	4	7	6	Steel	0.5"	416
Ducrete Curing Area								
Overhead crane	2	52	1	8	20	Steel	0.25"	104
Final Assembly, QC, Interim Storage and Shipping Area								
Overhead crane	2	52	1	9	20	Steel	0.25"	104

Table E.2 Low Temperature Shielding Manufacturing Facility: MaintenanceActivities: 100% Throughput (continued)

SHIELDING CASK PRODUCT STORAGE BUILDING (4 Buildings)								
Overhead crane	2	52	4	10	20	Steel	0.25"	416
UPS/UBS	2	26	4	10	20	Steel	0.25"	208
HVAC	2	520	4	10	20	Steel	0.25"	4160
GENERAL WAREHOUSE AND STORAGE BUILDING								
UPS/UBS	2	26	1	1	600	Steel	0.095"	52
HVAC	2	520	1	1	600	Steel	0.095"	1040
WASTE MANAGEMENT BUILDING								
Cement Mixer	2	52	2	11	3	Steel	0.053"	208
Compactor	2	52	2	13	3	Steel	0.053"	208
UPS/UBS	2	26	1	11	20	Steel	0.053"	52
HVAC	2	520	1	11	20	Steel	0.053"	1040
RADWASTE STORAGE BUILDING								
UPS/UBS	2	26	1	12	20	Steel	0.053"	52
HVAC	2	520	1	12	20	Steel	0.053"	1040
UTILITY SUPPLY BUILDING								
HEPA	2	26	1	13	50	Steel	1.0"	52
Power Station Equipment	3	520	1	13	10	Steel	1.0"	1560
Compactor package	2	104	1	13	3	Steel	1.0"	208
N2 package	2	52	2	13	50	Steel	1.0"	208
DI water system	2	104	5	13	50	Steel	1.0"	1040
Diesel generator	2	52	2	13	50	Steel	1.0"	208
Cooling tower fan	2	52	2	13	50	Steel	1.0"	208
UPS/UBS	2	26	2	13	50	Steel	1.0"	104
HVAC	2	520	1	13	50	Steel	1.0"	1040

Table E.2 Low Temperature Shielding Manufacturing Facility: MaintenanceActivities: 100% Throughput (continued)

HEALTH PHYSICS AND RCA ACCESS CONTROL BUILDING								
Assay instrumentation	2	26	4	1	200	Steel	0.095"	208
UPS/UBS	2	26	2	1	200	Steel	0.095"	104
HVAC	2	520	1	1	200	Steel	0.095"	1040
EMERGENCY SERVICES BUILDING								
UPS/UBS	2	26	1	1	500	Steel	0.095"	52
HVAC	2	520	1	1	500	Steel	0.095"	1040
ADMINISTRATIVE AND TECHNICAL SERVICES BUILDING								
Elevator	2	104	1	1	500	Steel	0.095"	208
UPS/UBS	2	26	2	1	500	Steel	0.095"	104
HVAC	2	520	1	1	500	Steel	0.095"	1040
								24492.00
								11.78

1) Cumulative inventory of MPB.
2) Cumulative inventory of DUO storage area.
3) Six DUO hoppers.
4) Cumulative inventory of mixing/casting area.
5) Single DUO hopper.
6) Single DUO drum.
7) Single shear mixer.
8) Cumulative inventory of ducrete curing area.
9) Cumulative inventory of finished cask interim storage and shipping area.
10) Cumulative inventory of a single SCPSB.
11) LLW bundles in WMB.
12) Cumulative inventory of LLW bundles in RSB.
13) Inventory of Compactor.
14) 2 hours per week (104) for complex systems with multiple active components (conveyors, elevators) - includes instrumentation.
 1 hour per week (52) on active components (cranes, mixers, pumps, fans, generators) - includes instrumentation.
 1/2 hour per week (26) on passive components (HEPA, monitoring equipment, power supply) - includes instrumentation.
 10 hours per week (520) on HVAC and power station.
15) Materials do not include walls between operating areas.

Table E.3 High Temperature Shielding Manufacturing Facility: Maintenance Activities: 100% Throughpu

Equipment	Number of Workers per station	Hours per Component per year (Note 12)	Number of Components	Source	Distance (ft)	Material (Note 13)	Thickness	Person Hours per year
SHIELDING CASK ASSEMBLY BUILDING								
Overhead Crane	2	52	3	1	100	Steel	0.095"	312
UPS/UBS	2	26	2	1	100	Steel	0.095"	104
HVAC	2	520	1	1	100	Steel	0.095"	1040
MAIN PROCESSING BUILDING								
UPS/UBS (Control Room)	2	26	2	2,3	40,30	Steel	0.095",0.5"	104
HVAC (Control Room)	2	520	1	2,3	40,30	Steel	0.095",0.5"	1040
Depleted Uranium Metal Receiving/Storage Area								
Overhead crane	2	52	1	4	20	Steel	0.095"	104
Depleted Uranium Shielding Casting Area (2 Areas)								
Overhead crane	2	52	1	3	20	Steel	0.5"	104
Vacuum furnace conveyor	2	104	4	3	10	Steel	0.5"	832
Vacuum melting furnace	2	52	16	5	3	Steel	0.5"	1664
Soaking pit	2	52	2	3	3	Steel	0.5"	208
Vibratory feeders	2	52	16	3	3	Steel	0.5"	1664
Depleted Uranium Metal Shielding Cooling Area								
Overhead crane	2	52	4	6	20	Steel	3.0"	416
Annealing furnace	2	52	6	6	6	Steel	3.0"	624
Final Assembly, QC, Interim Storage and Shipping Area								
Overhead crane	2	52	4	7	20	Steel	3.0"	416
Ultrasonic equipment	2	26	4	7	20	Steel	3.0"	208

Table E.3 High Temperature Shielding Manufacturing Facility: Maintenance Activities: 100% Throughput (continued)

SHIELDING CASK PRODUCT STORAGE BUILDING (4 Buildings)								
Overhead crane	2	52	4	8	20	Steel	3.0"	416
UPS/UBS	2	26	4	8	20	Steel	3.0"	208
HVAC	2	520	4	8	20	Steel	3.0"	4160
GENERAL WAREHOUSE AND STORAGE BUILDING								
UPS/UBS	2	26	1	1	600	Steel	0.095"	52
HVAC	2	520	1	1	600	Steel	0.095"	1040
WASTE MANAGEMENT BUILDING								
Cement Mixer	2	52	2	9	3	Steel	0.053"	208
Compactor	2	52	2	11	3	Steel	0.053"	208
UPS/UBS	2	26	1	9	20	Steel	0.053"	52
HVAC	2	520	1	9	20	Steel	0.053"	1040
RADWASTE STORAGE BUILDING								
UPS/UBS	2	26	1	10	20	Steel	0.053"	52
HVAC	2	520	1	10	20	Steel	0.053"	1040
UTILITY SUPPLY BUILDING								
HEPA	2	26	1	1	200	Steel	1.0"	52
Power Station Equipment	3	520	1	1	200	Steel	1.0"	1560
N2 package	2	52	2	1	200	Steel	1.0"	208
DI water system	2	104	5	1	200	Steel	1.0"	1040
Diesel generator	2	52	2	1	200	Steel	1.0"	208
Cooling tower fan	2	52	2	1	200	Steel	1.0"	208
UPS/UBS	2	26	2	1	200	Steel	1.0"	104
HVAC	2	520	1	1	200	Steel	1.0"	1040

Table E.3 High Temperature Shielding Manufacturing Facility: Maintenance Activities: 100% Throughput (continued)

HEALTH PHYSICS AND RCA ACCESS CONTROL BUILDING								
Assay instrumentation	2	26	4	1	200	Steel	0.095"	208
UPS/UBS	2	26	2	1	200	Steel	0.095"	104
HVAC	2	520	1	1	200	Steel	0.095"	1040
EMERGENCY SERVICES BUILDING								
UPS/UBS	2	26	1	1	500	Steel	0.095"	52
HVAC	2	520	1	1	500	Steel	0.095"	1040
ADMINISTRATIVE AND TECHNICAL SERVICES BUILDING								
Elevator	2	104	1	1	500	Steel	0.095"	208
UPS/UBS	2	26	2	1	500	Steel	0.095"	104
HVAC	2	520	1	1	500	Steel	0.095"	1040
								25532.00
								12.28

1) Cumulative inventory of MPB.
2) Cumulative inventory of DU metal storage area.
3) Inventory of four full furnaces within a single DU metal shielding casting area.
4) Cumulative inventory of DU metal receiving area.
5) Inventory of a single furnace.
6) Cumulative inventory of DU metal shielding cooling area.
7) Cumulative inventory of final assembly, QC, interim storage and shipping area.
8) Cumulative inventory of a single SCPSB.
9) LLW bundles in WMB.
10) Cumulative inventory of LLW bundles in RSB.
11) Inventory of Compactor
12) 2 hours per week (104) for complex systems with multiple active components (conveyors, elevators) - includes instrumentation.
 1 hour per week (52) on active components (cranes, pumps, fans, generators) - includes instrumentation.
 1/2 hour per week (26) on passive components (HEPA, monitoring equipment, power supply) - includes instrumentation.
 10 hours per week (520) on HVAC and power station.
13) Materials do not include walls between operating areas.

Table E.4 High Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 15)	Source	Distance (ft)	Material (Note 16)	Thickness	Person Hours per year
SHIELDING CASK ASSEMBLY BUILDING								
Building Operations	45	8	520	1	100	Steel	0.095"	187200
Building Management	3	8	520	1	100	Steel	0.095"	12480
Security	1	2	1095	1	100	Steel	0.095"	2190
MAIN PROCESSING BUILDING								
Control Room Operations	10	8	260	2,3	40,30	Steel	0.095",0.5"	20800
Building Management	1	8	520	2,3	20,30	Steel	0.095",0.5"	4160
Security	1	8	1095	2,3	20,30	Steel	0.095",0.5"	8760
Depleted Uranium Metal Receiving Area								
Unload/inspect uranium billet pallets	2	0.25	7350	4	3	Steel	0.095"	3675
Transfer pallet to storage unit position	2	0.25	7350	4	6	Steel	0.095"	3675
Area surveillance	1	2	260	5	10	Steel	0.095"	520
Security	1	1	1095	5	15	Steel	0.095"	1095
Depleted Uranium Metal Storage Area								
Transfer pallet to vacuum furnace conveyor	2	0.25	7350	4	6	Steel	0.095"	3675
Area management	1	8	260	2	10	Steel	0.095"	2080
Area surveillance/engineer	1	4	260	2	10	Steel	0.095"	1040
Security	1	1	1095	2	15	Steel	0.095"	1095
Depleted Uranium Shielding Casting Area (2 Areas)								
Load billet onto vacuum furnace conveyor	2	0.015	558600	6	3	Steel	0.095"	16758
Load used packing material onto pallet	1	0.05	29400	4	15	Steel	0.095"	1470
Transfer used packing material pallet to truck bay	1	0.2	7350	3	15	Steel	0.5"	1470
Load used packing material pallet onto truck for WMB	2	0.2	7350	3	15	Steel	0.5"	2940

Table E.4 High Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

Unload empty cask from rail	2	0.3	440	3	30	Steel	0.5"	264
Transfer empty cask to cask soaking stand	2	0.3	440	3	10	Steel	0.5"	264
Transfer empty cask to casting stand	2	0.3	440	3	10	Steel	0.5"	264
Transfer DU metal cask from casting stand to cooling pit	2	0.5	440	3	10	Steel	0.5"	440
Install temporary seal for top	1	0.5	440	7	1	Steel	3.0"	220
Transfer DU metal cask to cooling stand	2	0.5	440	7	6	Steel	3.0"	440
Transfer DU metal cask to cleaning stand	2	0.5	440	7	6	Steel	3.0"	440
Clean DU metal cask / remove scale	2	1	440	7	3	Steel	3.0"	880
Transfer DU metal cask to DU metal cooling area	2	0.3	440	7	6	Steel	3.0"	264
Furnace charging/casting operations	2	8	520	3	10	Steel	0.5"	8320
Area Management	1	8	520	3	15	Steel	0.5"	4160
Area Surveillance/engineer	4	8	520	3	10	Steel	0.5"	16640
Security	1	1	1095	3	15	Steel	0.5"	1095
Depleted Uranium Metal Shielding Cooling Area								
Load cask into cooling station #1	2	0.2	440	7	3	Steel	3.0"	176
Transfer cask to annealing station #1	2	0.2	440	7	6	Steel	3.0"	176
Transfer cask into cooling station #2	2	0.2	440	7	6	Steel	3.0"	176
Transfer cask to annealing station #2	2	0.2	440	7	6	Steel	3.0"	176
Transfer cask into cooling station #3	2	0.2	440	7	6	Steel	3.0"	176
Transfer cask to final assembly	2	0.2	440	7	6	Steel	3.0"	176
Annealing Operations	1	8	520	8	10	Steel	3.0"	4160
Area Management	1	8	520	8	15	Steel	3.0"	4160
Cask surveillance/testing	2	8	520	7	6	Steel	3.0"	8320
Security	1	1	1095	8	15	Steel	3.0"	1095
Final Assembly and Quality Control Area								
Load cask into assembly stand	2	0.2	440	7	3	Steel	3.0"	176
Transfer cask to test stand	2	0.2	440	7	6	Steel	3.0"	176
Transfer cask to finished interim storage	2	0.25	440	7	6	Steel	3.0"	220

Table E.4 High Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

Assembly/test operations	12	8	260	7	6	Steel	3.0"	24960
Area Management	1	8	260	7	40	Steel	3.0"	2080
Area surveillance/engineer	1	8	260	7	10	Steel	3.0"	2080
Security	1	1	1095	9	15	Steel	3.0"	1095
Finished Cask Interim Storage and Shipping Area								
Unload cask into storage position	2	0.2	440	7	3	Steel	3.0"	176
Transfer cask to shipping bay	2	0.25	440	7	6	Steel	3.0"	220
Load cask onto transport	2	0.25	440	7	3	Steel	3.0"	220
Area surveillance/engineer	1	4	260	7	10	Steel	3.0"	1040
Security	1	1	1095	10	15	Steel	3.0"	1095
SHIELDING CASK PRODUCT STORAGE BUILDING (4 Buildings)								
Unload cask from rail	2	1	440	7	3	Steel	3.0"	880
Transfer cask to storage position	2	1	440	7	6	Steel	3.0"	880
Transfer from storage position to rail	2	1	440	7	6	Steel	3.0"	880
Load cask onto rail	2	6	440	7	3	Steel	3.0"	5280
Surveillance	1	8	520	11	6	Steel	3.0"	4160
Building Management	1	8	260	11	6	Steel	3.0"	2080
Security	1	2	1095	11	30	Steel	3.0"	2190
GENERAL WAREHOUSE AND STORAGE BUILDING								
Building Operations	16	8	260	1	600	Steel	0.095"	33280
Building Management	2	8	260	1	600	Steel	0.095"	4160
Security	1	2	1095	1	600	Steel	0.095"	2190
WASTE MANAGEMENT BUILDING								
Building Operations	18	8	260	12	3	Steel	0.053"	37440
Compactor Operations	19	8	365	14	10	Steel	1.0"	55480
Building Management	2	8	260	12	10	Steel	0.053"	4160
Security	1	2	1095	12	30	Steel	0.053"	2190

Table E.4 High Temperature Shielding Manufacturing Facility: Operational Activities: 100% Throughput (continued)

RADWASTE STORAGE BUILDING								
Building Operations	7	8	260	13	3	Steel	0.053"	14560
Building Management	1	8	260	13	10	Steel	0.053"	2080
Security	1	2	1095	13	30	Steel	0.053"	2190
UTILITY SUPPLY BUILDING								
Building Operations	20	8	260	1	200	Steel	0.095"	41600
N2 and DI Water Operations	7	8	365	1	200	Steel	0.095"	20440
Security	1	2	1095	1	200	Steel	0.095"	2190
HEALTH PHYSICS AND RCA ACCESS CONTROL BUILDING								
Building Operations	27	8	260	1	200	Steel	0.095"	56160
Building Management	1	8	520	1	200	Steel	0.095"	4160
Security	1	2	1095	1	200	Steel	0.095"	2190
EMERGENCY SERVICES BUILDING								
Building Operations	6	8	1095	1	500	Steel	0.095"	52560
Building Management	2	8	260	1	500	Steel	0.095"	4160
Security	1	2	1095	1	500	Steel	0.095"	2190
ADMINISTRATIVE AND TECHNICAL SERVICES BUILDING								
Building Operations	44	8	260	1	500	Steel	0.095"	91520
Management/Staff	4	8	520	1	500	Steel	0.095"	16640
Security	3	8	1095	1	500	Steel	0.095"	26280
								855273.00
								411.19

1) Cumulative inventory of MPB.
2) Cumulative inventory of DU metal storage area.
3) Inventory of four full furnaces within a single DU metal shielding casting area.
4) Single pallet of DU metal billet boxes.
5) Cumulative inventory of DU metal receiving area.
6) Single DU metal billet.
7) Single large cask with inclusive DU metal shield.
8) Cumulative inventory of DU metal shielding cooling area.
9) Cumulative inventory of final assembly and quality control area.
10) Cumulative inventory of finished cask interim storage and shipping area.
11) Cumulative inventory of a single SCPSB.
12) LLW bundles in WMB.
13) Cumulative inventory of LLW bundles in RSB.
14) Inventory of compactor.
15) 558600 DU metal billets received per year.
    29400 DU metal billet boxes received per year (558600 DU metal billets / 19 billets per box).
    7350 DU metal pallets received per year (29400 DU metal billet boxes / 4 billet boxes per pallet).
    440 casks with inclusive DU metal shield produced per year.
    260 days per year X 2 shifts per day = 520 shifts per year.
    365 days per year X 3 shifts per day = 1095 shifts per year.
16) Materials do not include walls between operating areas.

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Section 6.12

Storage Options for Depleted Uranium Management

6.12
Storage Options for Depleted Uranium Management

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ABBREVIATIONS AND ACRONYMS

AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
°C	degrees centigrade
CaF_2	calcium fluoride
CaO	calcium oxide
CAR	Cost Analysis Report
cc	cubic centimeter
CDR	conceptual design report
CFR	Code of Federal Regulations
cm	centimeter
CWA	Clean Water Act
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
EAP	Engineering Analysis Project
EAR	Engineering Analysis Report
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
ft	feet
g	gram
ha	hectares
HEPA	high efficiency particulate air filter
HF	hydrogen fluoride
HVAC	heating, ventilation, and air conditioning
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
JMN	Justification of Mission Need
JNS	Justification of New Start

ABBREVIATIONS AND ACRONYMS (Continued)

KD	Key Decision
kg	kilogram
KL	kiloliter
LLNL	Lawrence Livermore National Laboratory
LWR	light water reactor
m	meter
m^2	square meters
m^3	cubic meters
MW-hr	megawatt-hour
MW-yr	megawatt-year
Ml	milliliter
ML	megaliter or 1 million liters
MSA	Major Systems Acquisition
MSCM	million standard cubic meters
NCA	
NEPA	National Environmental Policy Act
NO_x	nitrogen oxides
NPH	natural phenomena hazards
NPHM	Natural Phenomena Hazards Mitigation
NRC	U.S. Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Act
P^3	Public Participation Plan
PP	Project Plan
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
SAR	Safety Analysis Report
SO_x	sulfur oxides
SSC	structure, systems, and components
TAR	Technology Assessment Report
te	metric tonne (1,000 kg)

ABBREVIATIONS AND ACRONYMS (Continued)

U	uranium
U_3O_8	triuranium octaoxide
U^{235}	uranium having molecular weight of 235
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride

PREFACE

This report presents and evaluates potential storage options for depleted uranium. For the purposes of the report, the depleted uranium is assumed to be in the form of UF_6, UO_2, or U_3O_8. The report includes preconceptual designs for three storage options: aboveground buildings, below-grade vaults, and underground mined cavities. Each storage option is evaluated for the three forms of depleted uranium except vault storage. This option is evaluated for UO_2 and U_3O_8 only. The base case is the storage of UF_6 in Type 48 cylinders, the form in which it is now stored.

The report contains a description of the storage facilities considered for depleted uranium, including background on current storage practices in the United States. It presents the basic storage configurations under the three options evaluated for the various depleted uranium forms. Specific information on building layouts, site layouts, staffing required, resources required, wastes generated, and potential accidents associated with facility operation is also presented.

1.0 DESCRIPTION OF STORAGE OPTIONS FOR DEPLETED URANIUM

This section provides information on current practices for depleted uranium storage, background on the storage of depleted uranium, reuse options for depleted uranium, descriptions of the storage form and storage requirements for depleted uranium, other considerations affecting the choice of storage form and facility options, and a brief description of the facility types considered in this report. Potential accidents are also considered for these storage facilities and the various depleted uranium forms.

Three different chemical forms of depleted uranium are considered: uranium hexafluoride (UF_6), uranium dioxide (UO_2), and triuranium octaoxide (U_3O_8). In addition, three separate types of storage facilities are considered: buildings, vaults, and mined cavities. All combinations of chemical forms and storage facility options are considered but one, UF_6 storage in vaults, was not included in the analysis due to practicality considerations.

In developing these options, depleted uranium is considered a resource to be managed for reuse. The depleted uranium is therefore not considered to be a waste and would not be regulated under the Resource Conservation and Recovery Act (RCRA). This is consistent with the DOE's current position on depleted uranium and is one of the reasons for the development of a long-term strategy for depleted uranium hexafluoride management.

1.1 Current Status

Gaseous diffusion is used to separate the radioactive isotope of uranium (U^{235}) from the nonradioactive isotope (U^{238}). A major consequence of the gaseous diffusion process is the accumulation of a significant amount of UF_6 that has low percentages of U^{235}. This is depleted uranium. Although ratios may vary in practice, producing 1 kilogram (kg) of UF_6 enriched to 3.0 percent U^{235} will typically result in 5.5 kg of depleted UF_6 at 0.3 percent U^{235}. From 1945 through July 1, 1993, approximately 560,000 metric tons of depleted UF_6 have accumulated at the three plant sites. This depleted UF_6 is stored as a solid in a partial vacuum in 10- to 14-ton steel cylinders with 5/16-in thick walls (referred to as Type 48 cylinders in this report). The majority of the cylinders are approximately 12 ft long and 4 ft in diameter.

The depleted UF_6 occupies a total of about 47,000 cylinders distributed as follows: approximately 29,000 cylinders at Paducah, 13,000 at Portsmouth, and 5,000 at Oak Ridge (K-25 Site). The cylinders are stacked two high and rest on concrete or wooden storage chocks in open gravel, asphalt, or concrete storage yards. Cylinders are regularly inspected and corrective maintenance activities such as restacking cylinders, lining wooden storage chocks or replacing wooden storage chocks (which can contribute to corrosion by retaining water) with concrete chocks, and replacing and refurbishing cylinders are performed, as needed.

1.2 Background on Storage of Depleted Uranium

Three major considerations lead to a decision on the form of depleted uranium to be stored: (1) why it is being stored, (2) how much area is required to store it in its various forms, and (3) environmental considerations (which will be evaluated in the EIS). Storage rationale and area are discussed below.

1.2.1 Reuse Options and Base Case for Storage of Depleted Uranium

Storage of depleted uranium implies that it will be reused at a later date. Reuse options include:

- Light water reactor (LWR) fuel cycle
- Advanced fuel cycles
- Dense material applications
- Shielding applications

The most appropriate form for storage of the depleted uranium depends in part on which of these reuse options is chosen. If the uranium is to be further enriched, uranium hexafluoride or uranium metal might be the most appropriate form. Other reuse scenarios use various starting point forms of depleted uranium including, but not limited to, shielding from U-metal, UO_2 or U_3O_8. Uranium metal is not evaluated as a storage form due to its instability (e.g., it is pyrophoric).

It is not currently possible to determine which of these reuse options will be the most appropriate. UF_6 is the chemical form that provides the greatest flexibility for any future reuse option, so the base case for storage is to maintain depleted uranium in the uranium hexafluoride form in the containers in which it is now stored (primarily Type 48 cylinders).

1.2.2 Storage Area Required

The area required to store depleted uranium depends on four factors: the percentage weight of uranium in the total weight of the compound stored, the bulk density of the compound stored, the type of storage containers used, and the configuration used for the storage of containers. Of the three compounds selected for evaluation, UO_2 has the highest proportion of weight of uranium for the total weight of the compound (see table 1-1), UF_6 has the second highest percentage weight of uranium, and U_3O_8 the least. All other things being equal, storage in the UO_2 form would require the least space.

The bulk densities of the three compounds (see table 1-1) are engineering estimates of the weight of the compounds that can routinely be obtained in common storage applications. These estimates are subject to wide variations depending on the technology used to generate and package the compounds. The bulk densities listed have been selected assuming that no special efforts would be used to increase the bulk densities of the compounds for packaging for storage. Using these bulk densities, the weight of uranium per volume of storage container is highest for UO_2 and lowest for U_3O_8. Using the bulk densities listed in table 1-1, storage as UO_2 uses the least amount of space.

Table 1-1. Physical Properties of Selected Uranium Compounds

Uranium Compound	Molecular Weight	Percent U by Weight	Bulk Density (g/cc)	g U / cc
UF_6	352	68	4.6	3.1
UO_2	270	88	9.0	7.9
U_3O_8	842	85	3.0	2.5

The storage container used for each compound depends largely on how the compounds are currently stored, which in turn depends on weight and other factors. The greatest proportion of depleted uranium is currently stored as UF_6 in Type 48 pressure cylinders. These large cylinders (1.23 m diameter and 3.73 m long) are filled with UF_6 as a gas and allowed to cool to ambient temperature. At ambient temperature, UF_6 is a solid. As long as the cylinders are kept at relatively low ambient temperatures (less than 40°C, 100°F), the internal pressure is slightly negative, minimizing the loss of UF_6 should faults develop. UO_2, a crystalline solid in sintered form, is usually stored in 30-gallon drums. These small drums are used largely because of the weight of UO_2—a 30-gallon drum weighs about 1,066 kg (2,350 lb) filled. U_3O_8, also a crystalline solid usually in powdered form, is generally stored in 55-gallon drums. The weight of these filled drums is about 703 kg (1,550 lb).

The storage configuration for these containers is the same for each storage option and is based on long-term (up to 40 years) storage. A standard storage configuration for each container type was developed for estimating the size and number of storage buildings (vaults, drifts) required. These are as follows (see figures 1-1, 1-2, and 1-3).

- UF_6 in Type 48 cylinders would be stored in rows (3.73 m [12 ft] wide) on 1.5-m (5-ft) centers with 1.2-m (4-ft) inter-row spacing. The cylinders would be stacked two high as is the current practice for outside storage of these cylinders. A 1.2-m inter-row spacing would allow relatively easy access to both ends of the cylinders for inspection and minor repairs.

Figure 1-1: Storage Configuration for UF_6

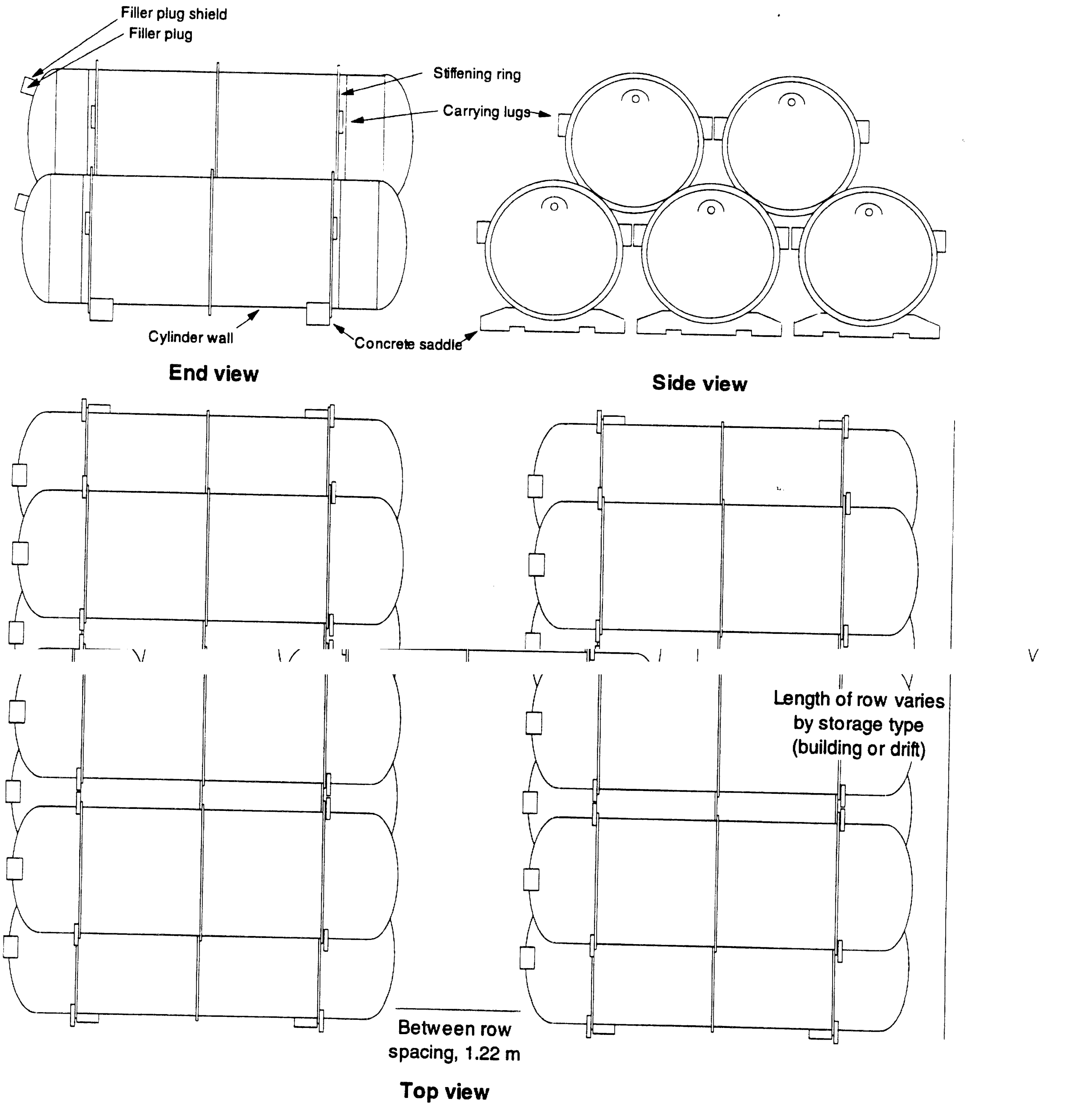
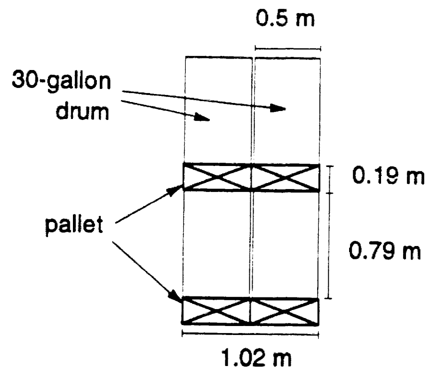
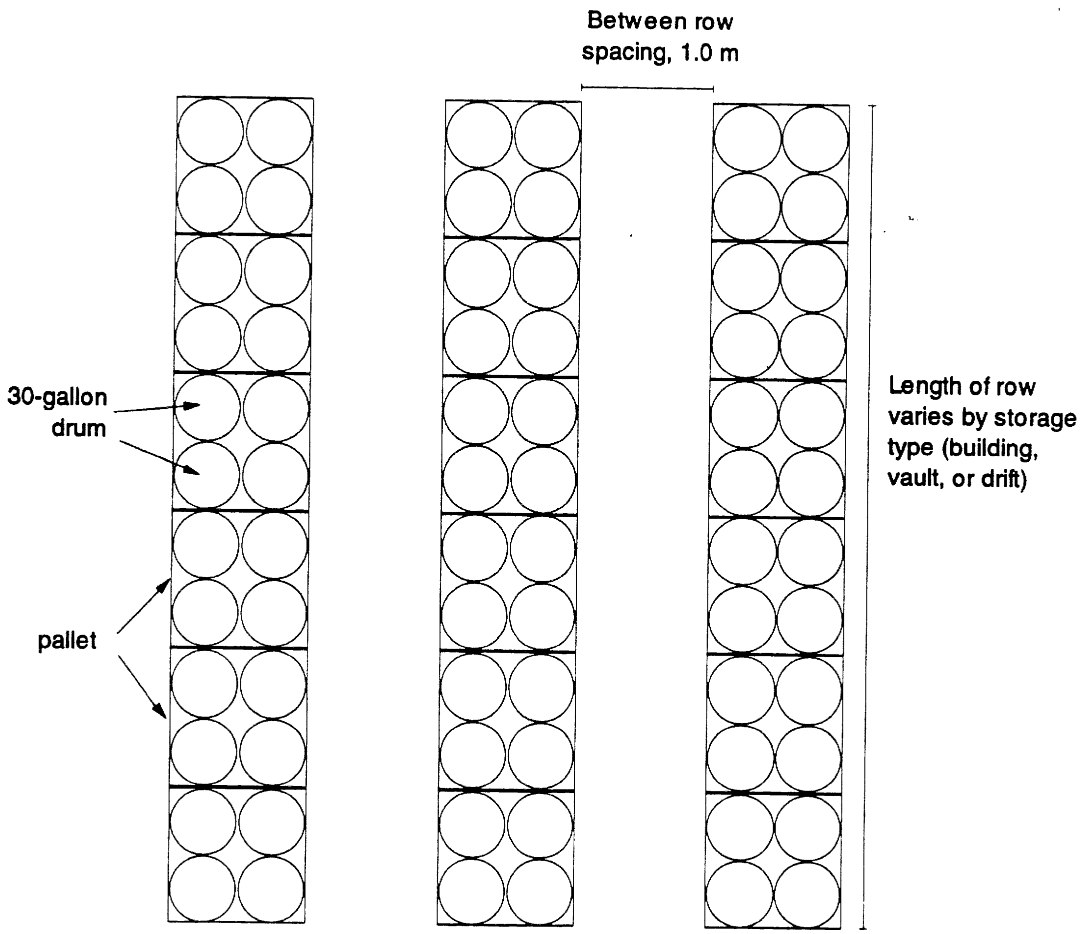


Figure 1-2: Storage Configuration for UO_2

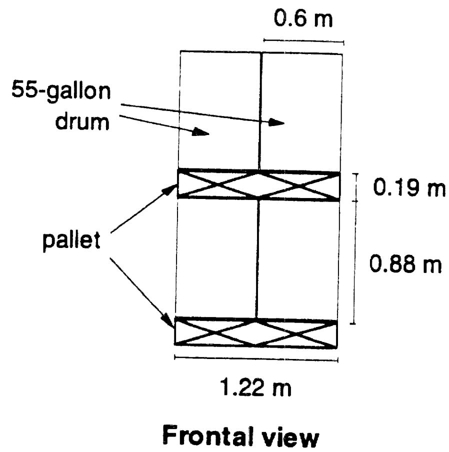


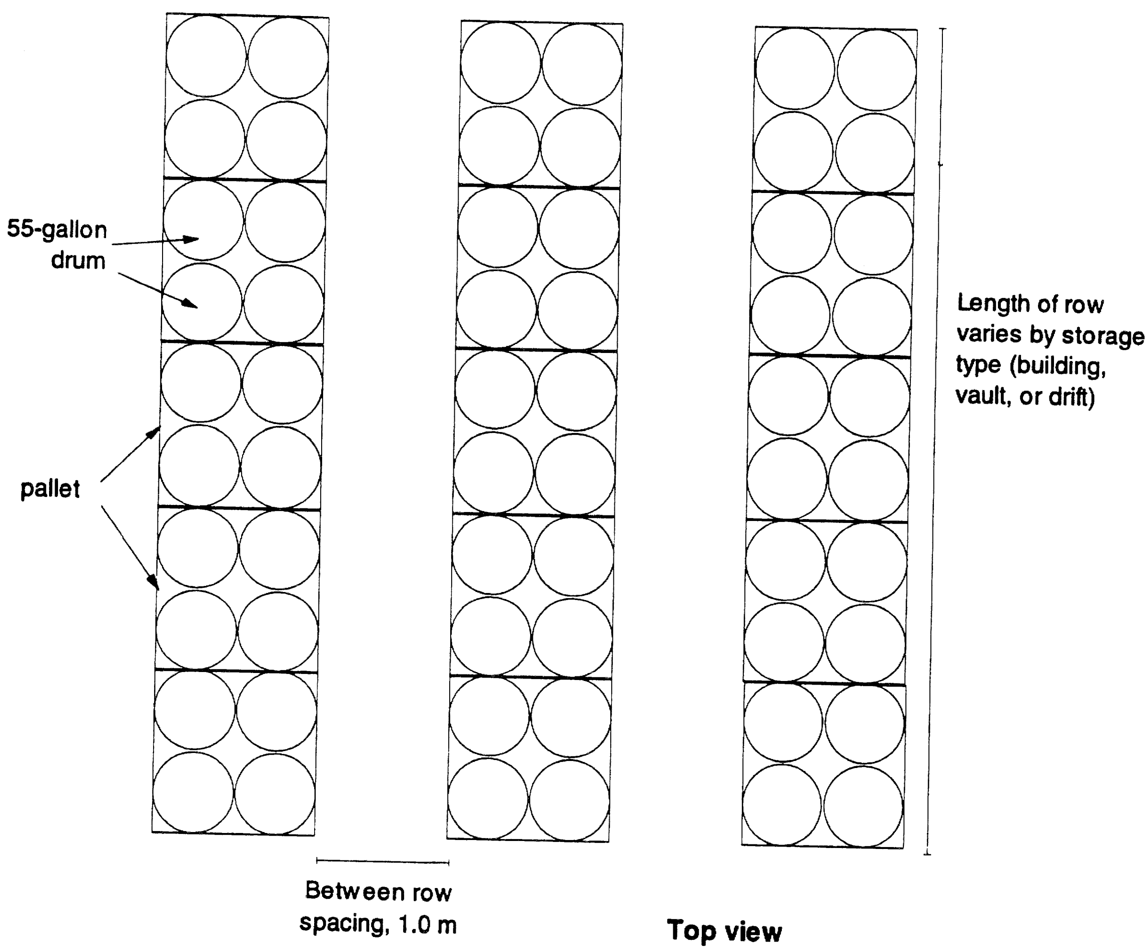
Frontal view



Top view

Figure 1-3: Storage Configuration for U_3O_8





- UO_2 in 30-gallon drums would be stored in rows of four-drum pallets, two pallets high. The width of each row would be approximately 1 m (3 ft) with 1-m (3-ft) inter-row spacing. While the aisle width is narrow, it would allow inspection of each drum from above, with floor-level access from the side for more detailed inspection of each drum should it be required.

- U_3O_8 in 55-gallon drums would be stored in rows of four-drum pallets, two pallets high, as in the UO_2 storage configuration. The width of the row would be approximately 1.2 m (4 ft) with 1 m (3 ft) inter-row spacing. Each drum would be accessible for inspection as in the UO_2 storage case.

In these storage configurations, the total area required for UF_6 would be 18 hectares (44 acres), for UO_2 would be 11 hectares (27 acres), and for U_3O_8 would be 24 hectares (59 acres) of enclosed space.

1.2.3 Other Considerations

The primary concern for storage of depleted uranium is the integrity of the container in which it resides. Because storage implies that the depleted uranium will later be used, it is important to maintain the integrity of the storage container. The container is what will protect the material from the environment and prevent potential releases of the material to the environment. Further, the containers could be used for shipping the depleted uranium for future use. All of the containers are assumed to be soft steel and are therefore subject to corrosion (rust) if exposed to the weather or dampness. Although painting provides moderate protection against corrosion, storage within buildings, vaults, or mined cavities means that temperature, humidity, and dampness would vary less than in the outside air and thus reduce corrosion rates.

The chemical form of the uranium makes relatively little difference in terms of environmental releases as long as there is a continuing maintenance program for the storage facility that (1) prevents water intrusion into storage areas and (2) ensures the integrity of the storage containers. The absence of water will reduce corrosion rates, and if by accident water enters the storage facility and the containers are all intact, no environmental release would occur with the removal of water from the facility. Thus recurring inspections and remediation of problems will reduce the effects of accidental water entry.

UF_6 is soluble in water, forming soluble uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF), a highly corrosive acid. UO_2 and U_3O_8, on the other hand, are essentially insoluble in water. With leakage from containers, UF_6 would be the most reactive of the three chemical forms (if it were to come in contact with accidently introduced water [e.g., runoff]). The general consensus of many studies on the appropriate storage form for depleted uranium is that U_3O_8 is the optimum storage form.

1.3 Overview of Storage Facilities

The three options for storage facilities—buildings, vaults, and mined cavities—are all single-purpose facilities. They are designed for receiving, inspecting, and repackaging (when necessary) containers of depleted uranium and storing them in a series of buildings (vaults, drifts).

Each of the facilities has the following support buildings: an Administration Building, a Receiving Warehouse, a Repackaging Building (attached to the Receiving Warehouse) and a Workshop. Each facility storing UF_6 would also have a cylinder washing facility. The functions of these buildings are largely self-explanatory and are described later.

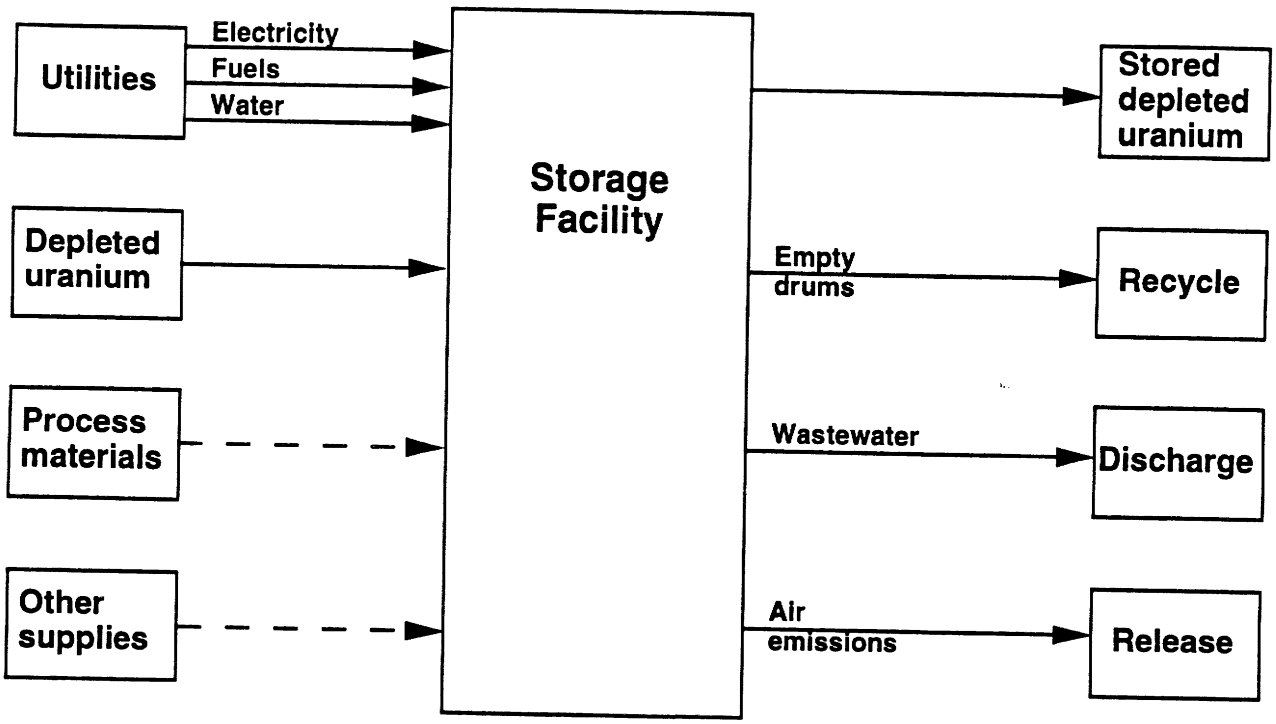
The remainder of the facilities have a varying number of storage buildings (vaults, drifts) and, in the case of mined-cavity storage, accessory access and ventilation shafts. The number of buildings (vaults, drifts) depends on the chemical form of the product and the container in which it is received.

The general site plans for the facilities are laid out to minimize, where possible, the distance that containers of depleted uranium must be moved onsite. Aboveground connections are primarily paved roads. There are gravel roads for the vault storage facility because access to each vault is required, and this would require a very large area of paved surface. Underground access for mined cavities is through vertical shafts served by elevators and, at the storage level, through empty drifts or connecting tunnels or aisleways.

The general process flow within a storage facility is simple: containers of depleted uranium are received at the facility, inspected and repackaged if necessary, and stored. This is presented in figure 1-4. Containers of depleted uranium are received at the facility by rail or road. Containers would be unloaded at an unloading dock attached to the Receiving Warehouse and Repackaging Building by davit crane and would be placed in the Receiving Warehouse. The containers would be visibly inspected for damage, faulty seals, and external smearable contamination. Undamaged containers would be transported to the temporary storage area of the Receiving Warehouse by a bridge crane with a capacity of 10 to 15 te (22,000 to 33,000 lb). Damaged containers would be transported by bridge crane to the Repackaging Building to await repackaging. Repackaging would entail transfer of the container contents to clean, undamaged containers. Empty, damaged drums would be cleaned in the Repackaging Building and then be shipped offsite for disposal. Empty, damaged Type 48 cylinders would be moved to the cylinder washing facility for cleaning. Clean, undamaged containers would be stored in the Repackaging Facility and would be used as needed.

Repackaging operations would vary depending on the chemical form of the received material. For UF_6, repackaging requires heating the cylinder in an autoclave and transferring the contents

Figure 1-4: Overall Process Flow Diagram for the Storage Facility During Operations



to a clean cylinder. Once the successful transfer operation has occurred, the cylinder would be cooled and transported by bridge crane to the loading dock.

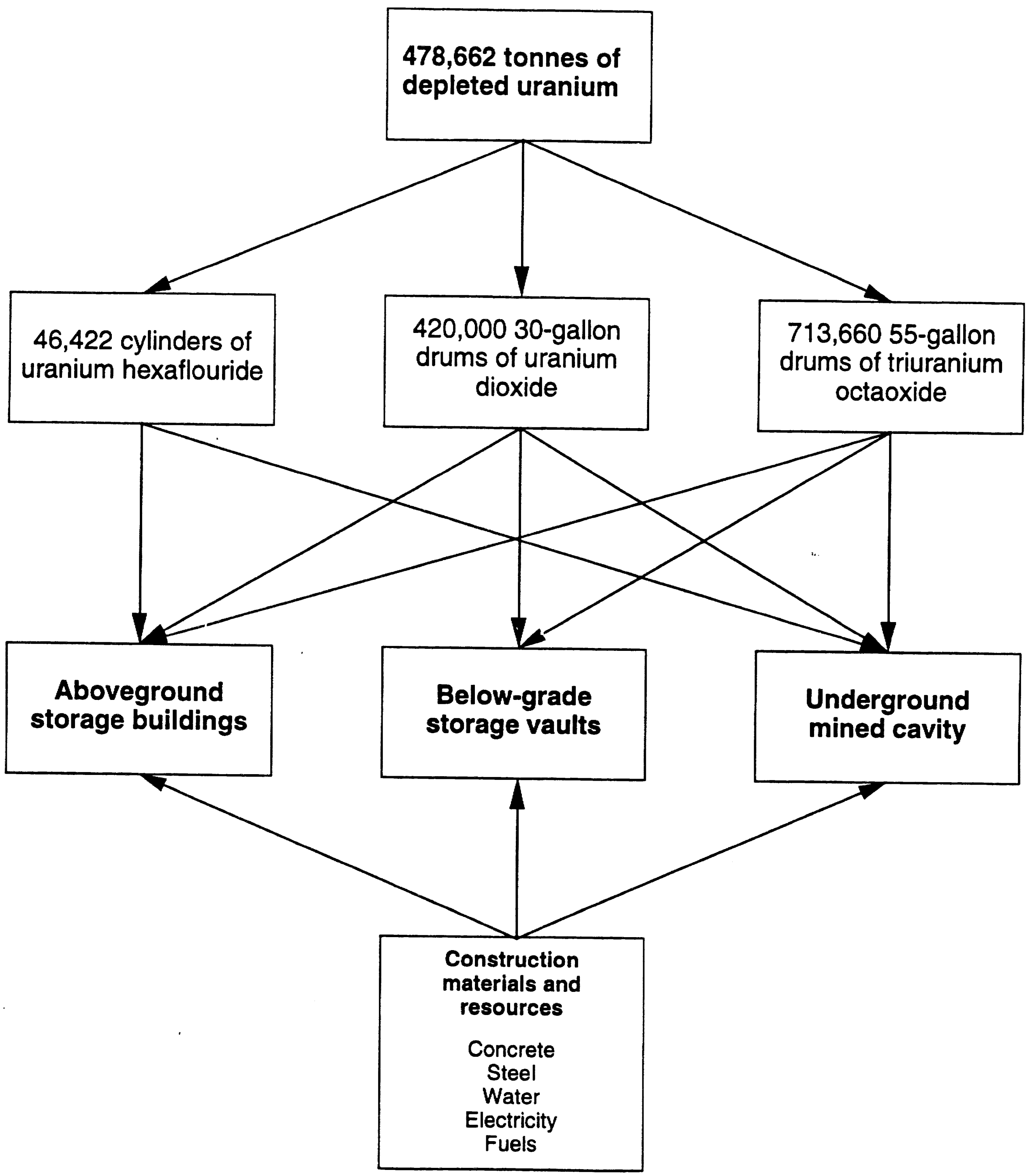
For drum containers holding either U_3O_8 or UO_2, electrically-powered transfer equipment would pour the contents of the damaged drum into a clean drum. This drum would be transported by bridge crane into temporary storage with other undamaged drums.

From the Receiving Warehouse and Repackaging Building, the depleted uranium-filled containers would be transported by truck to a storage facility (building, vault, or shaft). Unloading at the storage facility would occur by davit crane. For the building and mined-cavity storage, containers would be moved from the unloading area by straddle carriers. For vault storage, a mobile crane would place the container directly into a storage vault.

Little energy and few materials are used in the receipt and relocation of the containers. The major consumable item is the diesel fuel used in the intrasite transportation of the containers. Minor amounts of wastes are generated, the most obvious being the air emissions from intrasite transportation and from minimal space heating.

The materials and energy flows for the storage facilities are dominated by the materials and energy used in their construction. This is depicted for the general case in figure 1-5.

Figure 1-5: Material Flow Diagram for the Storage Facility



2.0 DESCRIPTION OF THE FACILITIES

This section describes the structures that would be associated with each of the three storage options for depleted uranium: building storage, vault storage, and mined-cavity storage. One basic storage building (vault, drift) has been designed for each storage option, and the number of buildings (vaults, drifts) needed to contain each type of material to be stored has been calculated. Storage space has not been optimized for each type of stored material in this preconceptual design.

Each subsection shows the storage configuration for each type of material to be stored. These configurations are based on the "standard" storage configurations described in Section 1.2.2.

2.1 General Design Criteria

The following criteria are applied to the designs.

1. The designs must address three types of storage facilities and three depleted uranium material types. The required combinations of facilities and materials are presented in table 2-1.

2. The storage systems must provide for receipt of the following materials over a 20-year period and storage for 20 years after receipt of the last container (40 years after storage of the first container). Table 2-2 presents the storage container types for each depleted uranium material form.

3. The storage systems must provide systems or methods for: (a) inspection of the integrity of the containers; (b) monitoring of storage air for indications of failed containers; and (c) removal and management of any failed containers.

4. For storage systems involving UF_6 cylinders, humidity control systems should be provided to prevent condensation on cylinders.

5. The facility will be designed, constructed, and operated so that workers, the general public, and the environment are protected from the impacts of natural phenomena hazards. DOE Order 5480.28 Natural Phenomena Hazards Mitigation (NPHM) identifies these requirements.

Table 2-1. Depleted Uranium Material Types and Storage Options Evaluated

Facility Type	UF_6	UO_2	U_3O_8
Building Facility	Yes	Yes	Yes
Vault Facility	No	Yes	Yes
Mined-Cavity Facility	Yes	Yes	Yes

Table 2-2. Storage Container Types, Mass, and Numbers of Containers

Depleted Uranium Form	Container	Mass/Filled Container - Contents Only (kg)	Number of Containers
UF_6	Type 48 cylinders	12,247	46,422
UO_2	30-gallon drums	1,021	420,000
U_3O_8	55-gallon drums	667	713,660

The selection of structure, systems, and components (SSCs) that require NPHM design should be based on the safety classifications developed for the SSCs. Mission importance and economic considerations should also be used in selecting these components. Once these SSCs are assessed, DOE 5470.28 specifies the hazard requirements to ensure that the components are adequately designed to resist natural phenomena hazards.

The natural phenomena hazard standard, DOE-STD-1020-94, was developed from UCRL-15910, and provides criteria to follow for design of new SSCs so that DOE can evaluate and upgrade SSCs against the effects of such hazards as earthquakes, floods, and extreme winds. DOE-STD-1020-94 is used by all DOE sites and provides the means to implement DOE Order 5480.28 for all NPHM and to comply with DOE's safety policy, SEN-35-91.

DOE-STD-1020-94 essentially replaces the four-category hazard ranking system of UCRL-15910 with five performance categories.

The design and evaluation criteria for SSCs in Performance Categories 0, 1, and 2 are similar to those given in model building codes. Performance Category 0 recognizes that for certain lightweight equipment items and for other special circumstances where there is little or no potential impact on safety, mission, or cost, design or evaluation for natural phenomena hazards may not be needed. Assignment of an SSC to Performance Category 0 is intended to be consistent with, and not take exception to, model building code natural phenomena hazards (NPH) provisions. Performance Category 1 criteria include no extra conservatism against natural phenomena hazards beyond that in model building codes that usually include earthquake, wind, and flood considerations. Performance Category 2 criteria are intended to maintain functionality and to keep the SSCs operational in the event of natural phenomena event. Model building codes would treat hospitals, fire and police stations, and other emergency handling facilities in a similar manner to DOE-STD-1020 Performance Category 2 NPH design and evaluation criteria.

Performance Category 3 and 4 SSCs involve significant amounts of hazardous materials or are programmatically significant. Damage to these SSCs could potentially endanger worker and public safety and the environment or interrupt a significant mission. As a result, these SSCs must continue to function in the event of a natural disaster so that hazardous materials may be controlled and confined. For these categories, there must be a very small likelihood of damage due to natural events. DOE-STD-1020 NPH criteria for Performance Category 3 and higher SSCs are more conservative than requirements found in model building codes and are similar to Department of Defense (DOD) criteria for high risk buildings and Nuclear Regulatory Commission (NRC) criteria for various applications.

For Performance Category 1 SSCs, the primary concern is preventing major structural damage or collapse that would endanger personnel. A performance goal of an annual probability of exceedance of about 10^{-3} of the onset of significant damage is appropriate for this category.

Performance Category 2 SSCs are of greater importance because of their importance to mission. Failure of these SSCs may also pose a greater danger to onsite personnel than Performance Category 1 SSCs because of the operations or materials involved. The performance goal is to maintain occupant safety and the capacity to function. Performance Category 2 SSCs should allow relatively minor structural damage in the event of natural phenomena. This is damage that results in minimal interruption to operations or damage that can be easily and readily repaired following the event. A reasonable performance goal is judged to be an annual probability of exceedance of between 10^{-3} and 10^{-4} of structure or equipment damage, with the SSC being able to function with minimal interruption. This performance goal is slightly more severe than that corresponding to the design criteria for essential facilities (e.g., hospitals, fire and police stations, centers for emergency operations) in accordance with model building codes.

Performance Category 3 and higher SSCs pose a potential hazard to public safety and the environment because radioactive or toxic materials are present. Design considerations for these categories are to limit SSC damage so that hazardous materials are controlled and confined, occupants are protected, and functioning of the SSC is not interrupted. The performance goal for Performance Category 3 and higher SSCs is to limit damage such that DOE safety policy is achieved. For these categories, damage must typically be limited in confinement barriers (e.g., buildings, gloveboxes, storage canisters, vaults), ventilation systems and filtering, and monitoring and control equipment in the event of an occurrence of severe earthquakes, winds, or floods. In addition, SSCs can be placed in Performance Categories 3 and 4 if improved performance is needed due to cost or mission requirements.

A qualitative assessment of the hazard ranking and performance category for the three proposed storage facilities (building, vault, and mined cavity) has been performed. Table 2-3 summarizes the results of this assessment.

Table 2-3. Qualitative Assessment of Hazard Ranking for Storage Facility Buildings

Building/Area	Hazard Ranking/Category*	Qualitative Rationale
Administration Building	None/Performance Category 0	No hazard
Receiving Warehouse and Repackaging Facility	Low/Performance Category 2	No offsite*, minimal onsite consequences from nonradioactive materials
Cylinder Washing Facility	Low/Performance Category 3	Small offsite, onsite consequences from nonradioactive materials
Workshop	Low/Performance Category 1	No offsite releases, minimal onsite releases from radioactive materials; no consequences
Storage Building	Low/Performance Category 2	No offsite*, minimal onsite releases; essential to mission
Vault	Low/Performance Category 2	No offsite, minimal onsite releases; essential to mission
Mined Cavity	Low/Performance Category 2	No offsite*, minimal onsite releases with consequences; essential to mission

*UF_6 in cylinders could allow offsite releases through surface or groundwater.

Potential hazards and accident analyses dictate the specific design and construction requirements of DOE and NRC facilities via established protocols. At the preconceptual level, qualitative assessments and hazard rankings only are possible. Most of the buildings are assigned low hazard rankings. These buildings and areas contain and process radioactive materials. However, due to the nature of the operations and the chemical and physical forms, there is minimal energy for dispersion and contamination. Hence, there would be limited offsite consequences and minimal onsite consequences. The receiving warehouse and storage buildings would potentially contain large inventories of radioactive materials. However, the radionuclides would exist in solidified forms, preferably in nonrespirable sizes, and release fractions would be minimal.

2.2 Building Storage Facility

The building storage facility is basically a set of buildings that are constructed on concrete pads.

2.2.1 Major Buildings

The major buildings for a building storage facility include the following:

- The storage buildings (a varying number of buildings, depending on the form of the stored material).
- A Receiving Warehouse and Repackaging Building in which the containers are temporarily stored, inspected, and repackaged (when necessary) prior to being placed in one of the storage buildings.
- A Cylinder Washing Building (UF_6 only) for cleaning damaged or corroded cylinders and converting the UF_6 heel to UO_2F_2 and calcium fluoride (CaF_2).
- A workshop for maintaining equipment necessary for the repair of inspection and repackaging equipment.
- An administration building.

These buildings are described in the following sections. The buildings, although large, follow generally accepted designs and would not require unusual construction or unique construction equipment. No unusual contractor or supplier requirements appear necessary. The designs do not use unusual or rare materials. The buildings are designed to use standard concrete floors and metal wall construction on spread footings, with at-grade construction. Stainless steels (probably 300 series low carbon, "L" grades) and nickel alloys (primarily inconel and some monel) represent the principal metals of construction.

2.2.1.1 Storage Buildings

Storage buildings would be "Butler" buildings. The dimensions were scaled by maintaining approximately the same length of the building (265 m, 870 ft) and increasing the width to accept about 1-year's worth of product (about 19,000 te Uranium) to be stored for the material requiring the greatest space (U_3O_8). A 50-m (160-ft) wide building width would be adequate to store 22,000 metric tons (te) U_3O_8. The overall dimensions and layout for the storage buildings for each product are presented in figures 2-1a and 2-1b. The number of containers stored in each building and the overall dimensions are presented in table 2-4 for each of the product storage options.

Figure 2-1a: Plan View of Storage Building Showing Storage Configurations

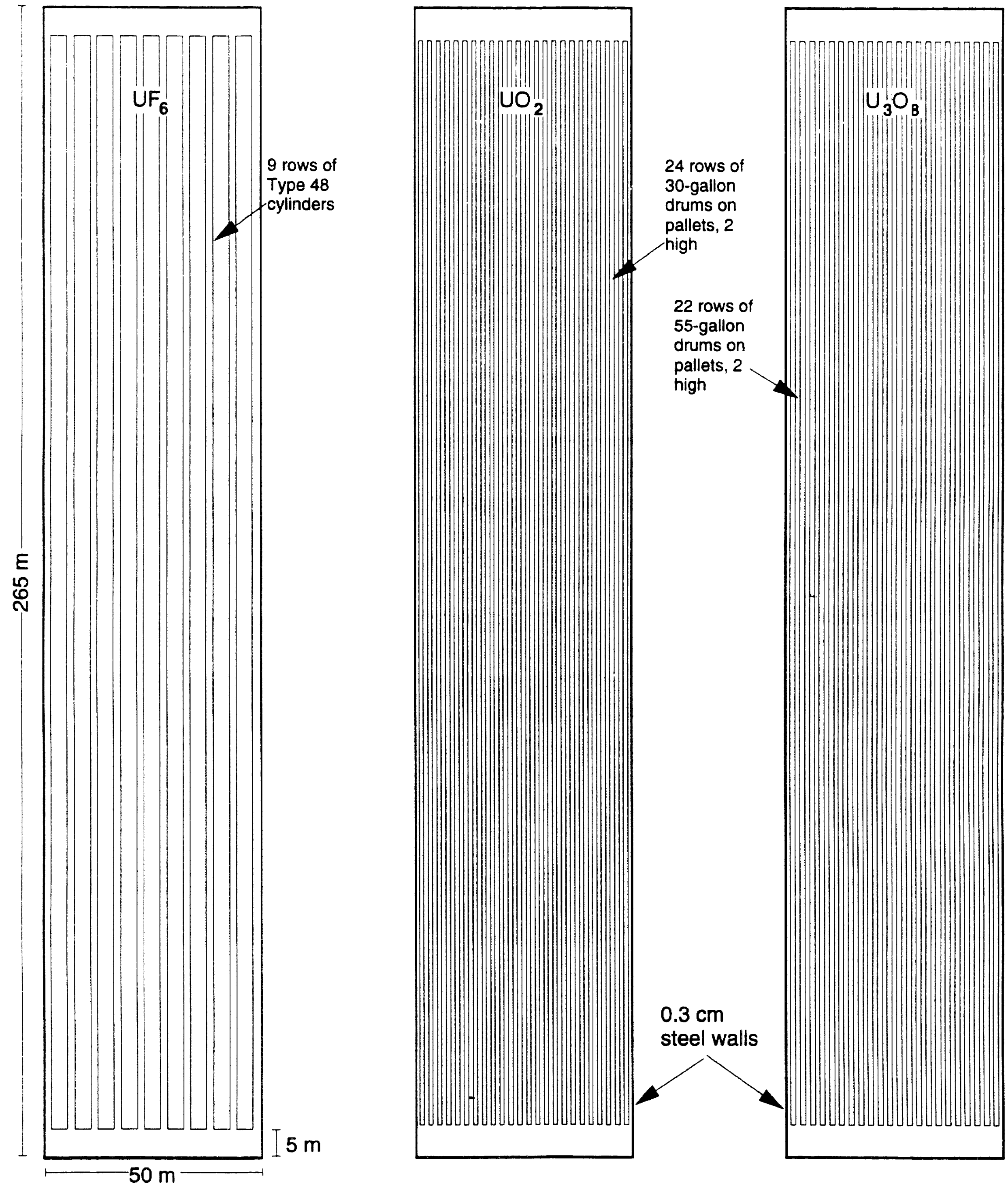


Figure 2-1b: Elevation View of Storage Building Showing Storage Configurations

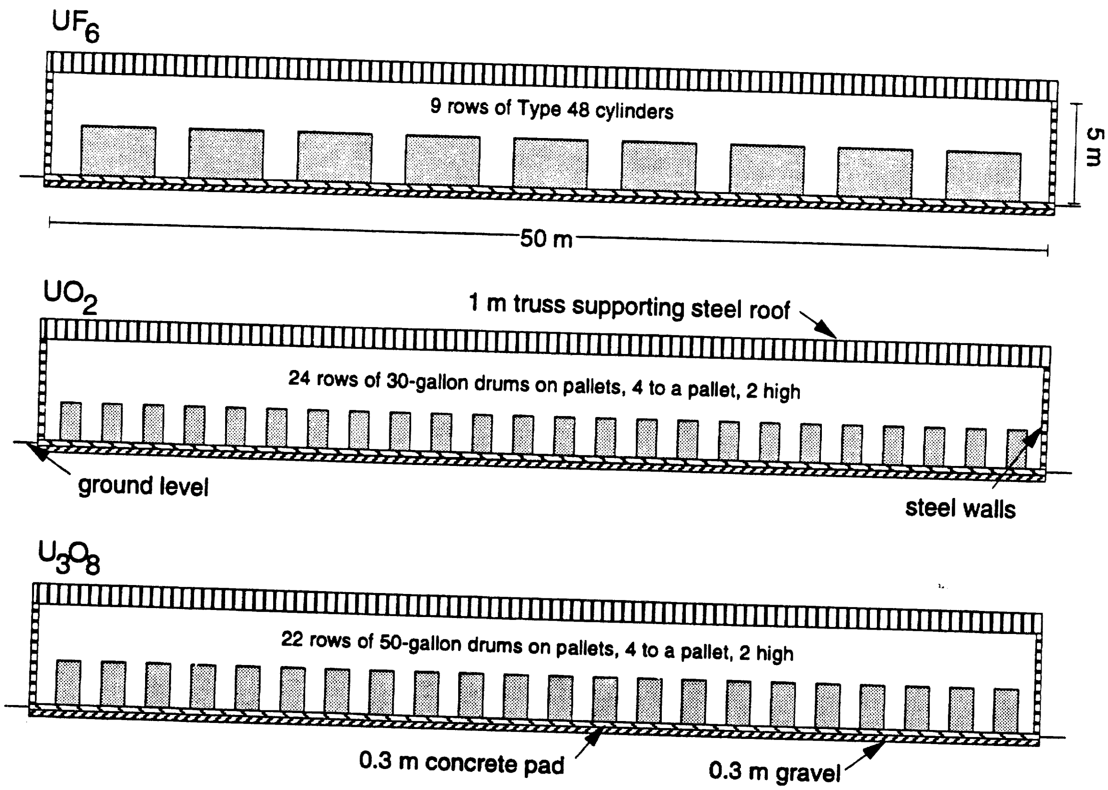


Table 2-4. Dimensions of Storage Buildings and Storage Capacity per Building

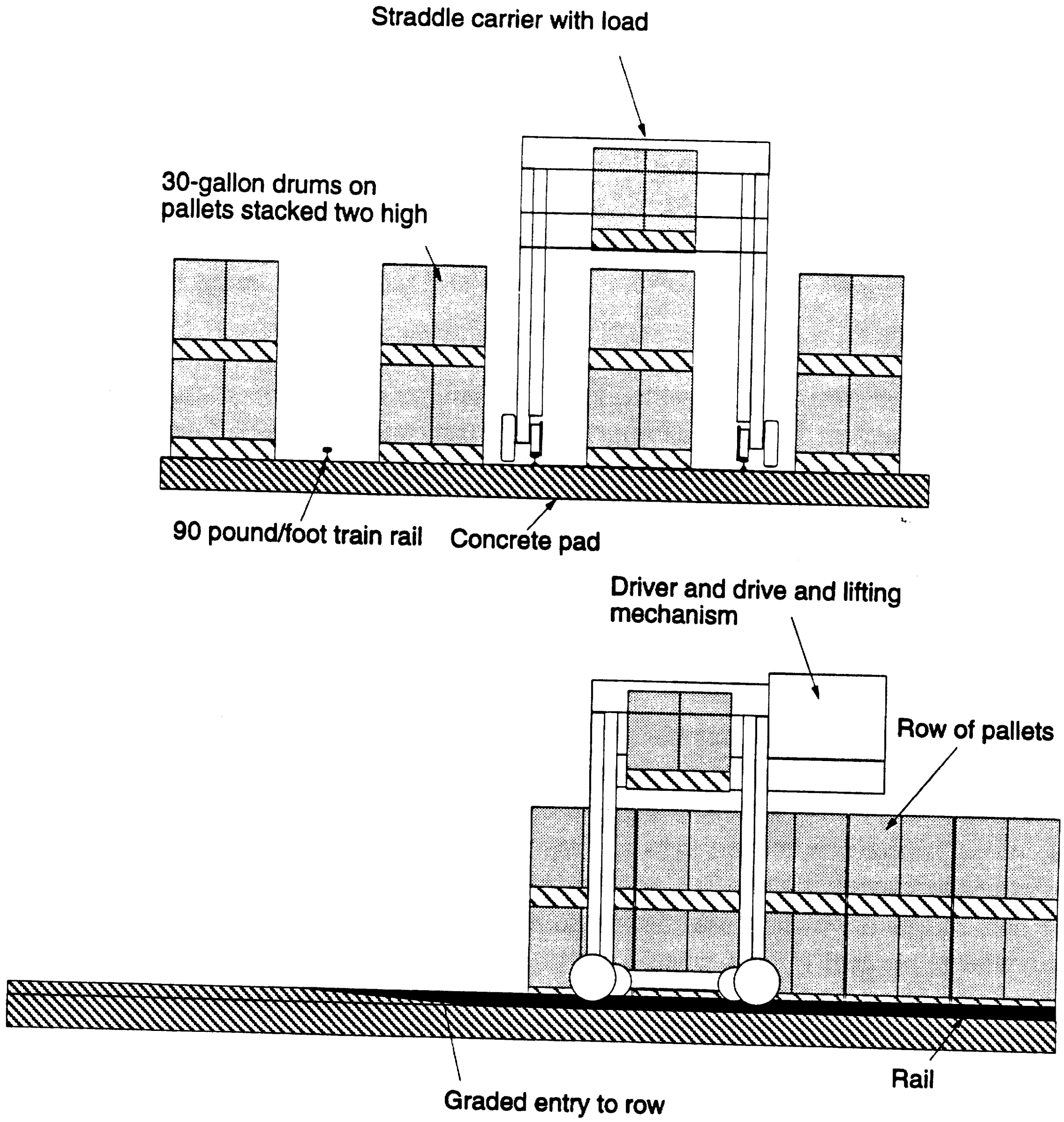
Depleted Uranium Form	Length (m)	Width (m)	Number of Rows	Containers/ Row	Containers/ Building	Number of Buildings	
UF_6	265	50	9	319	2,871	17	16.17
UO_2	265	50	24	1,944	46,656	9	9.002
U_3O_8	265	50	22	1,616	35,552	20	20.07

Each building has a shipping/receiving bay at each end, but otherwise, the entire building is designed to contain rows of storage drums with 1-m wide aisles between rows and between the walls and the end rows. Storage of UF_6 cylinders would be in rows with cylinders on 1.5-m (5-ft) centers, with 1.2 m (4 ft) between rows. This is the practice now being implemented at the Portsmouth facility.

All containers must be readily removable, since containers may fail in storage and the contents would require repackaging. It would be impractical to remove all of the pallets from a row simply to remove a damaged drum on the last pallet in a row, so forklift access is not a practical solution for this tightly packed storage configuration. If overhead cranes were used, there would need to be one or more overhead cranes for each building. This requires considerable structural strength in the building. A crane would potentially cause more damage to stored materials should the roof collapse because of an environmental disaster (earthquake, tornado, snow burden, etc.) than a facility without a crane.

The best alternative to offset the impacts of structural strength and potential damage in a natural disaster would be a straddle carrier (see figure 2-2). The wheels of the carrier would pass through the narrow aisles and would attach to a pallet or cylinder from the top. The carrier would be steerable and thus could be moved between rows in a single building or between buildings as needed. Since the narrow aisle width makes steering down a row of pallets difficult, steel rails would be laid in the floor to guide the straddle carrier. The transfer of weight from rubber (steerable) wheels to steel (fixed) wheels on the carrier could be accomplished by grading the entry to the storage rows. A building could be served by one or more straddle carriers, as necessary.

Figure 2-2: Configuration of Storage with Rails to Guide Straddle Carrier



Otherwise, the building would be a standard, warehouse-type building. Spread footings and a 30-cm (1-ft) concrete floor are included. Exterior walls would be of sheet steel. There would be no interior pillars. Steel trestles would support a truss-supported flat roof. Heating, ventilation, and air conditioning (HVAC) would be limited to avoiding temperature and humidity extremes. High Efficiency Particulate Air (HEPA) filtration would be provided to periodically test for radioactivity losses from the stored material.

2.2.1.2 Receiving Warehouse and Repackaging Building

The Receiving Warehouse and Repackaging Building is designed for temporary storage and inspection of received product, with a repackaging facility to repackage damaged containers. The entire building would be HEPA filtered and would be served by two bridge cranes. The Receiving Warehouse is designed to store between a 5- and 6-week supply (50 UF_6 cylinders, 115 UO_2 pallets, and 190 U_3O_8 pallets would be delivered per week) of containers depending on the chemical form of the material to be stored. Each UF_6 cylinder would be stored one high and would have a 1-m area clearance to allow detailed inspection of all sides. Drums would be stored on pallets, one high. Each pallet would have a 1-m clearance to allow detailed inspections of all sides. The storage configuration is presented in table 2-5. This is depicted in figures 2-3a, 2-3b, and 2-3c. Undamaged containers would be moved directly to the shipping area for removal to a storage building; damaged containers would be moved to the repackaging area for transfer of contents to a new container.

Table 2-5. Dimensions, Storage Configuration, and Capacity of Receiving Warehouse

Depleted Uranium Form	Length (m)	Width (m)	Number of Rows	Containers per Row	Storage Capacity (Weeks)
UF_6	67	66	10	23	5
UO_2	67	66	24	108	6
U_3O_8	83	75	30	120	5

The Repackaging Building would include machinery to repackage drums or an autoclave for the transfer of UF_6 to a new cylinder. A small storage area would contain new containers, and a small cleaning area would be used to decontaminate used drums (a separate cylinder washing facility is provided for cleaning empty UF_6 cylinders). Drums would be moved in the receiving warehouse by bridge crane and from or to trucks or railcars by davit crane. Transfer of containers from the receiving warehouse to the repackaging facility would be by forklift.

Figure 2.3a: Plan View of Receiving Warehouse and Repackaging Building, UF_6, Base

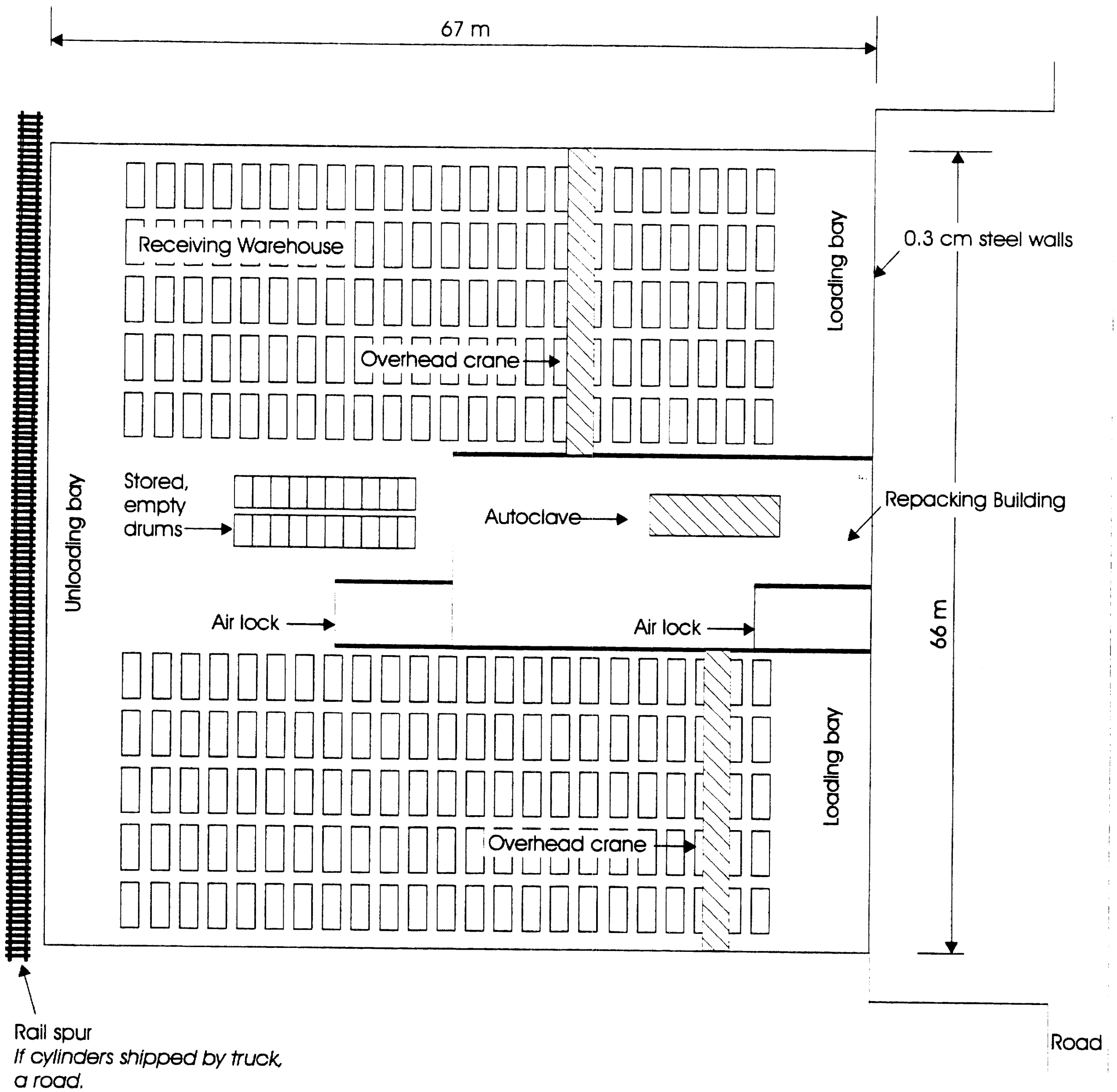
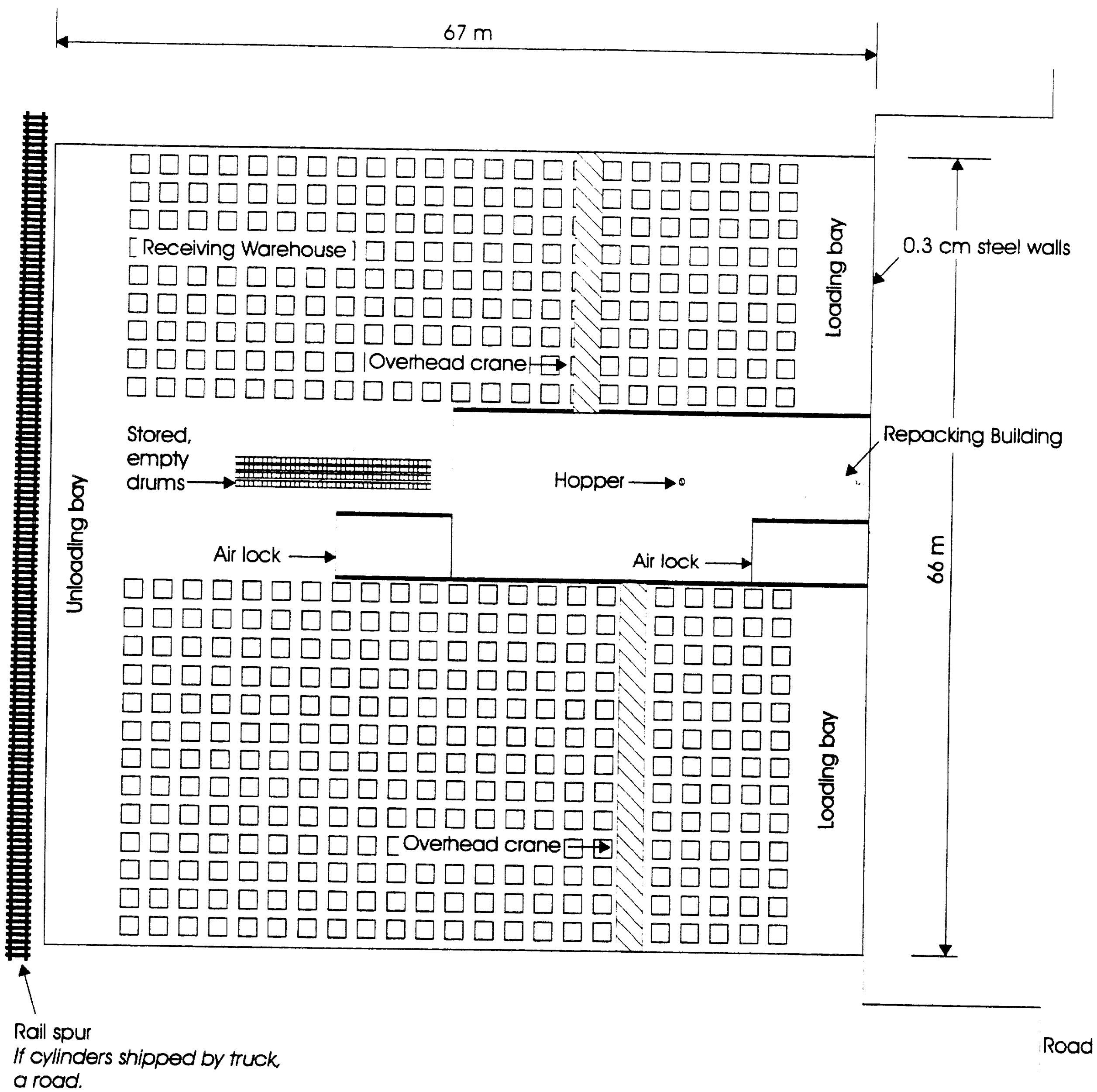
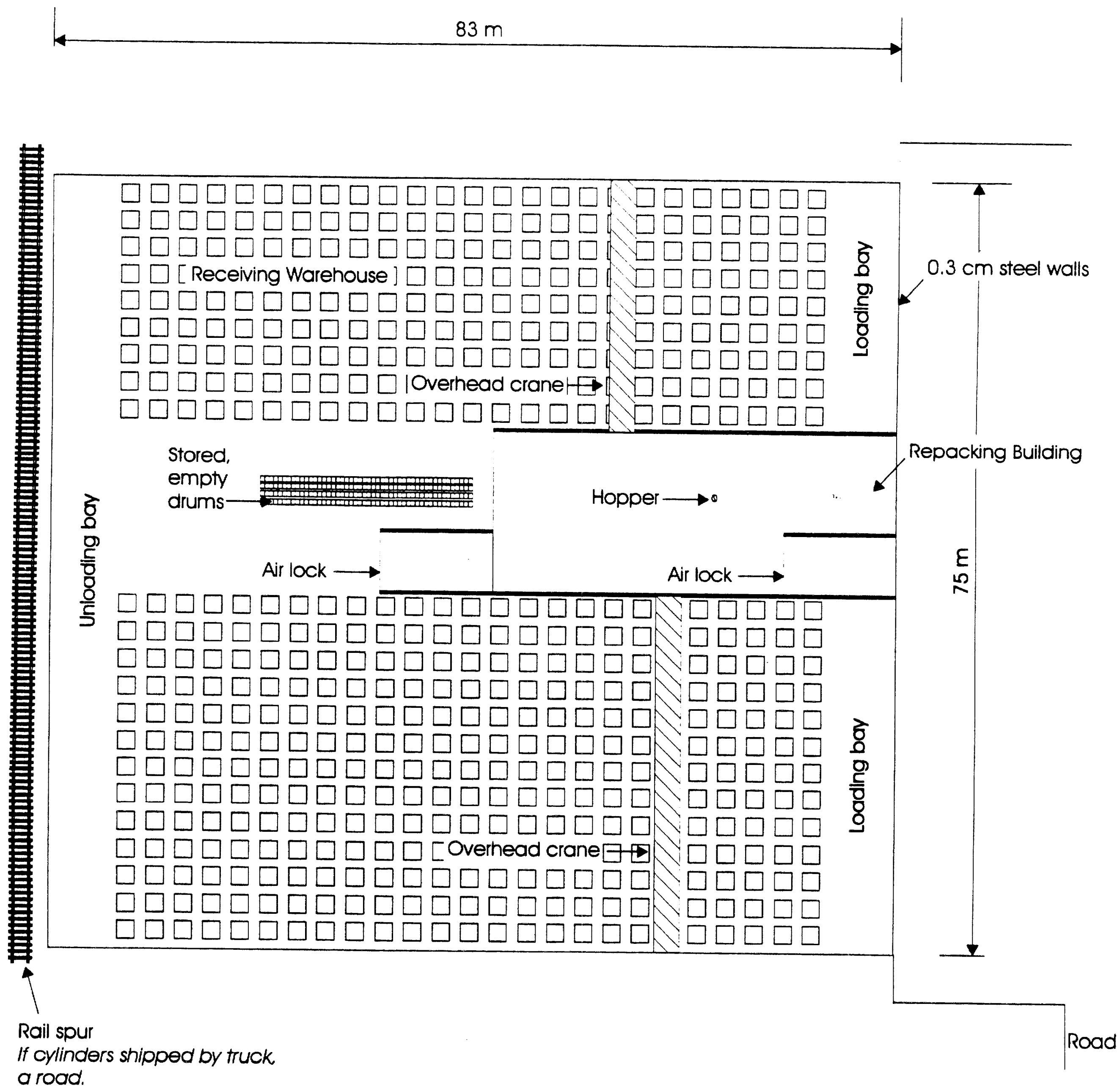


Figure 2.3b: Plan View of Receiving Warehouse and Repackaging Building, UO_2, Base



Note: Number of containers across each row is 108

Figure 2.3c: Plan View of Receiving Warehouse and Repackaging Building, U_3O_8, Base



Note: Number of containers across each row is 120
Number of rows is 30.

The building would be a standard, warehouse-type building. Spread footings and a 30-cm (1-ft) concrete floor are included. Exterior walls would be of sheet steel, with steel pillars providing additional support for crane rails as needed. There would be no interior pillars. Steel trestles would support a standard flat roof. HVAC would control temperature and humidity to comfortable working levels.

2.2.1.4 Cylinder Washing Building

The cylinder washing building is for cleaning empty, damaged Type-48 cylinders that would contain a heel of UF_6 up to 10 kg. It would be a two-story concrete building with areas for washing cylinders, evaporating wash water, converting the depleted uranium in the wash waster to UO_2F_2, and supporting areas. This building would not be needed for drum washing because drums would contain only UO_2 or U_3O_8, and both of these forms have low solubilities in water, would not generate hazardous HF, and would require much less space for drum cleaning (to be done in the Repackaging Building). The general layout of this building is presented in figure 2-4.

2.2.1.5 Workshop

The workshop is for maintaining equipment necessary for the repair of inspection and repackaging equipment. The interior has not been designed. The building would be a standard, warehouse-type building, 25 m x 25 m (82 ft x 82 ft). Spread footings and a 30-cm (1-ft) concrete floor are assumed. Exterior walls would be of sheet steel. There would be no interior pillars. Steel trestles would support a standard flat roof. HVAC would control temperature and humidity to comfortable working levels.

2.2.1.6 Administration Building

The administration building would be a small office structure to house the management and office staff of the storage facility. A common area is provided for facility staff. The common area would be serviced by showers and a changing area for personnel working with the depleted uranium containers. See figure 2-5.

2.3 Vault Storage Facility

2.3.1 Major Buildings

The major structures for a vault storage facility include the following:

- The vaults in which the depleted uranium is stored,

Figure 2-4: Plan View of the Cylinder Washing Building

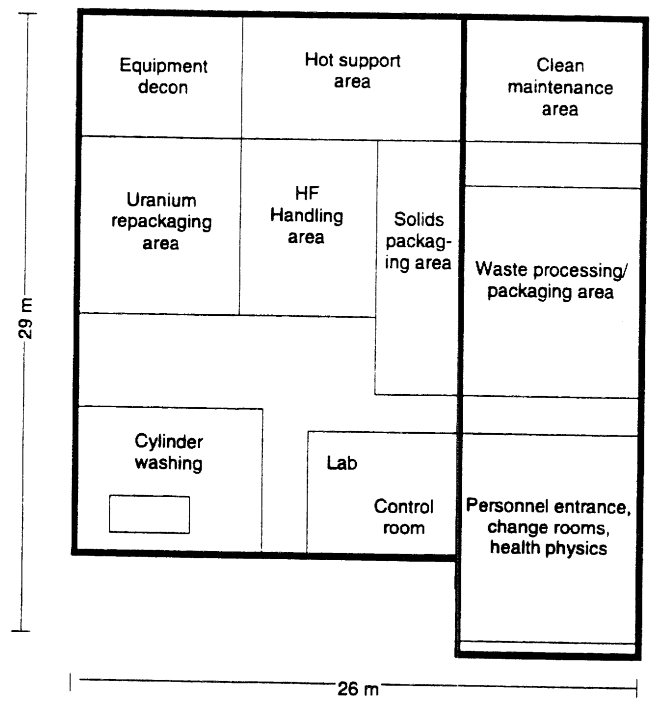
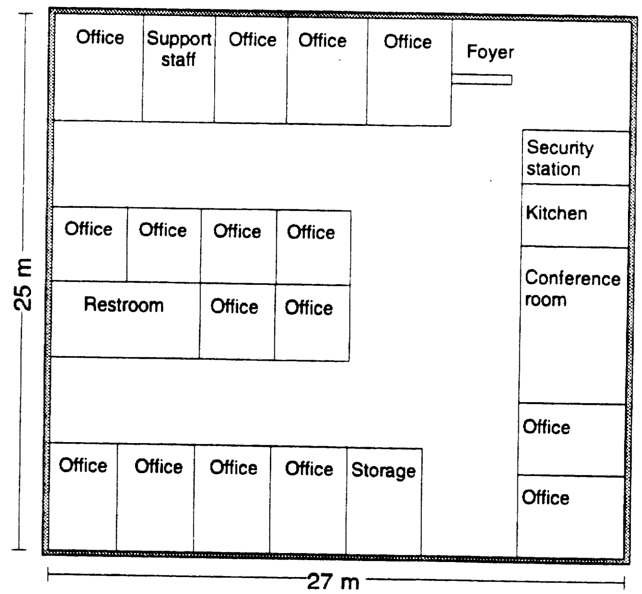


Figure 2-5: Plan View of the Administration Building



- A receiving warehouse and repackaging facility in which the containers are stored, inspected, and repackaged (if necessary) prior to placement in one of the storage vaults,

- A workshop for maintaining equipment necessary for the repair of inspection and repackaging equipment, and

- An administration building.

Each of these facilities is described below.

2.3.1.1 Vaults

The vaults are modeled after low level waste disposal vaults described in the *Disposal Options from Depleted Uranium Management* (see section 6.13) with some modifications. These are subsurface reinforced concrete structures, 40 m (131 ft) by 81 m (266 ft) (see figures 2-6a and 2-6b), but without the normal concrete walls that divide the vault into cells. The walls are not necessary because the design concept for the vault uses a steel roof rather than a concrete slab roof to prevent requiring access from the end. The lighter steel roof, supported by trusses, does not require interior support. This design allows part of the roof to be removed for access to the vault itself, and access can be by a mobile crane that can be relocated from vault to vault as necessary.

The length of the vault has been increased over the "standard" vault to increase storage area per vault and reduce the total number of vaults required (see table 2-6). A maximum length of approximately twice the width was considered workable. Even with the longer length, 35 vaults would be required to store the depleted uranium in the UO_2 form, and 79 vaults would be required to store the U_3O_8 form.

Table 2-6. Dimensions of Vaults and Storage Capacity per Vault

Depleted Uranium Form	Length (m)	Width (m)	Pallets/ Row	Number of Rows	Containers/ Vault	Number of Vaults
UO_2	81	40	162	19	12,312	35
U_3O_8	81	40	134	17	9,112	79

Forced ventilation would be provided for periods when people were working in a vault, but otherwise, no heating or air conditioning would be provided. Power would be needed for internal lighting and limited ventilation only.

Figure 2-6a: Plan View of Vault Showing Storage Configurations

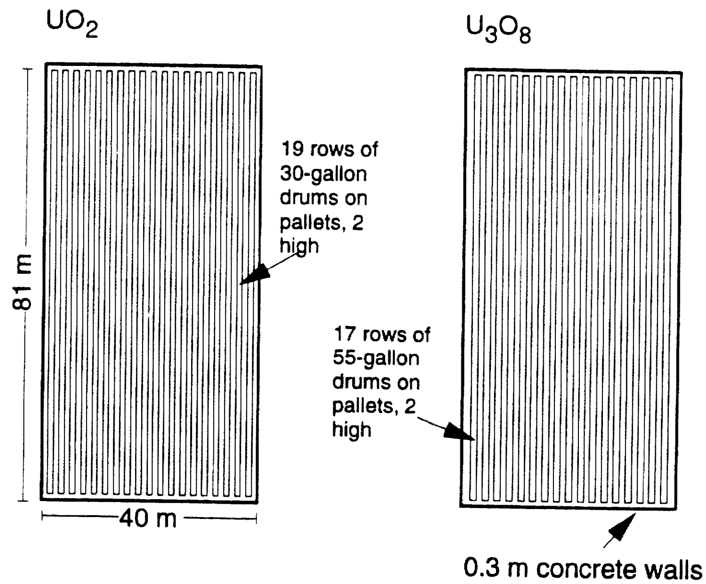
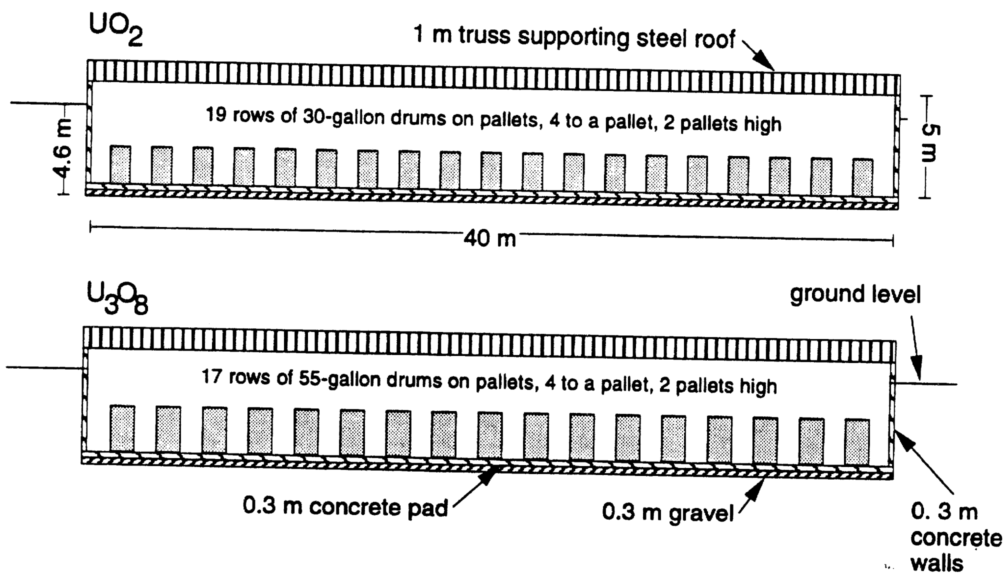


Figure 2-6b: Elevation View of Storage Vault Showing Storage Configurations



French drains would be constructed uphill of the vaults to direct groundwater away from the structures, and drains would be installed along the ends of the vaults to prevent the accumulation of rain water.

A 10-meter area around each vault would have a crushed stone road to support the crane and trucks that would transport repackaged containers to each storage vault.

2.3.1.2 Other Structures

The Receiving Warehouse and Repackaging Building, the Administration Building, and the Workshop Building would be the same for this facility as for the building storage facility. These buildings are described in Sections 2.2.1.2, 2.2.1.3, 2.2.1.4, and 2.2.1.5 respectively.

2.4 Mined-Cavity Storage Facility

Of the three options for storage of depleted uranium, the mined-cavity storage would be by far the most complex. There are several reasons for this:

- The size of the drifts would be limited by geological conditions; the width of the drifts would be restricted to less than 3 m (10 ft) in sedimentary shales, for example. This would mean that UF_6 in Type 48 cylinders would have to be stored end-to-end in a drift, a very inefficient storage method.

- Forced ventilation is needed throughout the shaft, tunnel, and drift system if people are to work in the area without breathing tanks. While this is technically possible, the cost of maintenance and the energy requirements for the ventilation are very high compared to other storage options.

2.4.1 Major Buildings

The major structures for a mined-cavity storage facility include the following:

- The drifts in which the depleted uranium is stored with connecting aisleways (tunnels) and shafts,

- A receiving warehouse and repackaging facility in which the containers are stored, inspected, and repackaged (if necessary) prior to placement in one of the storage drifts,

- A cylinder washing facility (for UF_6 storage only) in which damaged cylinders are cleaned and the removed heel of UF_6 converted to UO_2F_2 and CaF_2,

- A workshop for maintaining equipment necessary for the repair and inspection of repackaging equipment and relocation equipment, and
- An administration building.

Each of these facilities is described below.

2.4.1.1 Drifts

Drifts are lateral extensions of belowground tunnels in which depleted uranium can be stored. The size of the drifts is dependent on the geological structure in which they are cut—stronger and nonplastic strata can support larger drifts than softer, fractured, or plastic strata. While there are thick surface layers of shales near the current storage location for depleted uranium, these shales are generally fractured, and mines in these shales typically have small-sized drifts (on the order of 2 m x 2 m). This size drift would be ineffective for the storage of depleted uranium. On the other hand, other parts of the country have deep strata of basalt, tuff, or salt in which wide, tall drifts can be constructed. It would be these geologic materials that would house the mined-cavity storage.

The dimensions of the drifts are based on typical sizes of mined cavities in these rock strata. The dimensions of drifts are 12 m (39 ft) wide and 5 m (18 ft) high and are rectangular in cross section (see figures 2-7a and 2-7b). The length of each drift has been established at 100 m (330 ft). Each drift would contain 2 rows of UF_6 cylinders stored side-by-side, 5 rows of 30-gallon UO_2 pallets, or 5 rows of 55-gallon U_3O_8 pallets. The number of drifts and the storage capacity of each drift are presented in table 2-7. Storage arrangements are depicted in figures 2-7a and 2-7b.

Table 2-7. Dimensions of Drifts and Storage Capacity per Drift

Depleted Uranium Form	Drift Length (m)	Drift Width (m)	Rows/ Drift	Containers/ Drift	Number of Drifts	Total Drift Length (m)
UF_6	100	12	2	258	180	18,000
UO_2	100	12	5	4,000	105	11,000
U_3O_8	100	12	5	3,320	215	22,000

2.4.1.2 Other Structures

The Receiving Warehouse and Repackaging Building, the Cylinder Washing Building, the Administration Building, and the Workshop Building would be the same for this facility as for

Figure 2-7a: Plan View of Drift Showing Storage Configurations

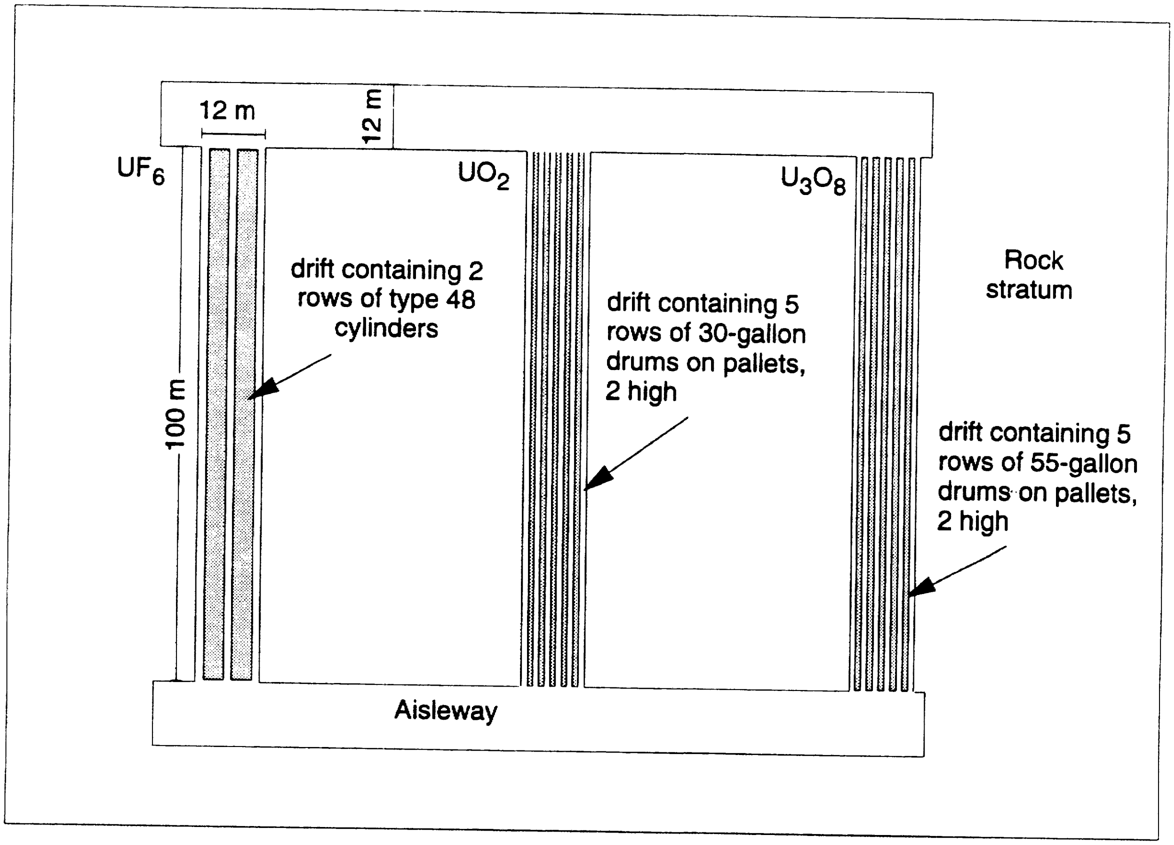
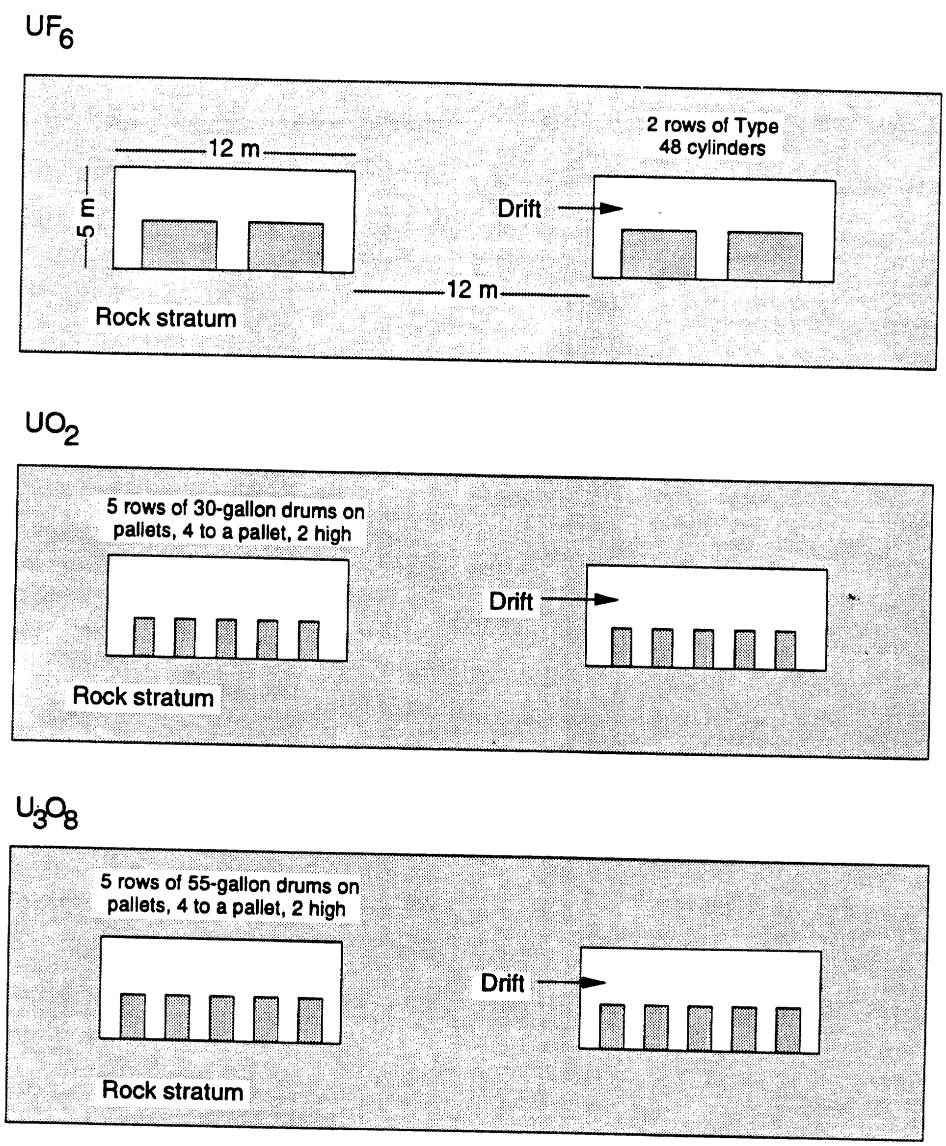


Figure 2-7b: Elevation View of Mined Cavity Showing Storage Configurations



the building storage facility. These buildings are described in Sections 2.2.1.2, 2.2.1.3, 2.2.1.4, and 2.2.1.5 respectively.

3.0 STORAGE SITE MAP AND USAGE REQUIREMENTS

The storage site maps were derived from general operating considerations of unloading containers from rail cars and trucks, storing and inspecting containers in the receiving warehouse, repackaging damaged containers, then distributing the repackaged containers to the storage areas on trucks. Where possible, some adjustments to the site maps were made according to the number of buildings, vaults, or drifts that were required. Additional considerations included restricted access to the site by road (security) and the need for open ground for rainwater infiltration. While total site area would be minimized by placing storage buildings (vaults) as close together as possible, this would create a very large area of impervious surface, compounding problems of storm water control. In general, impervious area (paving and buildings) was restricted to less than 50 percent of the site.

3.1 Building Storage Facility

The total area required for the site depends on the chemical form of the depleted uranium because more storage buildings are required for U_3O_8 storage than for the UF_6 or UO_2 storage. Land area required for the building storage facility is indicated in table 3-1.

Table 3-1. Site Land Area Requirements for the Building Storage Facility

Land Area (hectares [ha])	UF_6	UO_2	U_3O_8
Total site area*	53	32	60
Total disturbed area*	25	14	29
Total paved area	2.1	1.4	2.4

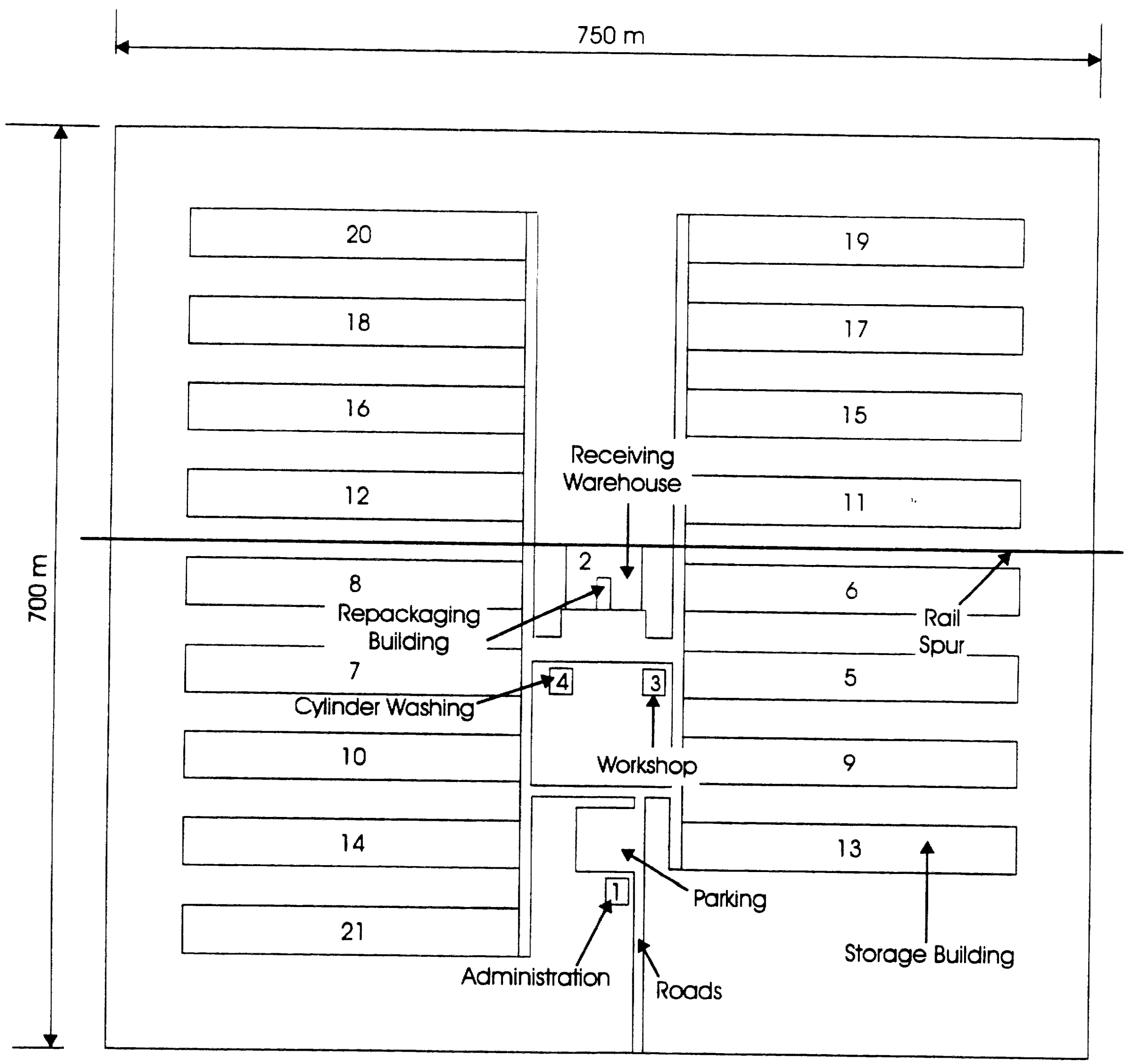
*Rounded to nearest whole hectare.

3.1.1 Site Map and Land Area Requirements During Construction

The construction sequence of the buildings is indicated in figures 3-1a, 3-1b, and 3-1c. Construction begins with the Administration Building, proceeds with the Receiving Warehouse and Repackaging Building and the Cylinder Washing Building (for UF_6), and then continues with the Workshop Building. Storage buildings are constructed near the Repackaging Building first and then away from this central location.

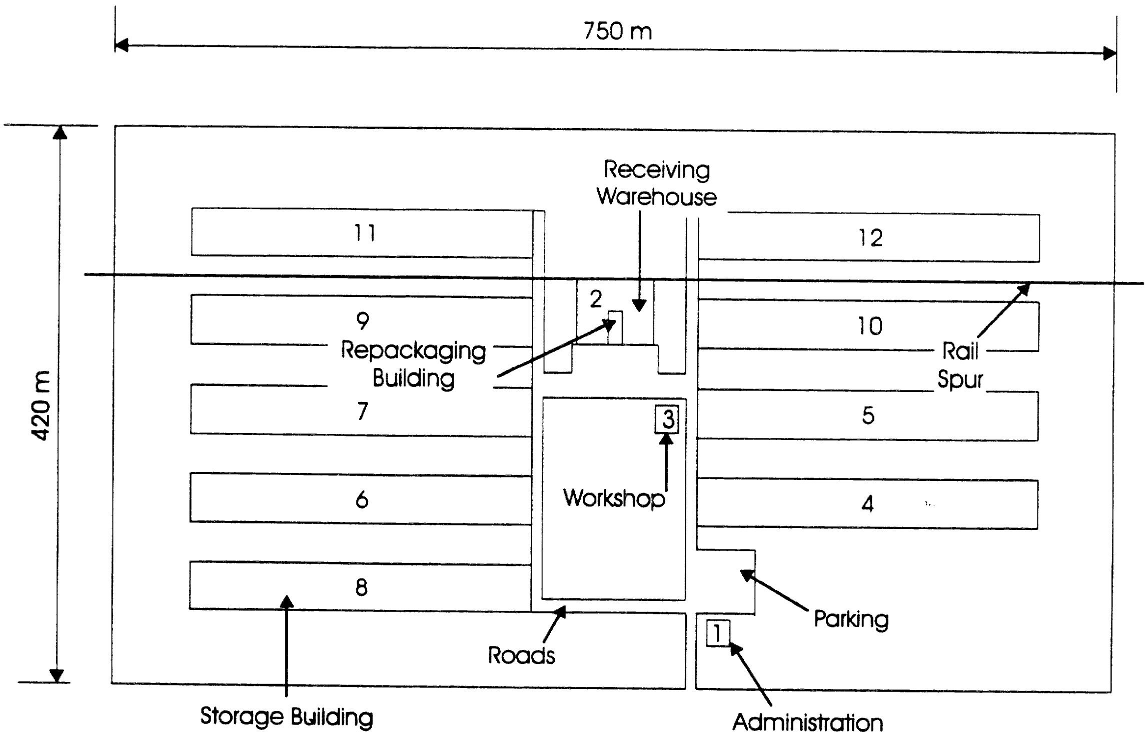
Construction material storage and movable construction trailers would be located near the centroid of the site to start and then move away from the centroid as new storage buildings are constructed. Because of the size of the site, no single location for materials storage and movable trailers has been selected. Materials storage and trailers could be located adjacent to buildings under construction.

Figure 3.1a: Site Layout, Building Storage Facility, UF_6, Base



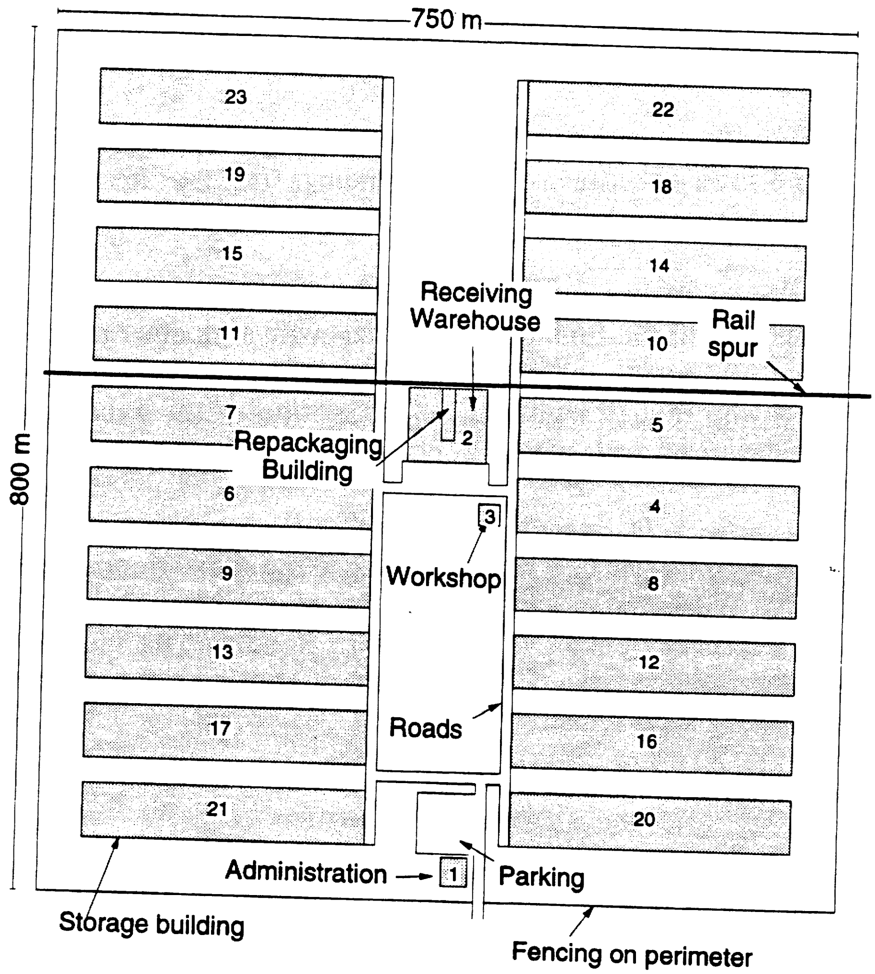
Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is 12 indicating 9 storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 3.1b: Site Layout, Building Storage Facility, UO_2, Base



Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is 12 indicating 9 storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 3-1c: Site Layout, U_3O_8, Building Storage Facility



Note: 1 Numbers refer to construction order of buildings. The highest numbered storage building is 23 indicating 20 storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Clearing and grubbing of the site would be done each year for the area where construction will begin in that year. It would not make sense to clear and grub the entire site at the beginning of construction because in 20 years' time substantial additional growth could occur, and it would only be necessary to clear and regrub the site for the last storage buildings to be built. Assuming a relatively flat site that does not require extensive grading, this approach should not affect the cost of construction appreciably.

3.1.2 Site Map and Land Area Requirements During Operation

For storage in different chemical forms, between 9 and 20 storage buildings are required. These have been laid out in two rows of between 5 and 10 buildings long (see figures 3-1a, 3-1b, and 3-1c). The area between the rows of buildings is open area for rain water infiltration.

The complex has road access from one end of the site and rail access through the center. This is to prevent road traffic and rail traffic from posing conflicts with each other and to minimize the travel time and distance required to move the containers from the Receiving Warehouse or Repackaging Building to the storage buildings. The location of the Receiving Warehouse, however, has not been optimized with regard to other buildings. This should be done at the conceptual design stage.

The Administration Building is located near the road access to the site so that the building can also house security staff. The Workshop is located centrally, near the repackaging area, to allow reasonable access to the Repackaging and Cylinder Washing Buildings, the buildings most likely to need extensive ongoing maintenance. The Workshop is also located at the centroid of the storage buildings, minimizing access time.

3.2 Vault Storage Facility

Land area required for the vault storage site is indicated in table 3-2.

Table 3-2. Site Land Area Requirements for the Vault Storage Facility

Land Area (ha)	UO_2	U_3O_8
Total Site Area*	46	86
Total Disturbed Area*	16	35
Total Paved Area	3.8	8.3

*Rounded to nearest whole hectare.

3.2.1 Site Map and Land Area Requirements During Construction

The construction sequence of the buildings and vaults is indicated in figures 3-2a and 3-2b. Construction begins with the Administration Building, proceeds with the Receiving Warehouse and Repackaging Building, and then continues with the Workshop. Storage vaults are constructed near to the Repackaging Building first, and then away from this central location.

Construction material storage and movable construction trailers would be located near the centroid of the site to start and then move away from the centroid as new storage vaults are constructed. Because of the size of the site, no single location for materials storage and movable trailers has been selected. An area the size of four storage vaults should be adequate for materials storage and trailers, so space near the vaults being constructed is a suitable location.

Clearing and grubbing of the site would be done each year for the area where construction will begin in that year. It would not make sense to clear and grub the entire site at the beginning of construction because in 20 years' time substantial additional growth could occur, and it would only be necessary to clear and regrub the site for the last storage vaults to be built. Assuming a relatively flat site that does not require extensive grading, this approach should not affect the cost of construction appreciably.

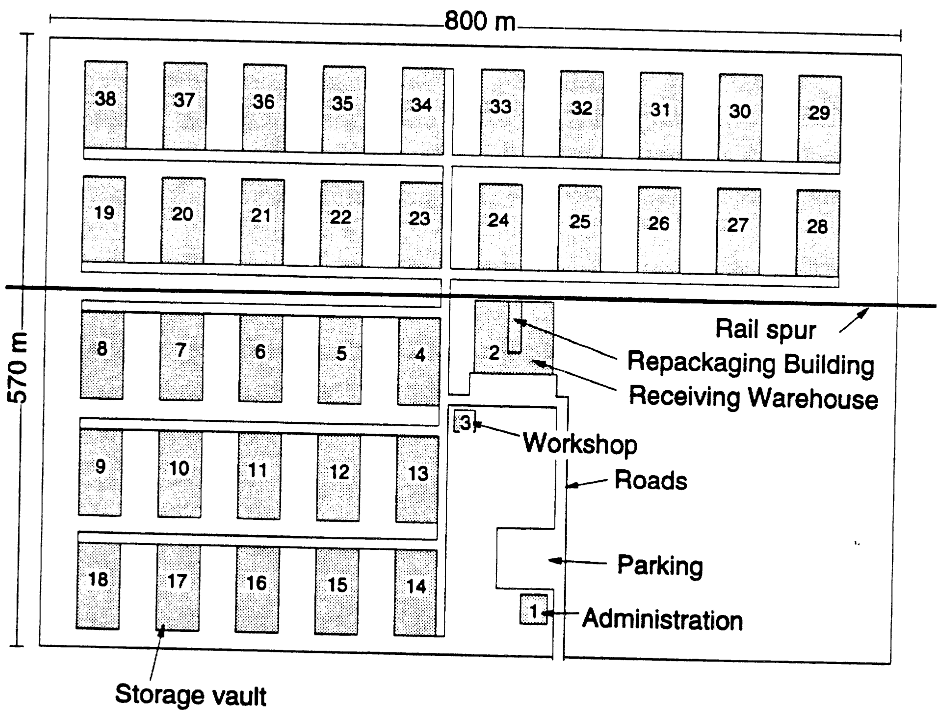
3.2.2 Site Map and Land Area Requirements During Operation

For storage in different chemical forms, between 35 and 79 storage vaults are required. These have been laid out in a grid pattern the size of which depends on the number of vaults required (see figures 3-2a and 3-2b). The area between the rows of vaults is open area for rain water infiltration.

The facility has road access from one end of the site and rail access through the center. This is to prevent road traffic and rail traffic from posing conflicts with each other and to minimize the travel time and distance required to move containers from the Receiving Warehouse or Repackaging Building to the storage vaults. The location of the Receiving Warehouse, however, has not been optimized with regard to the vaults. This should be done at the conceptual design stage.

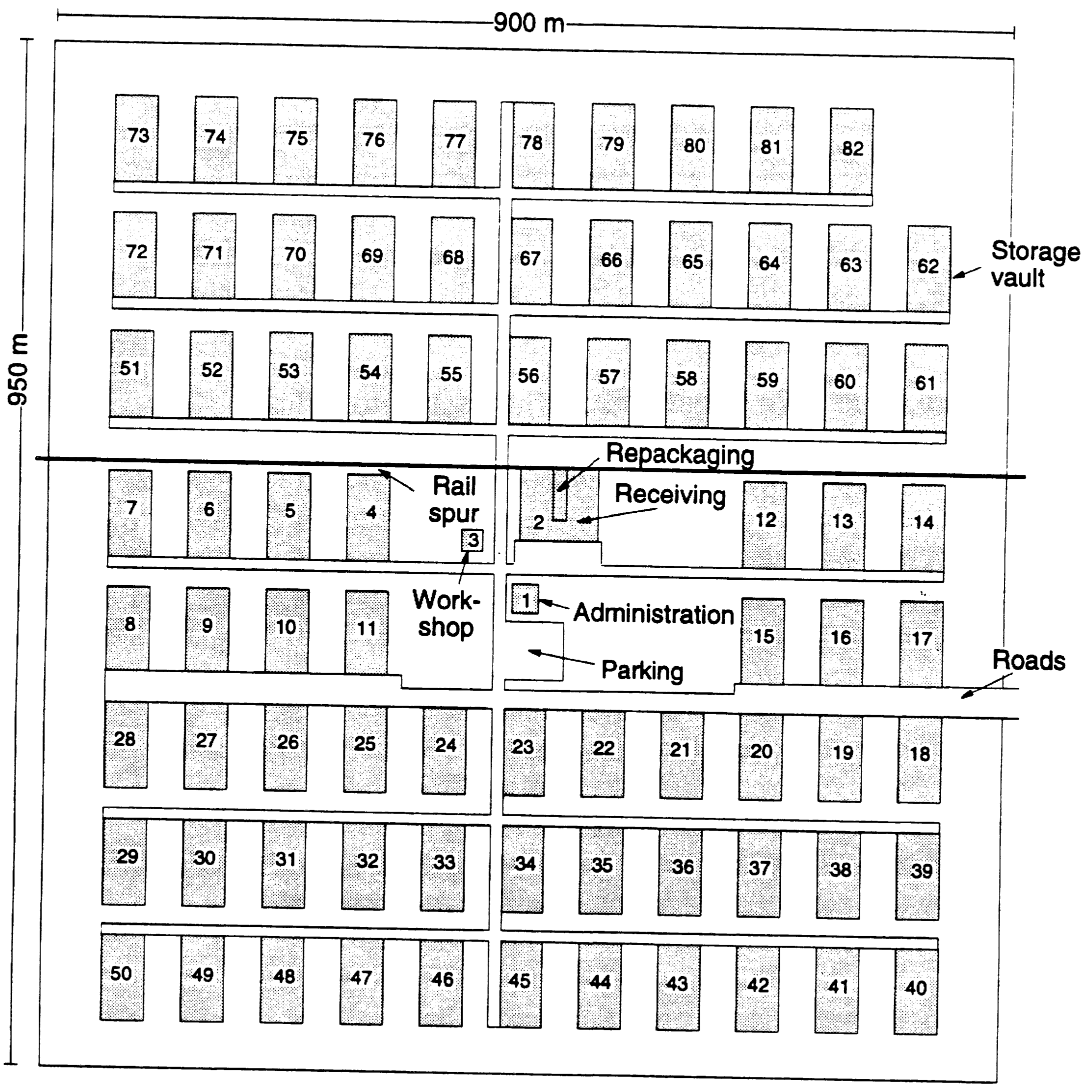
The Administration Building is located near the road access to the site so that the building can also house security staff. The Workshop is located centrally near the repackaging area to allow reasonable access to the Repackaging Building, the building most likely to need extensive ongoing maintenance. The Workshop is also located at the centroid of the storage vaults, minimizing access time.

Figure 3-2a: Site Layout, UO_2 , Vault Storage Facility



Note 1: Numbers refer to construction order of buildings. The highest numbered vault is 38 indicating 35 vaults and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 3-2b: Site Layout, U_3O_8, Vault Storage Facility



Note 1: Numbers refer to construction order of buildings. The highest numbered vault is 82 indicating 79 vaults and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

3.3 Mined-Cavity Storage Facility

Land area required for the mined-cavity storage site is indicated in table 3-3.

Table 3-3. Site Land Area Requirements for the Mined-Cavity Storage Facility

Land Area (ha)	UF_6	UO_2	U_3O_8
Total Site Area*	39	30	50
Total Disturbed Area*	13	10	22
Total Underground Area*	46	31	56
Total Paved Area	1.1	1.2	1.1

*Rounded to the nearest whole hectare.

3.3.1 Site Map and Land Area Requirements During Construction

The site for mined-cavity storage would be built in two stages. In the first, the aboveground buildings would be built, the Administration Building first, then the Receiving Warehouse and Repackaging Facility and the Cylinder Washing Building, followed by the Workshop. Accessory structures necessary for the ventilation of the mined cavity, elevator access, and other support functions would be built last. Their locations appear in figures 3-3a, 3-3b, and 3-3c.

The second stage of construction would involve the mining itself. First, two vertical shafts would be sunk, one for the removal of rock spoil, the other for transport of staff and depleted uranium containers. Two shafts are necessary to allow tunneling during the placement of depleted uranium in the completed drifts. If placement of containers were delayed until all drifts were completed, shipments would be delayed until well into the 20-year period allowed for the relocation of the currently-stored depleted uranium. Configurations of the drifts appear in figures 3-4a, 3-4b, and 3-4c.

The major connecting tunnels would be the first underground activity. This would be followed by drift construction, the drifts farthest from the shaft entries first. This allows for the placement of containers in the farthest drifts without interference from the transport of spoil. As drifts are completed, ventilation shafts and equipment would need to be added ensuring a safe working environment for straddle carrier operators and container inspectors.

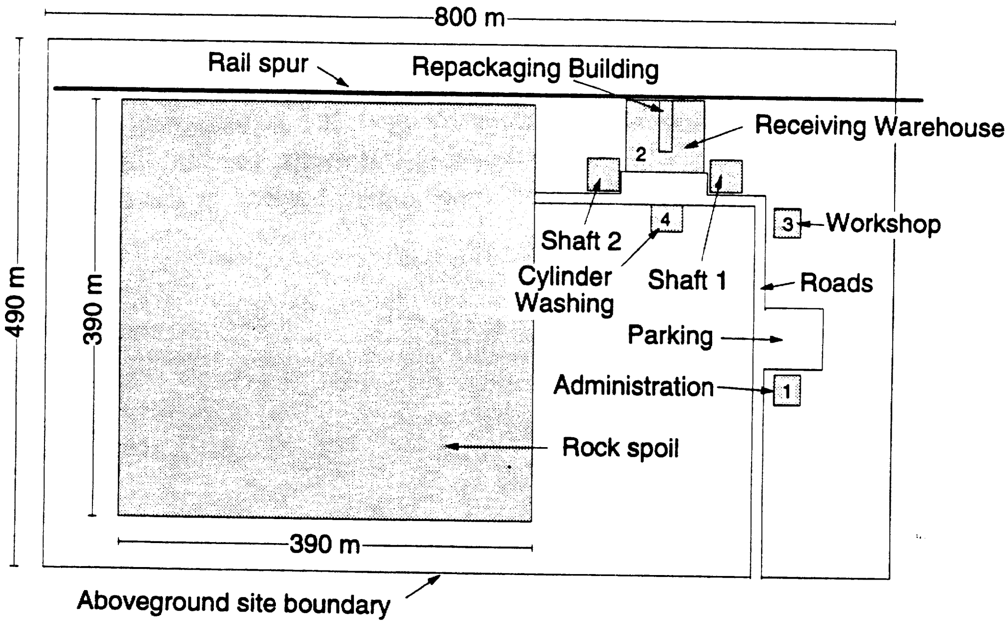
3.3.2 Site Map and Land Area Requirements During Operation

For storage in different chemical forms between 108 and 216 storage drifts are required. These have been laid out in a grid pattern the size of which depends on the number of drifts required (see figures 3-4a, 3-4b, and 3-4c). The area between the drifts is a rock pillar and is approximately 12 m wide. This gives structural support to the drifts.

The aboveground complex has road access from one end of the site and rail access through the other. This is to prevent road traffic and rail traffic from posing conflicts with each other and to minimize the travel time and distance required to move the repackaged containers from the Repackaging Building to the Storage Drifts.

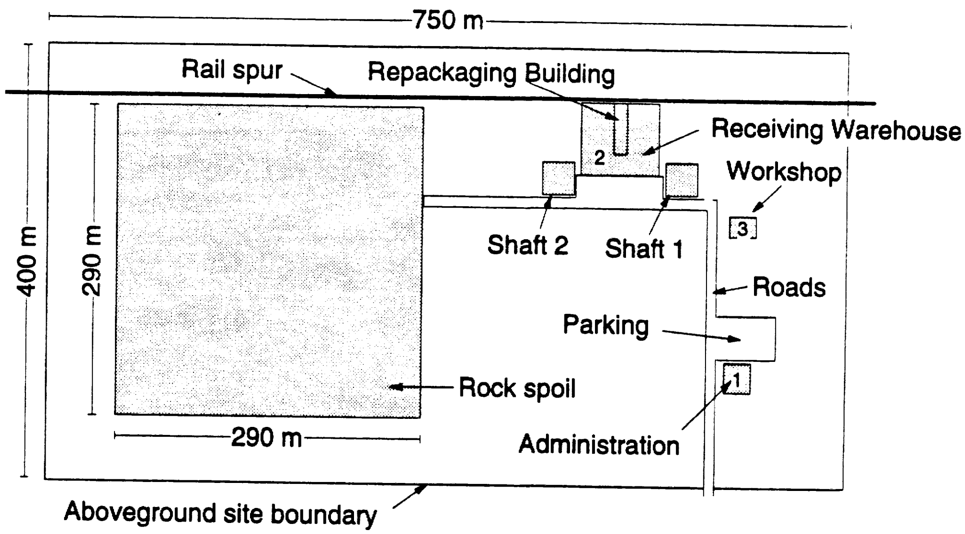
The Administration Building is located near the road access to the site so that the building can also house security staff. The workshop is located centrally near the repackaging area to allow reasonable access to the Repackaging and Cylinder Washing Buildings, the buildings most likely to need extensive ongoing maintenance. The Workshop is also located at the centroid of the storage drifts, minimizing access time.

Figure 3-3a: Aboveground Site Layout, UF_6, Mined-Cavity Storage Facility



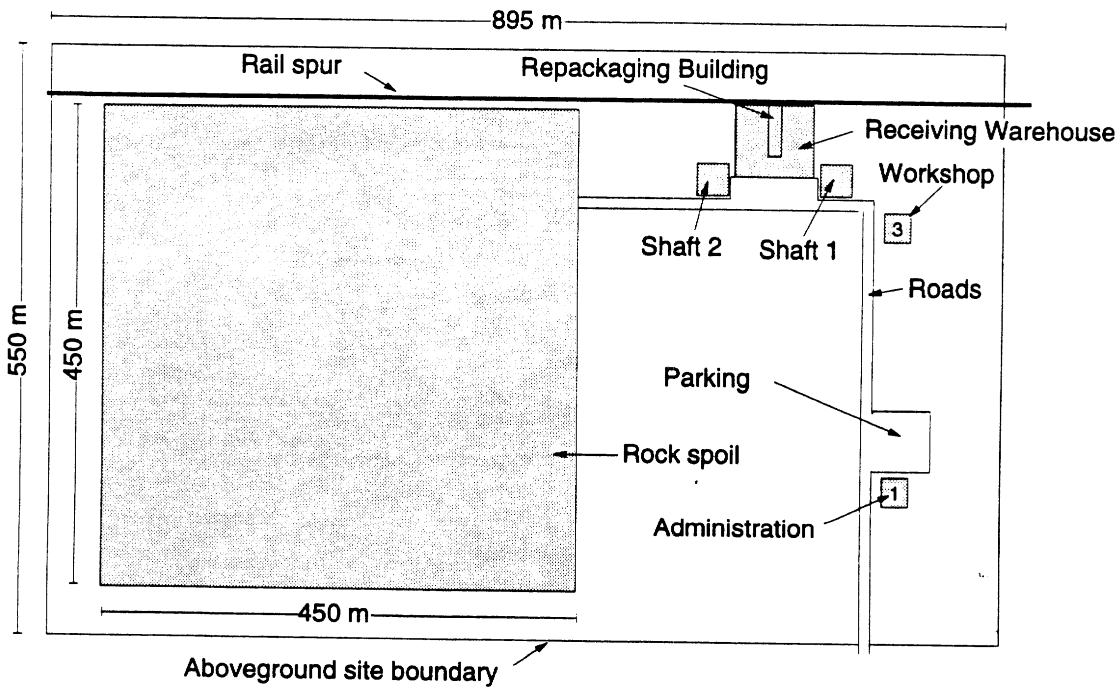
Note : If shipments are received by truck, the rail spur would be a road.

Figure 3-3b: Aboveground Site Layout, UO_2, Mined-Cavity Storage Facility



Note: If shipments are received by truck, the rail spur would be a road.

Figure 3-3c: Aboveground Site Layout, U_3O_8, Mined-Cavity Storage Facility



Note: If shipments are received by truck, the rail spur would be a road.

Figure 3-4a. Underground Site Layout, UF_6, Mined-Cavity Storage Facility

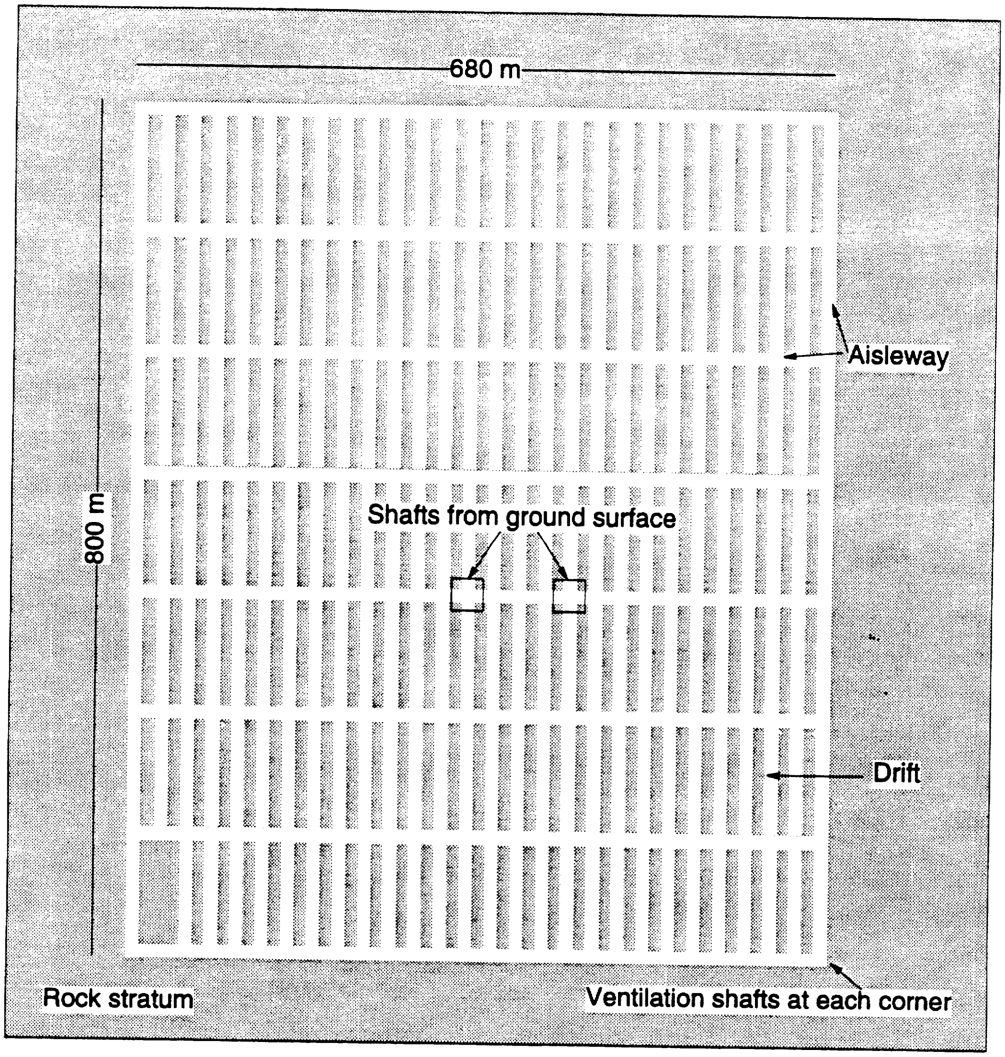


Figure 3-4b. Underground Site Layout, UO_2, Mined-Cavity Storage Facility

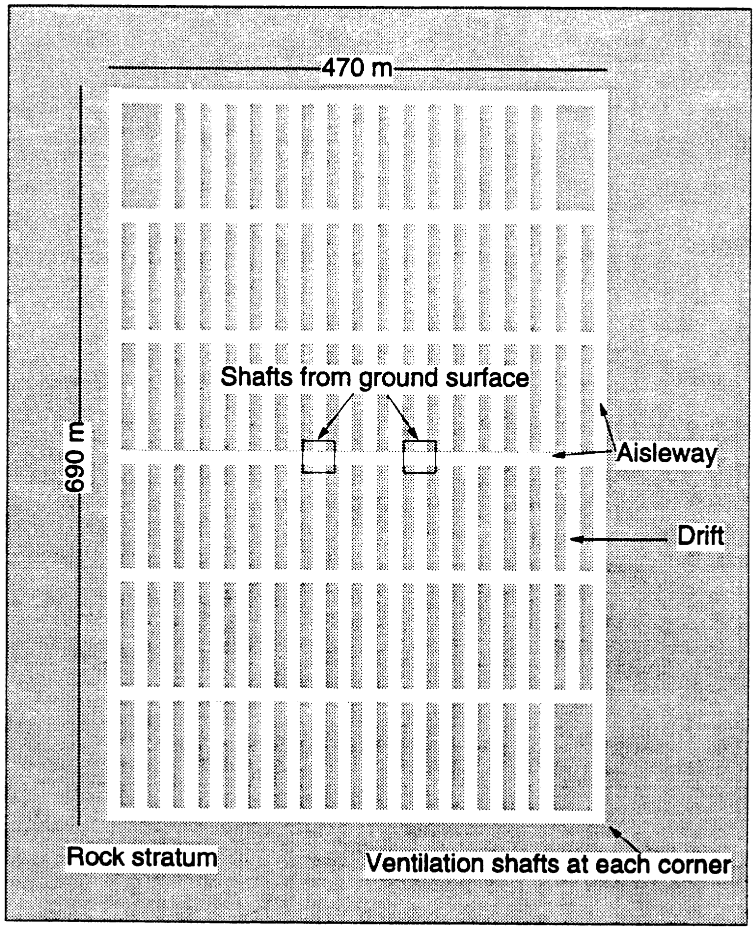
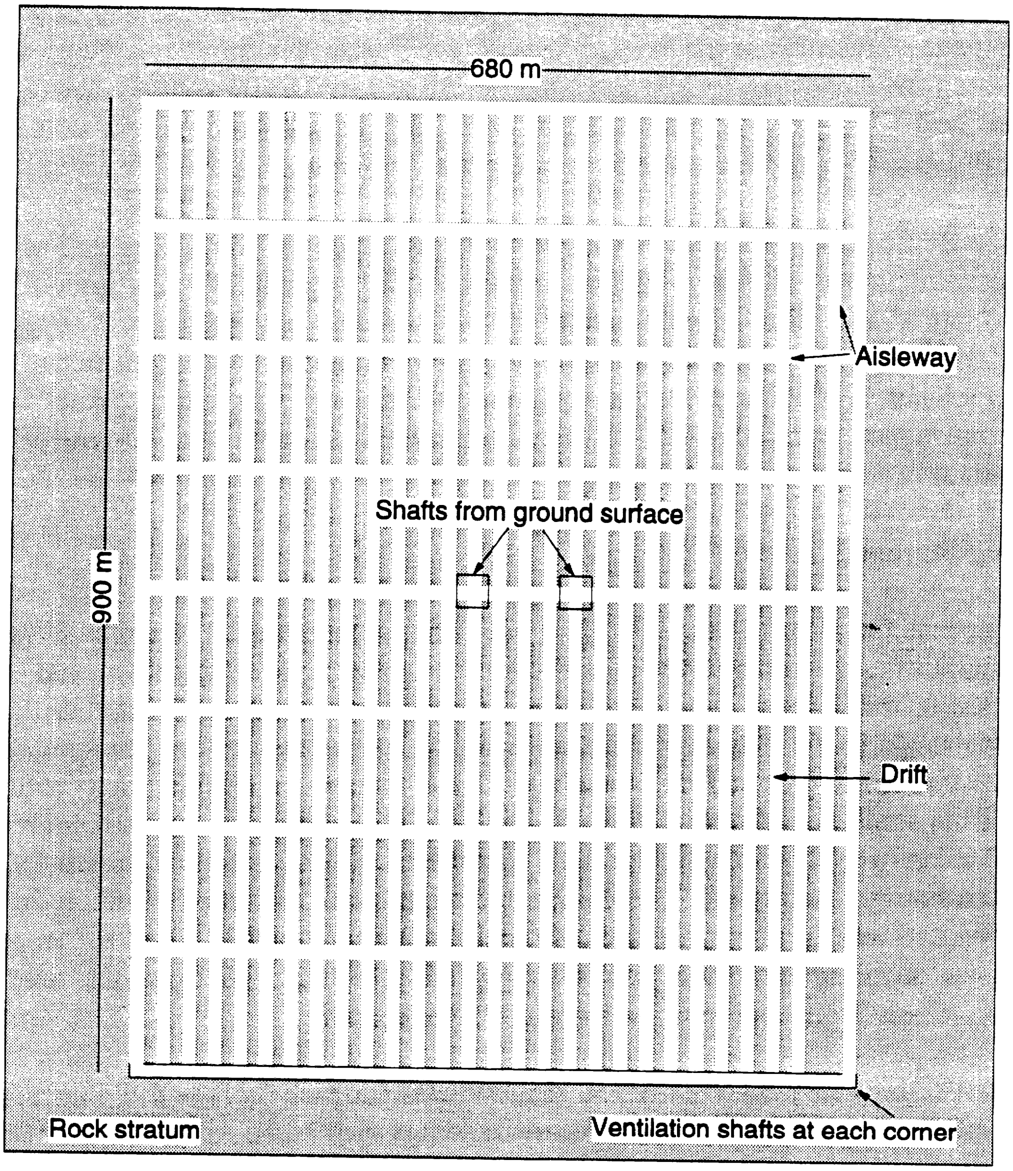


Figure 3-4c. Underground Site Layout, U_3O_8, Mined-Cavity Storage Facility



4.0 RESOURCE NEEDS

Resources for the storage facilities are required in two stages: the construction stage and the operational stage. The operational stage is divided into two phases: Phase I, in which the depleted uranium is being received and repackaged (if necessary), stored, and monitored and repackaged (when necessary) in the storage facility; and Phase II, when the depleted uranium is being monitored and repackaged (when necessary) in the storage facility after all depleted uranium has been received. The construction stage lasts over 20 years and is coincident with Phase I of operation. Phase II of operation lasts for an additional 20 years.

For all of the facilities, construction of the accessory buildings will occur first followed by the continued construction of storage buildings (vaults, drifts) over the 20-year period when the depleted uranium will be received and stored at the site. Because construction will be spread over a 20-year period and the construction of the accessory buildings is a small part of the total construction activity, it is assumed that an equal amount of material is used for construction per year. All construction materials used, however, are presented for the total 20-year period over which construction would occur.

4.1 Building Storage Facility

Table 4-1 presents the materials that would be used during construction of the building storage facility. Materials requirements during construction for cement, gravel, macadam, and steel were estimated based on the physical dimensions of the buildings and the types of materials being used for floors, walls, and roofs. No allowance was made for internal rooms (that are applicable only to the Administration Building and the Workshop). Diesel fuel, water, and electricity requirements were scaled from similar buildings in *Disposal Options for Depleted Uranium Management* (see section 6.13) using overall building footprints. Diesel fuel would be used by the trucks, cranes, and generators during construction. Gasoline requirements were estimated based on the number of construction staff and the size of the site (assuming each person would travel the length of the site twice each working day in a gasoline-powered vehicle). The gasoline used during transportation to and from work was not included in the estimate.

Table 4-1 also presents the total construction requirements for each Storage Building and for the total facility (adding allowances for the accessory buildings such as the Administration Building). Note that the great majority of the resources used are for the storage buildings themselves and that the differences in materials used among the three chemical forms for storage are related to the number of storage buildings to be constructed.

Table 4-1. Materials and Resources Used During Construction of the Building Storage Facility

One storage building			Total storage buildings			Building storage facility		
Material/ Resource	Units	Value	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Concrete	m^3	3,975	68,000	36,000	80,000	69,000	37,000	82,000
Cement	te	795	14,000	7,200	16,000	14,000	7,500	16,000
Sand	te	1,988	34,000	18,000	40,000	35,000	19,000	41,000
Gravel	te	3,975	68,000	36,000	80,000	68,000	36,000	80,000
Steel	te	1,614	28,000	15,000	33,000	29,000	16,000	34,000
Macadam	m^3					3,100	2,200	3,400
Water	ML	2.3	40	21	47	41	22	48
Diesel Fuel	ML	0.06	1.1	0.6	1.2	1.1	0.6	1.3
Gasoline	KL					8.6	3.5	11
Electricity	MW-yrs	0.29	5.0	2.6	5.8	5.4	3.0	6.3
Excavations	m^3	6,625	110,000	60,000	130,000	120,000	62,000	140,000

Materials and resources used during operation include the power to run the Repackaging Building and the Cylinder Washing Building, the fuel used in relocating the containers from the Repackaging Building to the storage buildings (a function of the total distance that must be traveled), and the minimal heating, cooling, and humidity control that is necessary for the storage buildings. Power consumption of the Administration Building, Receiving Warehouse, Cylinder Washing Building, and Workshop is assumed to be minimal. Water is used for drinking and sanitary waste disposal and, for a UF_6 facility, cylinder cleaning. These estimates assume that all buildings are constructed and that the Repackaging Building is operating at full capacity (at year 20). Materials and resources estimates are presented in table 4-2 for Phase I operation.

Materials requirements during operation for natural gas and electricity were based on the heating and lighting requirements for the buildings (assuming that only 10 percent of the storage buildings would be heated or lighted at any given time). Water requirements were based on the operations and maintenance workforce at the facility, assuming that 95 percent of the water used would become onsite wastewater. Diesel fuel consumption was based on the distance and number of trips required to relocate containers from the Receiving Warehouse to the storage buildings. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site three times per day in gasoline-powered vehicles. The gasoline consumed by the workers during transportation to and from work was not included in the estimate.

Table 4-2. Materials and Resources Used During Phase I Operation of the Building Storage Facility

Material/ Resource	Units	Annual*			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Diesel	KL	52	39	65	1,040	780	1,300
Gasoline	KL	10	8.0	13	200	160	260
Electricity	MW-hrs	1,600	1,200	1,700	32,000	24,000	34,000
Natural Gas	MSCM	0.31	0.21	0.35	6.2	4.3	7.0
Water	ML	4.4	4.2	5.3	88	84	106
Containers	Number						
Cylinders		16	--	--	320	--	--
55 gallon drums		17	4	250	340	80	5,000
30 gallon drums		--	140	--	--	2,800	--
CaO	kg	54			1,080		

* Estimates are for year 20 when all buildings have been built and depleted uranium is still being received.

There will be a minor continuing requirement for the removal, repackaging, and return of containers to the storage buildings. The number of containers required is based on an expected receipt of 0.1 percent damaged containers and expected failure rate of containers in storage weighted by the number of containers in the facility. The amount of calcium oxide (CaO) was estimated assuming a 10 kg UF_6 heel in each cylinder and the stoichiometric amount of CaO to neutralize the HF generated by conversion of UF_6 to UO_2F_2. Water consumption would be for drinking, sanitary waste disposal, and washing of damaged containers.

Materials and resources used during Phase II of operation are primarily related to the heating, cooling, and humidity control of the storage buildings. Materials and resources used during Phase II operation of this facility are presented in table 4-3. Materials and resources used over the life cycle of the facility (excluding construction) are presented in table 4-4, and include construction in table 4-5.

Table 4-3. Materials and Resources Used During Phase II Operation of the Building Storage Facility

Material/Resource	Units	Annual			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Diesel	KL	0.023	0.013	0.019	0.46	0.26	0.38
Gasoline	KL	8	5.7	8.5	160	114	170
Electricity	MW-hrs	1,600	1,200	1,700	32,000	24,000	34,000
Natural Gas	MSCM	0.31	0.21	0.38	6.2	4.2	7.7
Water	ML	3.6	3.3	3.6	72	66	72
Containers	Number						
Cylinders		1	--	--	20	--	--
55-gallon drums		3	1	12	60	20	240
30-gallon drums		--	7	--	--	140	--
CaO	kg	3.2			64		

Table 4-4. Materials and Resources Used Over the 40-Year Operation of the Building Storage Facility*

Material/Resource	Units	UF_6	UO_2	U_3O_8
Diesel	KL	1,040	780	1,300
Gasoline	KL	360	274	430
Electricity	MW-hrs	64,000	48,000	68,000
Natural Gas	MSCM	12.4	8.5	14.7
Water	ML	160	150	178
Containers	Number			
Cylinders		340	--	--
55-gallon drums		400	100	5,240
30-gallon drums		--	2,940	--
CaO	kg	1,144		

* Does not include construction.

Table 4-5. Materials and Resources Used Over the Total Life Cycle Including Construction of the Building Storage Facility*

Material/Resource	Units	UF_6	UO_2	U_3O_8
Diesel	ML	2.1	1.4	2.6
Gasoline	KL	369	278	441
Electricity	MW-yrs	12.7	8.4	14
Natural Gas	MSCM	12.4	8.5	14.7
Water	ML	201	172	226
Containers	Number			
Cylinders		340	--	--
55-gallon		400	100	5,240
30-gallon		--	2,940	--
CaO	kg	1,144		

* Construction materials such as concrete and steel are not included.

4.2 Vault Storage Facility

Table 4-6 presents the total construction requirements for each Storage Vault and for the total facility (adding allowances for accessory buildings such as the Administration Building). Note that the great majority of the resources used are for the storage vaults themselves and that the differences in materials used among the two chemical forms for storage are related to the number of storage vaults to be constructed.

Table 4-6. Materials and Resources Used During Construction of the Vault Storage Facility

One vault			Total storage vaults		Vault facility	
Material/Resource	Units	Value	UO_2	U_3O_8	UO_2	U_3O_8
Concrete	m^3	1,335	47,000	110,000	48,000	110,000
Cement	te	267	9,300	21,000	9,700	22,000
Sand	te	668	23,000	53,000	24,000	54,000
Gravel	te	2,790	98,000	220,000	98,000	220,000
Steel	te	461	16,000	36,000	17,000	37,000
Macadam	m^3				5,600	12,000
Water	ML	0.78	27	62	28	63
Diesel Fuel	ML	.05	1.8	4.1	1.8	4.1
Gasoline	KL				3.7	11
Electricity	MW-yrs	0.062	2.2	4.9	2.5	5.4
Excavations	m^3	16,200	570,000	1,300,000	570,000	1,300,000

Materials and resources used during operation include the power to run the Repackaging Building, the fuel used in relocating the containers from the Repackaging Building to the storage vaults (a function of the total distance that must be travelled). No power is assumed to be used for heating, cooling, or humidity control in the vaults. Power consumption of the Administration Building, Receiving Warehouse, and Workshop are the major power consumers. Water is used for drinking and sanitary waste disposal and washing damaged drums. These estimates assume that all buildings are constructed and that the Repackaging Building is operating at full capacity (at year 20). Materials and resources estimates are presented in table 4-7 for Phase I operation.

There will be a minor continuing requirement for the removal, repackaging, and return of drums to the storage vaults. The number of drums required is based on an expected receipt of 0.1 percent damaged containers and expected failure rate of drums in storage weighted by the number of drums in the facility. Water consumption would be for drinking, sanitary waste disposal, and cleaning damaged drums.

Table 4-7. Materials and Resources Used During Phase I Operation of the Vault Storage Facility

		Annual*		Over 20 years	
Material/Resource	Units	UO_2	U_3O_8	UO_2	U_3O_8
Diesel	KL	93	120	1,900	2,400
Gasoline	KL	8.5	13	170	260
Electricity	MW-hrs	1,100	1,700	22,000	34,000
Natural Gas	MSCM	0.10	0.10	2.0	2.0
Water	ML	4.1	4.5	82	91
Containers	Number				
55-gallon		4	250	80	5,000
30-gallon		140	--	2,800	--

* Estimates are for year 20 when all buildings and vaults have been built and depleted uranium is still being received.

Materials requirements during operation for natural gas and electricity were based on the heating and lighting requirements for the buildings. Water requirements were based on the operations and maintenance workforce at the facility, assuming that 95 percent of the water used would become onsite wastewater. A small amount of water would be used to clean damaged drums. Diesel fuel consumption was based on the distance and number of trips required to relocate containers from the Receiving Warehouse to the storage vaults and the operation of the mobile cranes servicing the vaults. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site three times per day in gasoline-powered vehicles.

Materials and resources used during Phase II of operation are primarily related to the operation of the Administration Building and limited onsite transportation. Materials and resources used during Phase II operation of this facility are presented in table 4-8. Materials and resources used over the life cycle of the facility excluding construction are presented in table 4-9 and including construction in table 4-10.

Table 4-8. Materials and Resources Used During Phase II Operation of the Vault Storage Facility

Material/Resource	Units	Annual		Over 20 years	
		UO_2	U_3O_8	UO_2	U_3O_8
Diesel	KL	0.031	0.036	0.60	0.70
Gasoline	KL	6.3	10	130	200
Electricity	MW-hrs	1,100	1,700	22,000	34,000
Natural Gas	MSCM	0.10	0.10	2.0	2.0
Water	ML	3.0	3.5	61	69
Containers	Number				
55-gallon		1	12	20	240
30-gallon		7	--	140	--

Table 4-9. Materials and Resources Used Over the 40-Year Operation of the Vault Storage Facility*

Material/Resource	Units	UO_2	U_3O_8
Diesel	KL	1,900	2,400
Gasoline	KL	300	460
Electricity	MW-hrs	44,000	68,000
Natural Gas	MSCM	4.1	4.1
Water	ML	142	160
Containers	Number		
55-gallon		100	5,240
30-gallon		2,940	--

* Does not include construction.

Table 4-10. Materials and Resources Used Over the Total Life Cycle Including Construction of the Vault Storage Facility*

Material/ Resource	Units	UO_2	U_3O_8
Diesel	ML	3.7	6.5
Gasoline	KL	304	470
Electricity	MW-yrs	7.5	13
Natural Gas	MSCM	4.1	4.1
Water	ML	170	223
Containers	Number		
55-gallon		100	5,240
30-gallon		2,940	--

* Construction materials such as concrete and steel are not included.

4.3 Mined-Cavity Storage Facility

Table 4-11 presents the materials that would be used during construction of the mined-cavity storage facility. Materials for drifts were estimated by scaling from *Disposal Options for Depleted Uranium Management* (see section 6.13). No allowance was made for the steel required for the overhead cranes in the Receiving Warehouse or Repackaging Building as these amounts are likely to be a very small portion of overall steel usage.

Materials requirements during construction for cement, gravel, macadam, and steel were estimated based on the physical dimensions of the buildings and the types of materials being used for floors, walls, and roofs. No allowance was made for internal rooms (that are applicable only to the Administration Building and the Workshop). Diesel fuel, water, and electricity requirements were scaled from similar buildings in *Disposal Options for Depleted Uranium Management* (see section 6.13) using overall building footprints. Diesel fuel would be used by the trucks, cranes, and generators used during construction. Gasoline requirements were estimated based on the number of construction staff and the size of the site (assuming each person would travel the length of the site twice each working day in a gasoline-powered vehicle).

Table 4-11 also presents the total construction requirements for each drift and for the total facility (adding allowances for the accessory buildings such as the Administration Building). Note that the great majority of the resources used are for the drifts themselves, and that the differences in materials used among the three chemical forms for storage are related to the number of storage drifts to be constructed. The largest difference between the mined-cavity storage and other storage types is in the electricity consumption required for drilling the drifts.

Table 4-11. Materials and Resources Used During Construction of the Mined-Cavity Storage Facility

One mine drift			Total drifts			Mined-cavity facility		
Material/Resource	Units	Value	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Concrete	m^3	792	140,000	83,000	170,000	140,000	85,000	170,000
Cement	te	158	29,000	17,000	34,000	29,000	17,000	34,000
Sand	te	396	71,000	42,000	85,000	72,000	42,000	86,000
Steel	te	272	49,000	29,000	59,000	50,000	29,000	59,000
Macadam	m^3					1,600	1,500	1,700
Water	ML	0.47	84	49	100	85	50	100
Diesel Fuel	KL	0.34	60	40	70	60	40	70
Gasoline	KL					11	6.0	15
Electricity	MW-yrs	4.7	840	490	1,000	840	490	1,000
Excavations	m^3	6,000	1,100,000	630,000	1,300,000	1,400,000	88,000	1,700,000

Materials and resources used during operation include the power to run the Repackaging Building and Cylinder Washing Building (for UF_6 storage), the fuel used in relocating the containers from the Repackaging Building to the storage drifts (a function of the total distance that must be travelled). No power is assumed to be used for heating, cooling, or humidity control in the drifts, but ventilation is a major power drain. Power consumption of the Administration Building, Receiving Warehouse, and Workshop are secondary to the ventilation in the drifts, which must be continuously maintained. Water is used for drinking and sanitary waste disposal and cleaning of damaged containers. These estimates assume that all drifts are cut and that the Repackaging Building is operating at full capacity (at year 20). No other materials are assumed to be used during the operational stage of the facility. Materials and resources estimates are presented in table 4-12 for Phase I operation.

Table 4-12. Materials and Resources Used During Phase I Operation of the Mined-Cavity Storage Facility

Material/ Resource	Units	Annual*			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Diesel	KL	25	14	14	510	290	280
Gasoline	KL	2.9	2.5	3.6	57	50	72
Electricity	MW-hrs	1,500	1,200	1,700	30,000	24,000	34,000
Natural Gas	MSCM	0.10	0.10	0.10	2.0	2.0	2.0
Water	ML	4.4	4.4	5.0	89	89	100
Containers	Number						
Cylinders		16	--	--	320	--	--
55-gallon		17	4	250	340	80	5,000
30-gallon		--	140	--	--	2,800	--
CaO	kg	54			1,100		

* Estimates are for year 20 when all buildings and vaults have been built and depleted uranium is still being received.

Materials requirements during operation for natural gas and electricity were based on the heating and lighting requirements for the buildings (assuming that only 10 percent of the storage drifts would be lighted at any given time). Water requirements were based on the operations and maintenance workforce at the facility, assuming that 95 percent of the water used would become onsite wastewater. Diesel fuel consumption was based on the distance and number of trips required to relocate containers from the Receiving Warehouse to the storage drifts. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site three times per day in gasoline-powered vehicles.

There will be a minor continuing requirement for the removal, repackaging, and return of containers to the drifts. The number of containers required is based on an expected receipt of 0.1 percent damaged containers and expected failure rate of cylinders or drums in storage weighted by the number of containers in the facility. The amount of CaO was estimated assuming a 10 kg UF_6 heel in each cylinder and the stoichiometric amount of CaO to neutralize the HF generated by conversion of UF_6 to UO_2F_2. Water consumption would be for drinking and sanitary waste disposal for onsite staff and cleaning of damaged containers.

Materials and resources used during Phase II of operation are primarily related to the continuing maintenance of ventilation in the drifts. Operation of the Administration Building and limited onsite transportation account for some additional power consumption. Materials and resources used during

Phase II operation of this facility are presented in table 4-13. Materials and resources used over the life cycle of the facility excluding construction are presented in table 4-14, and including construction in table 4-15.

Table 4-13. Materials and Resources Used During Phase II Operation of the Mined-Cavity Storage Facility

Material/ Resource	Units	Annual			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Diesel	KL	0.011	0.0048	0.0043	0.22	0.10	0.086
Gasoline	KL	2.2	1.9	2.7	44	37	54
Electricity	MW-hrs	1,500	1,200	1,700	30,000	24,000	34,000
Natural Gas	MSCM	0.10	0.10	0.10	2.0	2.0	2.0
Water	ML	3.4	3.3	3.7	68	66	75
Containers	Number						
Cylinders		1	--	--	20	--	--
55-gallon		3	1	12	60	20	240
30-gallon		--	7	--	--	140	--
CaO	kg	3.2			64		

Table 4-14. Materials and Resources Used Over the 40-Year Operation of the Mined-Cavity Storage Facility*

Material/ Resource	Units	UF_6	UO_2	U_3O_8
Diesel	KL	510	290	280
Gasoline	KL	100	87	130
Electricity	MW-hrs	60,000	48,000	68,000
Natural Gas	MSCM	4.1	4.1	4.1
Water	ML	160	160	170
Containers	Number			
Cylinders		340	--	--
55-gallon		400	100	5,240
30-gallon		--	2,940	--
CaO	kg	1,200		

* Does not include construction.

Table 4-15. Materials and Resources Used Over the Total Life Cycle Including Construction of the Mined-Cavity Storage Facility*

Material/ Resource	Units	UF_6	UO_2	U_3O_8
Diesel	KL	570	330	350
Gasoline	KL	110	93	140
Electricity	MW-yrs	850	500	1,000
Natural Gas	MSCM	4.1	4.1	4.1
Water	ML	240	210	270
Containers	Number			
Cylinders		340	--	--
55-gallon		400	100	5,240
30-gallon		--	2,940	--
CaO	kg	1,200		

* Construction materials such as concrete and steel are not included.

5.0 PERSONNEL STAFFING ESTIMATES

Personnel staffing estimates are derived by comparison to similar facilities. The staffing estimates are divided into construction and operations personnel requirements. Table 5-1 summarizes construction manpower estimates. Subsequent tables present staffing for the operations for the different facility types and the different storage materials types.

5.1 Construction Labor Force for All Facilities

Each of the facilities types (building, vault, and mined cavity) require substantially different types of construction. Storage buildings are essentially Butler buildings on concrete slabs, vaults are poured concrete structures, and mined cavities are dug from solid rock. Labor estimates reflect these different construction types and recognize that mining, in particular, is a highly automated process with a relatively low number of construction staff.

The estimates presented in table 5-1 have been developed independently of the other engineering data reports in this series, but the final results have been compared with them. The results appear to be consistent with the other data reports bearing in mind that there is little complex machinery or processes that need to be installed in any of the buildings—all of the storage facilities are essentially shells with no internal fittings except lights, ventilation, and for storage buildings only, heating and cooling.

As was indicated in the site map section of this report, construction would proceed by building the Administration Building first, the Receiving Warehouse and Repackaging Building second, the Workshop third, and storage facilities last. Construction of all of the facilities except for the storage buildings is a relatively minor component of the total construction force needed (between 2 to 3 percent of the total). Therefore, construction force has been indicated on a per year basis, assuming that construction would occur over a 20-year period. Each year's construction force thus approximately represents (within a few percent) the labor force required to build storage for one year's receipts of depleted uranium. These estimates are presented in table 5-1.

The number of FTEs required in the initial stages (when building the supporting buildings) would be slightly higher than those presented in the table and, in the later years, would be slightly lower.

Table 5-1. Estimated Labor Force for Construction of the Storage Facilities

Depleted Uranium Storage Option	FTEs per year			FTE-years (20-year period)		
	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Building Storage Facility	65	34	75	1,300	680	1,500
Vault Storage Facility		30	65		590	1,300
Mined-Cavity Storage Facility	100	60	120	2,000	1,200	2,400

5.2 Operations Labor Force

Manpower estimates are based on the last year of Phase I when there is still relocation of containers of depleted uranium from the Receiving Warehouse to the storage locations, but there is also a full complement of inspection staff.

There is relatively less difference in staffing among the different types of storage facilities than among the different forms of depleted uranium to be stored. This is primarily because of differences in handling and inspection requirements for the different types and numbers of containers.

Personnel will not be required to wear personal protective equipment (PPE) for protection from chemical or radiological hazards during normal operations. PPE will be available on site for certain maintenance or special operational activities (i.e., hooking up a line to an HF-carrying rail car or truck), or emergency situations. However, the accident analysis takes no credit for the use of PPE following an accident or process upset condition.

5.2.1 Operations Labor Force for the Building Storage Facility

The staffing of the Building Storage Facility is presented in table 5-2 for the three forms of depleted uranium to be stored.

Table 5-2. Estimated Labor Force for Operation of the Building Storage Facility*

Labor Force	Phase I			Phase II		
	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Site Manager	1	1	1	1	1	1
Deputy Manager	1	1	1			
Administrator	1	1	1	1	1	1
Clerk/Secretary	1	1	1	1	1	1
Clerk	1	1	1	1	1	
Repackaging Supervisor			1			
Bridge crane operator		1	1			
Repackagers	2	1	1			
Receipt Supervisor	1	1	1			
Bridge crane operator	1	1	1			
Clerk	1	1	1			
Inspectors/general hands	1	1	1			
Storage Supervisors	1	1	1	1	1	1
Straddle carrier operators	4	3	3	3	3	1
Inspectors	8	9	14	7	8	13
Cylinder Cleaning Supervisor	1			1		
Technicians	2			3		
Health and Safety Manager	1	1	1	1	1	1
Professionals	1	1	1	1	1	1
Technicians	2	2	2	1	1	1
Secretary	1	1	1			
Building/Grounds Maintenance Manager	1	1	1	1	1	1
General hands	2	2	2	2	2	2
Security Manager	1	1	1	1	1	1
Security staff	9	9	10	9	9	10
Clerk	1	1	1	1	1	1
Equipment Maintenance Manager	1	1	1	1	1	1
Air conditioning engineer	1	1	1	1	1	1
Mechanic	1	1	1	1	1	1
Metal worker	1	1	1	1	1	1
TOTAL	50	47	54	40	37	40

* Estimates are for year 20 when all buildings are built and depleted uranium is still being received.

Of these workers, many would work essentially full time near (and hence have exposure potential to) depleted uranium in containers. These would include the Receipt Supervisor and staff, the Repackaging Supervisor and staff, and the Storage Supervisor and staff. The Health and Safety Manager and staff and the Equipment Maintenance Supervisor and staff would have less exposure to depleted uranium in containers. Refer to Appendix B, Radiation Exposure and Manpower Distribution Estimating Data, for exposure data.

5.2.2 Operations Labor Force for the Vault Storage Facility

The staffing of the Vault Storage Facility is presented in table 5-3 for the two forms of depleted uranium to be stored in a vault facility.

Of these workers, many would work essentially full time near depleted uranium in containers. These would include the Receipt Supervisor and staff, the Repackaging Supervisor and staff, and the Storage Supervisor and staff. The Health and Safety Manager and staff would have less exposure to depleted uranium in containers. Refer to Appendix B, Radiation Exposure and Manpower Distribution Estimating Data, for exposure data.

Table 5-3. Estimated Labor Force for Operation of the Vault Storage Facility*

Labor Force	Phase I		Phase II	
	UO_2	U_3O_8	UO_2	U_3O_8
Site Manager	1	1	1	1
Deputy Manager	1	1		
Administrator	1	1	1	1
Secretary	1	1	1	1
Clerk	1	1		
Repackaging				
Repackagers	1	1		
Clerk	1	1		
Receipt Supervisor	1	1		
Bridge crane operator	1	1		
Clerk	1	1		
Inspectors/general hands	1	1		
Storage Supervisor	1	1	1	1
Crane operators	2	2	1	1
Inspectors	9	14	8	13
Health and Safety Manager	1	1	1	1
Professionals	1	1	1	1
Technicians	2	2	1	1
Secretary	1	1		
Building/Grounds Maintenance Supervisor	1	1	1	1
General hands	2	2	2	2
Security Manager	1	1	1	1
Security staff	10	10	10	10
Clerk	1	1		
Equipment Maintenance Supervisor	1	1	1	1
Air conditioning engineer	1	1	1	1
Mechanic	1	1	1	1
Metal worker	1	1	1	1
Total	47	52	34	39

* Estimates are for year 20 when all buildings are built and depleted uranium is still being received.

5.2.3 Operations Labor Force for the Mined-Cavity Storage Facility

The staffing of the Mined-Cavity Storage Facility is presented in table 5-4 for the three forms of depleted uranium to be stored.

Of these workers, many would work essentially full time near depleted uranium in containers. These would include the Receipt Supervisor and staff, the Repackaging Supervisor and staff, and the Storage Supervisor and staff. The Health and Safety Manager and staff and the Equipment Maintenance Supervisor and staff would have less exposure to depleted uranium in containers. Refer to Appendix B, Radiation Exposure and Manpower Distribution Estimating Data, for exposure data.

Table 5-4. Estimated Labor Force for Operation of the Mined-Cavity Storage Facility*

Labor Force	Phase I			Phase II		
	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Site Manager	1	1	1	1	1	1
Deputy Manager	1	1	1			
Administrator	1	1	1	1	1	1
Secretary	1	1	1	1	1	1
Clerk	1	1	1			
Repackaging						
Repackagers	1	1	1			
Receipt Supervisor	1	1	2			
Bridge crane operator	1	1	1			
Clerk		1	1			
Inspectors/general hands	1	1	4			
Storage Supervisor	1	1	1	1	1	1
Straddle carrier operators	2	2	3	1	1	1
Inspectors	8	9	14	7	8	13
Cylinder Cleaning Supervisor	1			1		
Technicians	1			1		
Health and Safety Manager	1	1	1	1	1	1
Professionals	1	1	1	1	1	1
Technicians	2	2	2	1	1	1
Secretary	1	1	1			
Building/Grounds Maintenance Supervisor	1	1	1	1	1	1
General hands	2	2	2	2	2	2
Security Manager	1	1	1	1	1	1
Security staff	10	10	10	10	10	10
Clerk	1	1	1			
Equipment Maintenance Supervisor	1	1	1	1	1	1
Air conditioning engineer	2	2	2	2	2	2
Mechanic	3	3	3	2	2	2
Metal worker	2	2	2	2	2	2
Total	50	50	60	38	37	42

* Estimates are for year 20 when all buildings are built and depleted uranium is still being received.

6.0 FACILITY EMISSIONS AND WASTES

6.1 Estimate of Emissions and Wastes Generated During Construction of the Storage Facilities

The wastes and emissions generated during construction of any of the three types of storage facilities would be typical of large construction projects. Wastes are essentially limited to construction debris and the sanitary wastes of the labor force, and emissions are related primarily to the consumption of fuels used for hauling in construction materials, removal of construction debris, and the operation of cranes. These estimates appear in table 6-1 for the Building Storage Facility, table 6-2 for the Vault Storage Facility, and table 6-3 for the Mined-Cavity Storage Facility.

Air emissions generated during construction were based on the amount of fuel consumed by the trucks and cranes used during construction using standard EPA generating factors. Emissions are calculated based on the total liquid fuel consumed (gasoline and diesel). Dust was estimated from the amount of disturbed land area and the time that the disturbed area would be under construction. Estimates of wastewater generated by construction staff assumed that 95 percent of the water used by staff onsite became wastewater (the majority of the water used during construction is for concrete).

Table 6-1. Estimated Emissions and Wastes from Construction of the Building Storage Facility

Emission	Units	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	19.0	10.4	22.5
Hydrocarbons	tons	7.3	4.0	8.7
NO_x	tons	89.3	48.6	105.6
SO_x	tons	5.9	3.2	6.9
Dust	tons	75	4.4	9.0
PM-10	tons	6.3	1.2	2.8
Waste	Units	UF_6	UO_2	U_3O_8
Wastewater	ML	4.0	2.1	4.7

Table 6-2. Estimated Emissions and Wastes from Construction of the Vault Storage Facility

Emission	Units	UO_2	U_3O_8
Carbon monoxide	tons	31.0	70.6
Hydrocarbons	tons	11.9	27.2
NO_x	tons	145.3	331.2
SO_x	tons	9.5	22.7
Dust	tons	5.0	10.0
PM-10	tons	3.6	8.2
Waste	Units	UO_2	U_3O_8
Wastewater	ML	2.7	6.2

Table 6-3. Estimated Emissions and Wastes from Construction of the Mined-Cavity Storage Facility

Emission	Units	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	1.2	0.8	1.5
Hydrocarbons	tons	0.5	0.3	0.6
NO_x	tons	5.7	3.7	6.8
SO_x	tons	0.4	0.2	0.4
Dust	tons	38.0	30.0	65.0
PM-10	tons	0.4	0.3	0.5
Waste	Units	UF_6	UO_2	U_3O_8
Wastewater	ML	8.5	5.0	10

6.2 Estimate of Emissions and Wastes Generated During Operation of the Storage Facilities

Phase I operation of the storage facilities involves the receipt, inspection, and repackaging (if necessary) of the depleted uranium containers and relocation of these containers to the storage buildings. The major wastes and emissions generated during operation are the sanitary wastes of the onsite labor force, the empty containers that have had to be repackaged, and emissions from transportation of the containers, and space heating.

The only process emissions would occur through a 30-m stack on the Cylinder Washing Building. This would release off-gas from the conversion of UF_6 to UO_2F_2 and the subsequent conversion of the resulting HF to CaF_2. All other buildings would have stacks for space heating by natural gas only. Emissions have been calculated based on the total liquid fuel (gasoline and diesel) and natural gas consumed.

During Phase II operation, the containers will be inspected once a year. Failed containers will be removed from storage, repackaged, and replaced in storage. The damaged containers are assumed to be low-level waste. Wastes and emissions generated during the maintenance and monitoring phase include the sanitary wastes of the onsite labor force, the empty containers that have had to be repackaged, and the emissions from transportation of the containers (gasoline and diesel) and space heating (natural gas). The conversion of "heels" of UF_6 in damaged cylinders to UO_2F_2 results in a UO_2F_2 "waste" and a CaF_2 waste.

Low-level wastes are estimated on the volume of containers that need to be repackaged. These containers, possibly acceptable for non-low-level waste disposal (land filling or recycling) after cleaning, bound the amount of low-level waste that would be generated. If the containers are low-level wastes, there would be no need to dispose of them separately from the lower volume of other low-level wastes. The volume of wastes is estimated on the crushed size of the containers, but there is no provision for crushing the containers onsite. Wipes, protective clothes, and other low-level wastes would be of sufficiently low volume compared to the containers, so they are not estimated separately.

CaF_2, generated in the UF_6 storage option only, is assumed to be of sufficiently low activity that it can be disposed of in a Subtitle D landfill (it is not a hazardous waste). All HF would be converted to CaF_2, and only a small amount of HF would be present in the off-gas for the Cylinder Washing Facility.

The wastes and emissions from operations are estimated at the point of maximum emissions—when all storage facilities have been built (and most have been filled) but during the receipt of the last year's shipment of containers. This simplifies the analysis to a single point in time and avoids the confusion associated with a 20-year "ramping up" of emissions as more and more storage facilities come on line. These estimates are presented in tables 6-4 through 6-7 for the Building Storage Facility, tables 6-8 through 6-10 for the Vault Storage Facility, and tables 6-11 through 6-14 for the Mined-Cavity Storage Facility. The four tables for each facility type include (a) Phase I operation, (b) Phase II operation, (c) the 40-year operation of the facility, not including construction, and (d) the total life cycle of the facility, including construction.

6.2.1 Building Storage Facility

Table 6-4. Estimated Emissions and Wastes from Phase I Operation of the Building Storage Facility

Emission	Units	Annual			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	1.28	0.96	1.59	25.7	19.2	31.7
Hydrocarbons	tons	0.42	0.32	0.53	8.4	6.3	10.5
NO_x	tons	5.44	4.09	6.79	108.8	81.9	135.7
SO_x	tons	0.33	0.25	0.42	6.6	5.0	8.3
PM-10	tons	0.37	0.28	0.46	7.4	5.6	9.2
HF	kg	0.009	N/A	N/A	0.2	N/A	N/A
Waste	Units	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Wastewater	ML	4.2	4.0	4.4	84	80	88
Low-level Waste	m^3	2.95	0.75	1.05	59	15	21
UO_2F_2	te	140	N/A	N/A	2,800	N/A	N/A
CaF_2	te	71	N/A	N/A	1,420	N/A	N/A

* Estimates are for year 20 when all buildings are built and depleted uranium is still being received.

Table 6-5. Estimated Emissions and Wastes from Phase II Operation of the Building Storage Facility

Emission	Units	Annual			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	0.36	0.25	0.42	7.1	4.9	8.4
Hydrocarbons	tons	0.06	0.04	0.07	1.2	0.9	1.4
NO_x	tons	1.09	0.76	1.24	21.8	15.2	24.7
SO_x	tons	0.05	0.03	0.05	0.9	0.6	1.0
PM-10	tons	0.06	0.04	0.07	1.2	0.9	1.4
HF	kg	0.0006	N/A	N/A	0.011	N/A	N/A
Waste	Units	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Wastewater	ML	3.4	3.1	3.4	68	62	68
Low-level Waste	m^3	0.2	0.04	0.05	3.6	0.72	0.96
UO_2F_2	kg	8.8	N/A	N/A	176	N/A	N/A
CaF_2	kg	4.4	N/A	N/A	88	N/A	N/A

Table 6-6. Estimated Emissions and Wastes Over the 40-Year Operation of the Building Storage Facility*

Emission	Units	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	32.8	24.1	40.1
Hydrocarbons	tons	9.6	7.2	11.9
NO_x	tons	130.6	97.1	160.4
SO_x	tons	7.5	5.7	9.3
PM-10	tons	8.6	6.4	10.6
HF	kg	0.19	N/A	N/A
Waste	**Units**	UF_6	UO_2	U_3O_8
Wastewater	ML	152	142	156
Low-level Waste	m^3	63	16	22
UO_2F_2	kg	3,000	N/A	N/A
CaF_2	kg	1,500	N/A	N/A

* Does not include construction.

Table 6-7. Estimated Emissions and Wastes Over the Total Life Cycle Including Construction of the Building Storage Facility

Emission	Units	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	43.1	28.5	52.2
Hydrocarbons	tons	16.6	10.9	20.1
NO_x	tons	202.2	133.6	245.1
SO_x	tons	13.3	8.8	16.1
PM-10	tons	14.3	9.4	17.3
HF	kg	0.19	N/A	N/A
Dust	tons	75	41	87
Waste	**Units**	UF_6	UO_2	U_3O_8
Wastewater	ML	156	144	160
Low-level Waste	m^3	63	16	22
UO_2F_2	kg	3,000	N/A	N/A
CaF_2	kg	1,500	N/A	N/A

6.2.2 Vault Storage Facility

Table 6-8. Estimated Emissions and Wastes from Phase I Operation of the Vault Storage Facility*

Emission	Units	Annual		Over 20 years	
		UO_2	U_3O_8	UO_2	U_3O_8
Carbon monoxide	tons	1.85	2.35	37.0	47.1
Hydrocarbons	tons	0.69	0.88	13.7	17.6
NO_x	tons	8.48	10.86	169.7	217.2
SO_x	tons	0.55	0.70	11.0	14.1
PM-10	tons	0.59	0.76	11.9	15.2
Waste	Units	UO_2	U_3O_8	UO_2	U_3O_8
Wastewater	ML	3.9	4.3	78	86
Low-level waste	m^3	0.8	1.1	15	21

* Estimates are for year 20 when all vaults are built and depleted uranium is still being received.

Table 6-9. Estimated Emissions and Wastes from Phase II Operation of the Vault Storage Facility

Emission	Units	Annual		Over 20 years	
		UO_2	U_3O_8	UO_2	U_3O_8
Carbon monoxide	tons	0.18	0.24	3.7	4.9
Hydrocarbons	tons	0.05	0.07	0.9	1.4
NO_x	tons	0.67	0.95	13.4	19.0
SO_x	tons	0.04	0.05	0.7	1.1
PM-10	tons	0.04	0.06	0.8	1.2
Waste	Units	UO_2	U_3O_8	UO_2	U_3O_8
Wastewater	ML	2.9	3.3	57	66
Low-level waste	m^3	0.04	0.05	0.73	0.95

Table 6-10. Estimated Emissions and Wastes Over the 40-Year Operation of the Vault Storage Facility *

Emission	Units	UO_2	U_3O_8
Carbon monoxide	tons	40.7	52.0
Hydrocarbons	tons	14.7	19.0
NO_x	tons	183.2	236.3
SO_x	tons	11.7	15.2
PM-10	tons	12.7	16.5
Waste	Units	UO_2	U_3O_8
Wastewater	ML	1,351	152
Low-level waste	m^3	15	22

* Does not include construction.

Table 6-11. Estimated Emissions and Wastes Over the Total Life Cycle Including Construction of the Vault Storage Facility

Emission	Units	UO_2	U_3O_8
Carbon monoxide	tons	68.8	119.7
Hydrocarbons	tons	26.4	46.0
NO_x	tons	322.6	561.8
SO_x	tons	21.2	36.8
PM-10	tons	22.7	39.6
Dust	tons	46	100
Waste	Units	UO_2	U_3O_8
Wastewater	ML	138	158
Low-level waste	m^3	15	22

6.2.3 Mined-Cavity Storage Facility

Table 6-12. Estimated Emissions and Wastes from Phase I Operation of the Mined-Cavity Storage Facility

Emission	Units	Annual			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	0.56	0.36	0.37	11.1	7.3	7.5
Hydrocarbons	tons	0.19	0.11	0.12	3.8	2.3	2.4
NO_x	tons	2.43	1.51	1.56	48.5	30.3	31.2
SO_x	tons	0.15	0.09	0.09	3.0	1.8	1.9
PM-10	tons	0.17	0.10	0.11	3.3	2.0	2.1
HF	kg	0.009	N/A	N/A	0.18	N/A	N/A
Waste	Units	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Wastewater	ML	4.25	4.25	4.75	85	85	95
Low-level waste	m^3	2.95	0.75	1.05	59	15	21
UO_2F_2	kg	140	N/A	N/A	2,800	N/A	N/A
CaF_2	kg	70	N/A	N/A	1,400	N/A	N/A

* Estimates are for year 20 when all vaults are built and depleted uranium is still being received.

Table 6-13. Estimated Emissions and Wastes from Phase II Operation of the Mined-Cavity Storage Facility

Emission	Units	Annual			Over 20 years		
		UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	0.11	0.10	0.12	2.2	2.0	2.3
Hydrocarbons	tons	0.18	0.15	0.02	0.4	0.3	0.4
NO_x	tons	0.32	0.29	0.36	6.4	5.8	7.2
SO_x	tons	0.013	0.01	0.02	0.3	0.2	0.3
PM-10	tons	0.018	0.016	0.02	0.3	0.3	0.4
HF	kg	0.00057	N/A	N/A	0.011	N/A	N/A
Waste	Units	UF_6	UO_2	U_3O_8	UF_6	UO_2	U_3O_8
Wastewater	ML	3.2	3.15	3.55	64	63	71
Low-level waste	m^3	0.185	0.037	0.05	3.7	0.73	1.0
UO_2F_2	kg	9	N/A	N/A	180	N/A	N/A
CaF_2	kg	4.45	N/A	N/A	89	N/A	N/A

Table 6-14. Estimated Emissions and Wastes Over the 40-Year Operation of the Mined-Cavity Storage Facility*

Emission	Units	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	13.4	9.4	9.9
Hydrocarbons	tons	4.2	2.6	2.8
NO_x	tons	55.1	36.2	38.6
SO_x	tons	3.3	2.0	2.2
PM-10	tons	3.7	2.4	2.5
HF	kg	0.2	N/A	N/A
Waste	Units	UF_6	UO_2	U_3O_8
Wastewater	ML	149	148	166
Low-level waste	m^3	62.7	15.7	22.0
UO_2F_2	kg	3,000	N/A	N/A
CaF_2	kg	1,500	N/A	N/A

* Does not include construction.

Table 6-15. Estimated Emissions and Wastes Over the Total Life Cycle Including Construction of the Mined-Cavity Storage Facility

Emission	Units	UF_6	UO_2	U_3O_8
Carbon monoxide	tons	11.7	7.3	8.4
Hydrocarbons	tons	4.5	2.8	3.2
NO_x	tons	55.0	34.1	39.6
SO_x	tons	3.6	2.2	2.6
PM-10	tons	3.9	2.4	2.8
HF	kg	0.19	N/A	N/A
Dust	tons	38	30	65
Waste	Units	UF_6	UO_2	U_3O_8
Wastewater	ML	158	153	176
Low level Waste	m^3	62.7	15.7	22
UO_2F_2	kg	3,000	N/A	N/A
CaF_2	kg	1,500	N/A	N/A

7.0 DESCRIPTION OF POTENTIAL ACCIDENTS

7.1 Accidents at Storage Sites and Properties of Depleted Uranium

Accidents could occur during the operation of the storage facilities that would impact site personnel and the offsite public. This chapter presents the potential accidents, estimates how much material that could be released by the accidents, and estimates the frequency of the accidents.

While there are different storage options, all the options involve the same basic operations (inspection, repackaging as necessary, and package movement) and the same material forms: uranium hexafluoride in cylinders, the triuranium octaoxide powder in drums and uranium dioxide powder in drums. Analyses of postulated release of uranium in NUREG-1140 for nuclear fuel plants have shown that the chemical toxicity of soluble uranium is much greater than the radiotoxicity. Specifically, a chemically toxic lethal exposure from uranium would be associated with a radiation dose of no more than 1 rem; such a radiation dose is not considered to have any significant health effects. However, it should also be noted that 10 CFR Part 20, 40 CFR Part 61, and 40 CFR Part 190 set specific public radiation dose standards that limit routine operational releases of radioactive material.

In addition to chemical and radiological hazards of uranium itself, UF_6 will react with water or atmospheric moisture to produce HF and UO_2F_2. This HF hazard can be more serious than the chemical or radiological hazards of uranium. The other depleted uranium forms (U_3O_8 and UO_2) do not produce hazardous chemical(s) upon contact with the atmosphere.

Depleted uranium is assumed to be delivered to the storage site either in 12-ft cylinders containing about 12,247 kg (27,000 lb) of UF_6, 55-gallon drums containing 633 kg (1,395 lb) uranium octaoxide powder (U_3O_8), or in 30-gallon drums that would contain 1021 kg (2,250 lb) of uranium dioxide microspheres (UO_2). Accidents related to the storage, transportation, and handling of depleted UF_6 in cylinders are found in the Supplemental Accident Analysis, section 7. Process related accidents are included in this section.

Uranium hexafluoride is a solid at room temperature. Heating to moderate temperatures (250°F) produces a liquid. UF_6 reacts with atmospheric moisture to produce UO_2F_2 and HF. The reaction rate can be significant with liquid UF_6 because of its higher temperature and its ability to form large surface areas if released. Accidents involving solid UF_6 are not expected to release more than about 100 grams of uranium more than two hours because of a slow reaction rate and the formation of UO_2F_2 plugs or diffusion barriers at any cylinder holes (U.S. NRC, 1994a).

The more serious accidents with UF_6 could occur when liquid UF_6 is present. The liquid UF_6 could be the result of fire involving a cylinder or the liquid could be produced by repackaging operations where the material is heated for transfer from one container to another.

The U_3O_8 powder has a mean particle size around 50 microns with a small fraction below 10 microns. The UO_2 powder consists of particles between 300 and 1200 microns in diameter. Both U_3O_8 and UO_2 are relatively inert chemical forms of depleted uranium with melting points of 1,300 C (2,372°F) and 2,878 C (5,212°F) respectively. The particle size distribution of both oxides is not expected to change as a result of exposure to high temperatures.

The ability of U_3O_8/UO_2 particles to become airborne in an accident is an important factor in calculating the effects of postulated accidents. Particles can become airborne due to a force, such as an explosion, that propels them. In order for particles to remain airborne, the air flow drag force must be equal to or greater than the gravitational force. Calculations of the required minimum air velocity as a function of particle diameter (TID-24190) show that an air velocity of 2 to 5 mph is sufficient to maintain the U_3O_8 powder airborne, while velocities of 10 to 50 mph are required to maintain UO_2 particles, with particle sizes of 300-1,200 microns, airborne. Although these velocities are possible, they would coincide with an atmospheric dispersion that would greatly dilute the uranium.

Another important parameter in evaluating accident consequences for the storage site is the respiratory intake of particles. Established data and models used in the nuclear industry (ICRP 1987) show that particles greater than 10 microns in diameter are retained in the nasal region, if they can even be inhaled, and are subsequently released from the nasal region with little residence time. Therefore, the presence of particles with a diameter greater than 10 microns will not pose any inhalation health hazard. It is important to note that inhalation is the primary means by which uranium particles would be expected to pose a toxic hazard.

A hazards review of the proposed operations identified (1) handling hazards associated with the movement of packages (drums) which include the potential for dropping the packages, impacting the packages with pieces of equipment such as the transport vehicles, and (2) fires involving combustible material in facilities. The following section discusses in more detail the accidents for surface facilities where the accidents and the scenario development are expected to be similar and underground facilities where accidents and accident scenario development are expected to be different from those for surface facilities.

7.2 Surface Processing and Storage Facilities

Drum handling accidents involving dropping, tipping, or pinching were identified for the operation of the surface facilities which include the Receiving Warehouse and Repackaging Building, the above grade storage facility, and the underground storage facility. In all these facilities, drum handling devices will be provided to reduce the frequency of these potential accidents.

In addition, the repackaging operation has the potential for releasing material to the environment from accidents. The UF_6 cylinders have the potential for releasing larger amounts of material because of its physical properties. This operation involves heating the cylinder to generate UF_6

vapor which is transferred to a cooled receiving cylinder. Failure of a liquid cylinder could release large quantities of UF_6 which would generate large quantities of HF gas. According to NUREG-1140, the release of 4,800 kg of soluble uranium would result in uranium uptakes of about 100 mg at distances of about 500 m.

7.3 Mined Cavity Storage Facility

The greatest radiological hazards in the mined cavity storage facility exist in the underground storage areas (drifts), in the event that ventilation is lost for a protracted period of time, and seepage of radon leads to dangerous concentrations.

Serious industrial hazards exist, particularly in the construction phase. Fatalities in excavating and drilling operations (most recently, in the excavation of the tunnel beneath the English Channel) are commonplace. These can be the consequence of flying debris, unstable heavy machinery, and failure to use adequate shoring. In the operating phase, accidents can also occur in the handling of heavy drums, by overloading cranes, dropping loads, etc. Finally, although the depleted uranium oxides do not represent a heat load, and are not combustible, an accidental fire in a drift could conceivably lead to drum rupture and dissemination of waste materials. Impacts of solid or liquefied UF_6 cylinder failure would be similar to those described for the Surface Processing and Storage Facilities (section 7.2) although there would be delays in release from the underground vault to the local atmosphere.

7.4 Scoping Assessment of Accident Frequencies

In order to gain an understanding of the risks associated with the operation of depleted uranium storage facilities, a scoping assessment of the frequencies of three potential accidents has been conducted. These accidents are drum drop, fire or explosion in the repackaging facility, and accidents initiated by external events such as natural phenomena. Details of the frequency estimation process are provided in the following sections.

Mishandling/Drop of Drum Inside the Facility

Drums of U_3O_8 or UO_2 powder are transported into the facility using a series of cranes and hoists. There is a potential that they may rupture if mishandled during transport. The probability of creating a leak from mishandling was calculated to be $1.1x10^{-5}$/operation where an operation is moving a container (a drum) from one location to another.

The number of U_3O_8 drums that would be handled each year is 35,683 while the number of UO_2 drums that would be handled each year is 21,000. Assuming that the drums arrive on pallets of four, and each pallet is handled six times, the probability of a mishandling accident is:

35,683 U_3O_8 drums/year x 1/4 pallet/drum x 6 operations/pallet x $1.1x10^{-5}$/operation
= 0.59 drops/year

21,000 UO_2 drums/year x 1/4 pallet/drum x 6 operations/pallet x $1.1x10^{-5}$/operation
= 0.35 drops/year

For the U_3O_8, the material at risk for four drums is approximately 2,532 kg. The damage fraction is estimated to be 0.25 and the release fraction is estimated as $2x10^{-4}$. HEPA filtration removes 99.9% of the oxide particles. Consequently, the environmental release source term becomes 40 mg as uranium oxide (U_3O_8).

For the UO_2, the material at risk contains approximately 4,084 kg. The damage fraction is estimated to be 0.25 and the release fraction is estimated as $5x10^{-5}$. HEPA filtration is expected to remove 99.9% of the particles. Thus, the environmental release source term is 0.1 mg as uranium dioxide.

Fire or Explosion Inside the Repackaging Building

A detailed design would be needed to accurately calculate the frequency of a fire or explosion that could cause a release of uranium particles inside the facility. If UF_6 was involved in such an accident, it would also involve the release of HF as a reaction product. It is likely that the initiator of such an accident would be the leak or rupture of a line or bin. Vessel and pipe rupture frequencies have been previously calculated for uranium processing to be from $5.8x10^{-6}$/year to $9.6x10^{-6}$/year (SAIC 1995a). As a conservative estimate since a vessel or pipe rupture may not necessarily lead to a fire, explosion, or chemically induced uranium release, the largest of these frequencies, $9.6x10^{-6}$/year, is assumed for this accident with both U_3O_8 and UO_2.

For UO_2, the maximum material at risk would be 4,084 kg (only one pallet is handled at any one time). Again, the respirable release fraction is $5x10^{-5}$. The HEPA filters would remove 99.9%. The environmental source term would become 0.2 g of uranium dioxide.

For U_3O_8, a similar argument yields a maximum material at risk of 2,532 kg. The respirable release fraction is $2x10^{-4}$. The HEPA filters remove 99.9%. The environmental source term is estimated to be 0.51 g of U_3O_8.

A line rupture involving UF_6 flowing from a liquid cylinder would be mitigated and the release should be less than 10 kg. Most of the uranium would be in the form of UO_2F_2 particles and would remain in the building although the HF would be released.

Externally Initiated Events

Externally initiated events tend to be site-specific. As a first approximation, the DOE performance category frequencies are used in the estimates. The release fractions used for internal events are based on falling powders, which would be found in localized accidents. For external events, most of the drums are at or near ground level, without open spaces for large amounts of freely falling powder. Although the contents of the drums will be released inside heavily damaged facilities, much lower respirable release fractions are assumed.

The storage facilities have a low hazard rating which corresponds to DOE hazard category 2. Events that have the potential to cause damage and loss of function should have an annual frequency of $5x10^{-4}$. For major earthquakes, failure of the structure and confinement systems occurs. The Receiving Warehouse/Repackaging Building has about 1.7 to 3.3 million kg of material at risk depending on the material form. Assuming the earthquake results in damage fraction of 10%, and inventory of 2.5 million kg of material in the Receiving Warehouse/Repackaging Facility and the released respirable fraction is $6x10^{-5}$, the resulting source term is 15 kg with a release duration of 30 minutes.

Similarly, a major tornado would also result in failure of the structures and the confinement systems. Tornado missiles could result in damage fraction to 10%. Using the same respirable fraction of $6x10^{-5}$, the resulting respirable source term would also be 15 kg with a release duration of 30 seconds.

It is assumed that these facilities are located at a site that precludes severe flooding. Therefore, flood related accidents have not been evaluated.

Table 7-1 presents a summary of the estimated frequencies for internal accidents and externally initiated events identified and evaluated in this section. The table also presents the estimated mass of respirable uranium particles released to the environment for each accident type.

Table 7-1. Scoping Assessment of Accidents for Internal and Externally Initiated Events

Accident	Frequency (per year)	Frequency Range			Effective MAR	RAF	RF	Leak Path	Source Term	Release Duration
		$>10^{-2}$/yr	10^{-2} to 10^{-4}/yr	$<10^{-4}$/yr						
Mishandling or Drop of Drum										
U_3O_8	0.59	x			633 kg	2×10^{-4}		1×10^{-3}	0.13 g	puff
UO_2	0.35	x			1021 kg	5×10^{-5}		1×10^{-3}	0.05 g	puff
Fire or Explosion Reagent Inside Repackaging Building										
UF_6	9.6×10^{-6}			x	10 kg	1		1×10^{-3}	10 g	5 min
U_3O_8	9.6×10^{-6}			x	2,532 kg	2×10^{-4}		1×10^{-3}	0.51 g	5 min
UO_2	9.6×10^{-6}			x	4,084 kg	5×10^{-5}		1×10^{-3}	0.2 g	5 min
Major Earthquake, Failure of Structure and Confinement Systems, Repackaging Building										
UF_6 U_3O_8 UO_2	5×10^{-4}		x		2,500,000 kg	6×10^{-5}		0.10	15 kg	30 min
Major Tornado, Failure of Structure and Confinement Systems, Repackaging Building										
UF_6 U_3O_8 UO_2	5×10^{-4}		x		2,500,000 kg	6×10^{-5}		0.10	15 kg	30 sec.

8.0 TRANSPORTATION

The major intrasite transportation required during operation of these storage facilities would entail the movement of the received product from the site boundary to the Receiving Warehouse on a railcar or truck, the movement within the Receiving Warehouse and Repackaging Building by overhead cranes, the movement from the Receiving Warehouse and Repackaging Building to the various storage buildings (vaults) or to the shaft of the mined cavity by truck, and the movement within the storage buildings (drifts) by straddle carriers or mobile cranes (vaults).

Containers for the various chemical forms of depleted uranium that would be handled include Type 48 cylinders (for UF_6), pallets of 30-gallon drums (for UO_2), and pallets of 55-gallon drums (for U_3O_8). A small number of empty containers would also be transported on site: new cylinders for receiving the contents of UF_6 cylinders damaged in transit, and empty or emptied 30- and 55-gallon drums to replace those damaged in transit. The basic characteristics and mode of transport for depleted uranium are presented in table 8-1. All other onsite transportation would be minimal.

Receipt of depleted uranium from offsite directly parallels the shipments by rail from the site boundary as indicated in table 8-1. Relatively small amounts of waste (< 1 truck/year) requiring offsite shipment will be generated.

Table 8-1. Onsite Transportation, Depleted Uranium

	UF_6	UO_2	U_3O_8
Physical form	Solid, powder	Solid, granular	Solid, granular
Container type	Type 48 cylinder	30-gallon drum	55-gallon drum
Weight per container	12,247 kg	1,021 kg	626 kg
Annual quantity, mass	28,000 te	21,500 te	22,300 te
Annual quantity, number of containers	2,322	21,000	35,683
Annual quantity, number of pallets	N/A	5,250	8,921
Transportation mode (from site boundary)	Rail	Rail	Rail
Containers per railcar, 12 railcars/shipment	4	48	76
Annual number of railcar shipments	49	37	40
Transportation mode (from site boundary)	Truck	Truck	Truck
Containers per truck	1	16	28
Annual number of truck trips	2,322	1,313	1,275
Transportation mode (Receiving Warehouse to storage)	Truck	Truck	Truck
Containers per truck trailer	2	4 pallets	7 pallets
Annual number of truck trips	1,161	1,313	1,275
Transportation mode (inside storage building, vault, drift)	Straddle carrier/ Mobile crane	Straddle carrier/ Mobile crane	Straddle carrier/ Mobile crane
Containers per lift	1	1 pallet	1 pallet
Annual number of lifts	13,932	31,500	53,526

9.0 PERMITTING AND REGULATORY COMPLIANCE

This section identifies and briefly discusses the more relevant requirements and regulations that impact construction and operation of a storage facility for depleted uranium. Many of these regulations and requirements require a specific site for analysis and evaluation. A specific site is beyond the scope of this report, and thus, only general effects are noted. Although the requirements and net effects are essentially the same for either DOE or commercial facilities, the approach differs. Thus, this section is split into three separate parts covering the storage facility as either a DOE-owned or a commercially-owned facility. Some regulations impact construction more than operations, and this is used as the major divider of the following sections. Table 9-1 summarizes the major DOE requirements and their effects. Table 9-2 summarizes the regulations and their effects for a commercial, depleted uranium storage facility.

Table 9-1. Effect of DOE Requirements on the Depleted Uranium Storage Facility

Requirement	Effect
4700.1	Defines project management and requirements
6430.1A	Identifies general design requirements
5400.5	Establishes ALARA and radiation limits for DOE facilities
5820.2A	Identifies waste management responsibilities and requirements
5400.3	Identifies hazardous and mixed waste requirements
5480.4	Establishes environmental protection, safety, and health standards

While a DOE-constructed facility for depleted uranium storage would not be subject to NRC requirements, depleted uranium is still regarded by DOE as source material, and if it were planned to dispose of any process wastes containing depleted uranium as low-level waste, it would be subject to DOE Orders at DOE disposal sites and to NRC licensing criteria at commercial disposal sites. On the other hand, a depleted uranium storage facility constructed for commercial use would be subject to NRC requirements as defined in Title 10, Part 40, of the Code of Federal Regulations (10 CFR 40), "Domestic Licensing of Source Material." No reference is made in Part 40 to the long-term storage of depleted uranium. Nevertheless, depleted uranium falls under the definition of source material as stated in Part 40 (as its U^{235} isotopic content exceeds 0.05 percent), and so it is highly probable that a commercial depleted uranium storage facility would have to be designed to meet the siting and operational requirements of Appendix A of Part 40.

Table 9-2. Effect of Commercial Regulations on the Depleted Uranium Storage Facility

Regulation	Effect
NEPA	Evaluate environmental impact.
CAA	Normal operational chemical emission air quality standards.
CWA	Normal operational water chemical pollutant standards.
RCRA	"Life-Cycle" of all plant hazardous waste.
NCA	Normal operational noise-level standards.
AEA	USNRC authority for all commercial nuclear energy applications.
10 CFR 20	Specific detailed worker occupational dose limits for organs and whole body (e.g., 5 rem whole body per year); allowable air and water radionuclide concentrations; worker radiological protection; dose calculation methodology; radwaste handling; public dose limits from normal operation; license requirements; record keeping.
40 CFR 190(B)	Public annual dose cannot exceed 25 millirems (whole body), 75 millirems (thyroid), and 25 millirems (other organs) from all discharges associated with normal operation of any nuclear fuel cycle facility.
40 CFR 61 (I)	Radionuclide air emissions from operation will not cause any individual annual dose to exceed 10 millirem; reporting; record keeping.
10 CFR 40	Licensing requirements for handling and storing source material such as uranium hexafluoride.
10 CFR 71	Design standards for packages that transport radioactive materials such as UF_6 and uranium end products; license conditions; operating controls; quality assurance.
29 CFR 1900	Nonnuclear safety and health standards for workers.
10 CFR 51	Application of NEPA to NRC regulated facilities; environmental impact statement requirements.
10 CFR 75	Nuclear material accountability and control for uranium.
NUREG-1140	One mile emergency evacuation zone protects against worst case, low probability uranium fire accident.
NUREG-1391	Chemical toxicity of UF_6 is greater than the radiation dose with appropriate limits of 10 mg uranium intake.
NUREG/CR-3058	Site-specific tornado probability calculation method.
R.G.1.145	Method to calculate atmospheric dispersion of uranium releases.
R.G.3.12	Ventilation system design for radioactive material.
R.G.3.16	Fire protection program for radioactive material.
R.G.3.39	License application format and content.
R.G.3.40	Method to calculate design basis floods.
R.G.3.42	Development of emergency plans.
R.G.3.67	Format and content of emergency plans.
D.G.-8013	Radionuclide effluent levels for ALARA.

9.1 Major Regulations Affecting Construction of a Storage Facility

9.1.1 Regulatory Requirements for DOE Facility Construction

Construction of a depleted uranium storage facility constitutes a Major Systems Acquisition (MSA) for DOE. Therefore, the DOE project management system, as defined by DOE Order 4700.1, becomes the major requirement. This Order defines the process for DOE's execution, construction, and completion of the MSA. It identifies key decisions (KDs), management roles, documents, estimating bases, and project control methods. Construction of the storage facility would initially require two new documents: Justification of New Start (JNS) and Justification of Mission Need (JMN). Both of these would be relatively short. After approval (usually designated as "KD-O"), DOE would prepare a Project Plan (PP) and a more detailed Project Management Plan that defines roles, provides organization (both management and as a Work Breakdown Structure), identifies additional documentation, and estimates schedules and costs. The additional documentation requirements would include a Conceptual Design Report (CDR), detailed design reports (usually Title 1 for preliminary, and Title 2 for final), an EIS, permit applications, laboratory program documents, and a safety analysis report (SAR).

The general design requirements for the construction of a DOE facility for storing depleted uranium are stated in DOE Order 6430.1A. Division 13 of this Order pertains to "Special Facilities," (as defined in DOE 5480.5, Safety of Nuclear Facilities). Subdivision 1319 of DOE 6430.1A refers to "Uranium Processing and Handling Facilities (UPHF)," which appears to include a storage facility, although it states, "This section is not process specific. It is principally directed at facilities that process and handle uranium enriched in U^{235}." Thus, portions of this Order, such as 1319-3, "Nuclear Criticality Safety," clearly are not applicable to the design of the facility.

9.1.2 Regulatory Requirements for Commercial Facility Construction

The laws and regulations that pertain to the construction and operation of a depleted uranium storage facility have been established by several Federal agencies with no single regulation specifically addressing all aspects of facility design. Many of these regulations apply to the storage facility because they generally encompass nuclear fuel cycle facilities that handle uranium. In the hierarchy of Federal regulations, acts and sections of the CFR constitute the law that must be met unless the government grants an exception. Other regulatory documents such as NRC RGs, industry standards, and NRC NUREG or NUREG/CR reports may be deviated from with sufficient technical justification.

Federal laws in the form of acts set general goals, standards, bases, and authority that relate to a depleted uranium storage facility. These acts and a brief summary are delineated below.

National Environmental Policy Act (NEPA) of 1970—NEPA sets national environmental policy and goals by requiring Federal government agencies to evaluate the environmental effects of major Federal actions in a detailed report.

Noise Control Act (NCA) of 1972—The NCA sets noise control responsibility at the state and local levels with specific requirements on noise levels that a facility must meet.

Atomic Energy Act (AEA) of 1954—This act gives the Nuclear Regulatory Commission licensing and regulatory authority for commercial nuclear energy applications. Its applicability to a DOE depleted uranium storage facility will depend on a decision by DOE to comply with NRC regulations.

Code of Federal Regulations—Parts of the CFR establish more specific standards for the design and operation of a depleted uranium storage facilities. Potentially applicable sections of the CFR for this plant are 10 CFR 51. This regulation establishes environmental protection requirements and documentation to comply with NEPA for nuclear facilities regulated by the NRC.

NUREG/CR-3058—"A Methodology for Tornado Hazard Probability Assessment," October 1983. This document describes how to calculate the probability of a specified severe tornado at a given specific site for safety analysis.

NRC R.G. 1.145—"Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," November 1982. This guide delineates the methodology for calculating doses due to the atmospheric release of radioactive materials. It is directly applicable to the release of uranium to the atmosphere.

NRC R.G. 3.12—"General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants," August 1973. This document provides criteria for the design of ventilation systems to ensure that no releases of radioactive material to the environment occur. Although not specifically designated for a depleted uranium storage facility, some of the principles and criteria are directly applicable.

NRC R.G. 3.16—"General Fire Protection Guide for Plutonium Processing and Fuel Fabrication Plants," January 1974. This document provides criteria for the design of a fire protection program to ensure that no releases of radioactive material to the environment occur. Although not specifically designated for a depleted uranium storage facility, many of the principles and criteria are directly applicable to the uranium handling parts of the facility.

NRC R.G. 3.39—"Standard Format and Content of License Application for Plutonium Processing and Fuel Fabrication Plants," January 1976. This document prescribes a format for license applications to the NRC that may be applicable to a depleted uranium storage facility with the exception that criticality accidents need not be considered.

NRC R.G. 3.40—"Design Basis Floods for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Fabrication Plants," Revision 1, December 1977. This document provides criteria for the determination of site-specific design basis floods to ensure that a facility is designed for these events without releasing any radioactive material to the environment. Although not specifically designated for a depleted uranium storage facility, many of the principles and criteria are directly applicable to the uranium handling parts of the facility.

9.2 Major Regulations Affecting Operations of a Depleted Uranium Storage Facility

9.2.1 Regulatory Requirements for DOE Facility Operations

DOE is committed to the operation of its facilities in accord with its own Orders and in accord with Federal environmental statutes, including the Atomic Energy Act (AEA), the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), the Clean Air Act (CAA), and the Clean Water Act (CWA).

Key DOE Orders include 5400.5, "Radiation Protection of the Public and the Environment." This Order specifically requires the application of the ALARA ("As Low as Reasonably Achievable") process for radiation protection of the public and the environment. The radiation protection system used in DOE 5400.5 is based on recommendations of the International Commission on Radiological Protection (ICRP). In its Publication No. 26 (1977), the ICRP recommended a system of dose limitations consisting of three basic principles:

1. No practice shall be adopted unless its introduction produces a positive net benefit ("justification");

2. All exposures shall be kept as low as is reasonable achievable, economic and social factors being taken into account ("ALARA," or "optimization"); and

3. The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission ("individual dose limits").

Other important DOE Orders include 5400.3 (the Hazardous and Radioactive Mixed Waste Program), 5440.1E (NEPA Compliance Program), 5480.4 (Environmental Protection, Safety, and Health Protection Standards), 5480.5 (Safety of Nuclear Facilities), and 5820.2A (Waste Management).

9.2.2 Regulatory Requirements for Commercial Facility Operations

CAA—The CAA requires that the U.S Environmental Protection Agency (EPA) set air quality standards for specific chemical pollutants. This act applies to normal emissions from a depleted uranium storage facility.

CWA—The CWA requires that the EPA establish specific limits on chemical pollutants in water. The state certifies that permitted discharge from a facility meets all standards.

RCRA—The RCRA is under the auspices of the EPA and encompasses the entire life cycle of hazardous waste. RCRA regulates hazardous waste during its generation, transport, use, storage, and disposal. RCRA-listed materials are not used at the depleted uranium storage facility. However, it is possible for a waste exhibiting hazardous characteristics (i.e., corrosivity, reactivity, ignitability, and EP toxicity) to be generated during a facility accident. Also, uranium is not currently regulated as a hazardous material. UO_2 and U_3O_8 are also not and are unlikely to become RCRA-regulated materials.

NCA—The NCA sets noise control responsibility at the state and local levels with specific requirements on noise level that a facility must meet.

10 CFR 20—Issued by the NRC, this regulation sets standards for radiation protection for nuclear facilities under the auspices of the NRC, with the primary emphasis being on radiation dose standards from normal operation of these facilities.

40 CFR 190 Subpart B—Sets public maximum radiation doses from normal operational releases.

40 CFR 61 Subpart I—Air emission of radioisotopes from normal operation of an NRC licensed facility is limited so that the annual public effective dose equivalent does not exceed 10 mrem (0.1 milli Sievert).

10 CFR 40—Sets requirements for domestic licensing of nuclear source material. This regulation may not apply to the low U^{235} enrichment of depleted uranium.

10 CFR 71—Under the authority of both the NRC and the Department of Transportation (DOT), this regulation provides specific criteria for the safe packaging and transport of radioactive material. This regulation would pertain to the shipment of depleted uranium into the depleted uranium storage facility.

29 CFR 1900-1999—This regulation enacts the Occupational Safety and Health Act (OSHA) of 1990, which sets standards for the safety of workers under the auspices of the Department of Labor (DOL).

10 CFR 75—In accordance with an agreement between the United States and the International Atomic Energy Agency (IAEA), this regulation provides for a system of accounting and control of nuclear material. The proposed storage facility may be eligible for exemption from this regulation because of the low U^{235} enrichment level involved in this facility.

Industry standards, NRC RGs and NUREG or NUREG/CR reports provide guidance and a framework for the regulating Government agencies to review designs and license applications.

These documents do not carry the power of the law but are respected as good technical practices. Deviations from such relevant documents usually require a detailed technical explanation and justification. These documents are summarized below.

NUREG-1140—"A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees," by S.A. McGuire, January 1988. This report evaluates historical data on accidents at fuel cycle and radioactive material plants. Analyses are performed for accidental releases of uranium in different meteorology, and the results are related to toxic chemical and radiation dosage limits. Recommended emergency actions for accidental releases of uranium are discussed in this document. A one-mile emergency response zone is recommended for uranium releases with respirable particles. This document influences site size and potential evacuation distances.

NUREG-1391—"Chemical Toxicity of Uranium Hexafluoride Compared to Acute Effects of Radiation," Stephen A. McGuire, February 1991. This report evaluates the comparative toxicological and radiation effects of uranium hexafluoride. It concludes that the equivalent health effects of a 25 rem whole body dose is the ingestion of 10 milligrams of uranium.

NRC R.G. 3.42—"Emergency Planning for Fuel Cycle Facilities and Plants Licensed under 10 CFR 50 and 70," Revision 1, September 1979. This document provides guidance in the design and development of emergency plans for facilities containing radioactive materials.

NRC R.G. 3.67—"Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities," January 1992. This document specifies the required format and contents of emergency plans that would be applicable to a depleted uranium storage facility.

These requirements also invoke certain standards and codes. For the storage facility, the two most important ones are ANSI and ASME. ANSI provides standards and specifications for chemical processing equipment, flanges, valves, pumps, etc. The ASME establishes standards and estimating protocols for pipes and vessels. For the storage facility (non-nuclear reactor, nondirect fixed), Section 8, Division 1 applies. Building code requirements specific to the site would also have to be met.

10.0 PRELIMINARY SCHEDULE ESTIMATES

Figure 10-1 shows the estimated schedule for the entire life cycle of the depleted uranium storage facility. A more detailed design phase is necessary for more definitive schedule estimates.

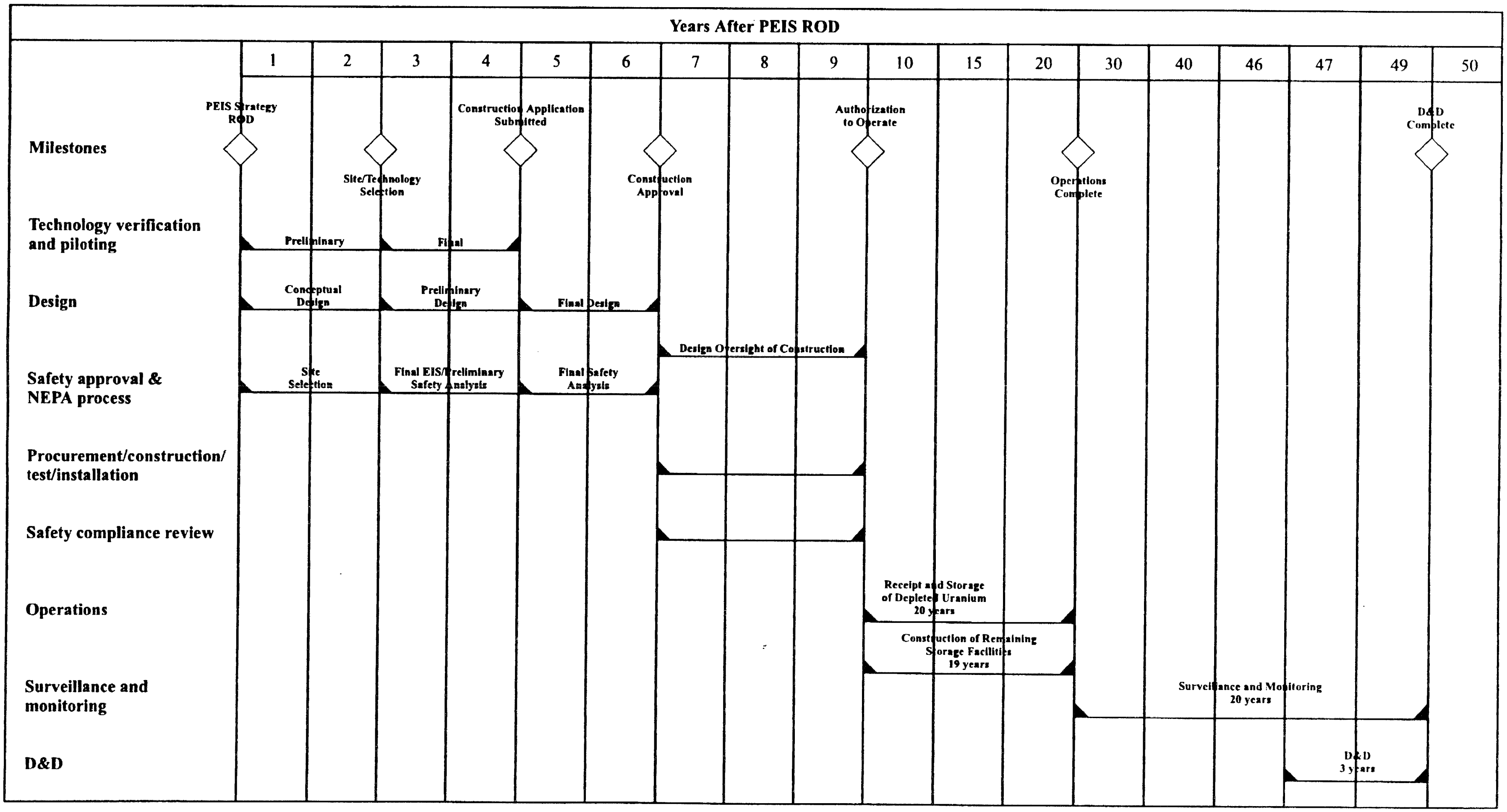
After a DOE Record of Decision (ROD), there would be a period of approximately one year for management plans, approvals, and initial budgeting. Next, there would be a period of approximately three years for depleted uranium storage form development and testing, and generation of baseline design parameters. This includes computer modeling of storage sites. Design and engineering activities would overlap this time and would probably add another year.

For DOE projects, this period provides sufficient time for initiating the Federal budget cycle planning, and NEPA activities, if necessary, would also parallel design and engineering.

Construction of the facility would occur over a period of twenty years. Initially, the supporting buildings would be built, followed by the storage buildings (vaults, drifts). The supporting structures, such as the Receiving Warehouse and Repackaging Building would thus be available for processing of receipts of depleted uranium as soon as they and at least one storage building (vault, drift) were completed. Construction of additional storage buildings (vaults, drifts) would then proceed over the next twenty years, providing just enough storage capacity to handle anticipated receipts over the near term. Since most of the construction involved in developing this facility would be relatively routine, no more than one year is needed before the facility would be able to receive depleted uranium shipments.

Once all of the depleted uranium has been shipped, the facility would then enter a maintenance and monitoring mode for the next 29 years. By the end of this period, arrangements will have been made for the reuse or disposal of the stored depleted uranium and the facility can be decommissioned.

Figure 10.1: Estimate of Overall Schedule for the Storage Program



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APPENDIX A

Equipment List

Table A-1. Equipment for Facilities Common to All Chemical Forms and All Storage Modes

Building	Area	Equipment	Use/Explanation	Number
Administration building	General	Telephone system	Common to all buildings	1
		HVAC	Maintain working temperature	1
	Offices	Office furniture	Desk, computer table, chair(s), filing cabinet, bookcase	16
		Computer, attached to LAN and printer	Audit inventory and inventory movement, prepare budget, track costs, and prepare reports	16
		LAN	Common to all buildings; access to inventory database; internal communications	1
		Printer	Printing, one each office group	4
	Kitchen	Kitchen equipment	Microwave, refrigerator, sink, storage area, cupboards	1
	Wash room	Toilets, sinks	Human waste and personal hygiene	2 (1 M, 1 F)
	Health physics station	Badging, reading, and record keeping equipment, computer	Radioactive dose control; issue and read dosimeters; maintain worker received dose data	1
	Security station	Badging equipment, location monitors, computer	Make security badges, activate badge numbers, monitor badge locations in complex	1
Maintenance Building	General	General maintenance equipment	Metal joining, drilling, cutting, and shaping equipment; electrical and electronic test equipment	1
		HVAC	Maintain working temperature	1
	Wash room	Toilet, sink	Human waste and personal hygiene	1 (M & F)

Table A-2. Equipment for UF_6 Facilities Common to All Storage Modes

Building	Area	Equipment	Use/Explanation	Number
Receiving Warehouse	Unloading bay	Davit crane, 25 ton	Unload cylinders from truck or railcar	2
		Scales	Weigh received cylinders for material accountability	2
		Hand-held bar coding equipment with computer link	Bar code cylinders and record cylinder condition in cylinder database	2
		Prime mover	Move railcars loaded with cylinders	1
	Loading bay	Davit crane, 25 ton	Load cylinders to truck	2
		Hand-held bar coding equipment with computer link	Record cylinder shipments to storage buildings; record cylinder condition	2
		Flat bed trailer truck	Move cylinders to storage areas	1
	Inspection area	Bridge crane, 25 ton	Move cylinders from unloading bay to storage area and from storage area to loading bay	2
		Computer, attached to LAN	Record inventory movements	2
		Radiation monitoring equipment	Monitor received cylinders, ambient environment, and workers on entry/exit	1
	General	Security station (automated)	Control personnel access to building	1
		Fire sensors/alarms; sprinkler system	Fire protection	1
		Toilet facilities	Human waste and personal hygiene	1 (M & F)
		HVAC	Maintain working temperature; maintain positive pressure over repackaging building	1
Repackaging Building	Repackaging area	Straddle carrier	Move damaged, overpressured, overfilled cylinders to repackaging area/move newly-filled cylinders to loading area	1
		Flat bed trailer truck	Move empty, damaged cylinders to Cylinder Washing Building	1
	Repackaging station	Autoclave	Autoclave for emptying damaged cylinders	1

Building	Area	Equipment	Use/Explanation	Number
Repackaging Building (continued)	Repackaging station (continued)	Cylinder stand	Hold cylinder while receiving depleted uranium from filled cylinder	1
		Hand-held bar coding equipment with computer link	Bar code new drums/read bar codes of repackaged drums	2
		Scales	Weigh received/repackaged cylinders for material accountability	
		Radiation monitoring station	Measure radiation on cylinders before/after emptying/filling and on workers on entry/exit	1
		LLW containment area	Contain LLW prior to offsite disposal	1
	General	HEPA filter	Scrub air of contaminated airborne particles	1
		HVAC	Maintain working temperature; maintain pressure drop between Repackaging Building and Receiving Warehouse	1
		Decontamination showers	Decontaminate workers after exposure to depleted uranium dust	1 (M & F)
		Fire sensors/alarms; sprinkler system	Fire protection	1
Cylinder Washing Building		Rotating stand	Agitate cylinders containing wash solutions	1
		Recycle water tank, 50 gal, contains some HF	Hold water from third rinse of cylinder	1
		Wash solution tank, 50 gal, contains HF	Hold water from second rinse of cylinder	1
		Filter	Removes particles prior to entry to wash evaporator feed tank	1
		Wash evaporator feed tank, 50 gal, contains HF	Hold wash (first rinse) water for batch processing in wash evaporator	1
		Wash evaporator, 3 gal/hr, batch	Evaporate wash solution to UO_2F_2 powder	1
		Condensor, 3 gal/hr	Condense evaporated solution to liquid containing HF and trace UO_2F_2	1

Building	Area	Equipment	Use/Explanation	Number
Cylinder Washing Building (continued)		UO_2F_2 repackaging hood	Contain UO_2F_2 dust during repackaging from wash evaporator tank to 55-gal drum	1
		HF tank, 50 gal	Hold HF solution for feed to neutralization tank	1
		CaO Hopper, 1.5' D X 1.5' H	Hold CaO for mixing with HF solution	1
		Neutralization tank, 2' D X 2' H	Neutralize HF with CaO	1
		CaF_2 filter press, 15 lb/day capacity	Remove water from CaF_2	1
		CaF_2 drying oven, 15 lb/day capacity	Dry CaF_2 prior to packaging	1
		CaF_2 packaging area	Place CaF_2 in 55-gal drums for disposal	1
		HEPA filter	Trap dust from UO_2F_2 and CaF_2 packaging	2
		HVAC	Maintain working temperature	1
		Hand-held bar code equipment with computer link	Bar code drums of UO_2F_2 and CaF_2	1
		Computer, attached to LAN	Record production of UO_2F_2 and CaF_2	1
		Fire sensors/alarms; sprinkler system	Fire protection	1
		Security station (automated)	Control personnel access to building	1
		Radiation monitoring station	Measure radiation on washed cylinders; measure radiation on workers on entry/exit	1
		HF monitoring station/alarm	Measure ambient HF concentrations; alarm at target levels	1

Table A-3. Equipment for UO_2 and U_3O_8 Facilities Common to All Storage Modes

Building	Area	Equipment	Use/Explanation	Number
Receiving Warehouse	Unloading bay	Davit crane, 10 ton	Unload pallets from truck or railcar	2
		Scales	Weigh received pallets for material accountability	2
		Hand-held bar coding equipment with computer link	Bar code drums and record in drum database	2
		Prime mover	Move railcars of drums	1
	Loading bay	Davit crane, 10 ton	Load pallets to truck	2
		Flat bed trailer trucks	Moving pallets from Receiving Warehouse to storage areas	3
		Hand-held bar coding equipment with computer link	Record drum shipments to storage buildings; record drum condition	2
	Inspection area	Bridge crane, 10 ton	Move pallets from unloading bay to storage area and from storage area to loading bay	2
		Computers, attached to LAN	Record inventory movements	2
	General	Radiation monitoring station	Monitor radiation levels in Receiving Warehouse and loading and unloading bays; monitor incoming drums; monitor workers on entry/exit	1
		Security station (automated)	Control personnel access to building	1
		Fire sensors/alarms; sprinkler system	Fire protection	1
		Generator	Backup power for repackaging operation during power outage	1
		Uninterruptible power supply	For computers during initial stages of power outage	1
Repackaging Building	Repackaging Area	Drum hoist/tipper-shaker	Raise overpacked drums to top of hopper and dump into hopper	1
		Hopper, 4' D by 5' H	Receive depleted uranium from overpacked, damaged drum and load into new drum	1
		Flexible overpack to hopper adapter/seal	Connect overpack and hopper to minimize dust loss when tipping overpack to hopper	1

Building	Area	Equipment	Use/Explanation	Number
Repackaging Building (continued)	Repackaging Area (continued)	Vibrator table	Compact product in new drum to minimize space used	1
		Flexible drum to hopper connection	Connect hopper to receiving drum to minimize dust escape	1
		Forklift, 5 ton	Moving overpacked, damaged drums between Receiving Warehouse and scales and hoist	2
		Scales	Weigh overpacked, damaged drums and refilled drums for material accountability	1
		Closed-circuit TV	Monitor dumping and cleaning activities in repackaging area	1
		Hand-held bar coding equipment with computer link	Read codes from damaged drums and make codes for new drums	1
		Computer attached to LAN	Recording movements and condition of drums in database	1
		Decontamination showers	Decontaminate workers after exposure to dust	1 (M & F)
		Toilet facilities	Human waste and personal hygiene	1 (M & F)
		Fire sensors/alarms; sprinkler system	Fire protection	1
		HEPA filter	Filter repackaging area exhaust; filter gloveboxes	4
		HVAC	Maintain working temperature; maintain pressure drop with Receiving Warehouse (50,000 cfm 120 hp exhaust fans; 50,000 cfm 50 hp air supply unit)	1
		Glovebox	Contain LLW prior to offsite disposal	1
	Low-level waste glovebox	Low-level waste compactor	Compact LLW for packaging in drums	1

Table A-4. Equipment for UF_6 Building Storage

Building	Area	Equipment	Use/Explanation	Number
Storage building	Unloading bay	Davit crane, 25 ton	Load cylinders from trucks to unloading bay or vice versa	2
	Storage area	Straddle carrier, 25 ton	Move cylinders from unloading bay to storage area or vice versa	4 (total for all buildings)
		Scales	Weigh cylinders on receipt/shipment for material accountability	2/building
		Hand-held bar coding equipment with computer link	Track receipt/shipment of cylinders from/to Receiving Warehouse or Repackaging Building	4 (total, for all buildings)
		Computer attached to LAN	Record receipt/shipment of cylinders from/to Receiving Warehouse or Repackaging Building	1/building
		Fire sensors/alarms; sprinkler system	Fire protection	1/building
		Radiation monitoring station	Measure radiation in ambient air, on received cylinders and on workers at entry/exit	1/building
		Security station (automated)	Control personnel entry to building	1/building
		HEPA filter	Trap particles on exhaust for radiation monitoring	1/building
		HVAC	Periodically heat/cool building during inspection; maintain temperature for computer during operation	1

Table A-5. Equipment for UO_2 and U_3O_8 Building Storage

Building	Area	Equipment	Use/Explanation	Number
Storage building	Unloading bay	Davit crane, 10 ton	Load drums on pallets from trucks to unloading bay or vice versa	2
	Storage area	Straddle carrier, 10 ton	Move drums on pallets from unloading bay to storage area or vice versa	4 (total for all buildings)
		Scales	Weigh drums on receipt/shipment for material accountability	2/building
		Hand-held bar coding equipment with computer link	Track receipt/shipment of drums from/to Receiving Warehouse or Repackaging Building	4 (total for all buildings)
		Computer attached to LAN	Record inventory movements	1/vault
		Radiation monitoring station	Measure radiation in ambient air, on received drums, and on workers at entry/exit	1/building
		Fire sensors/alarms; sprinkler system	Fire protection	1
		Security station (automated)	Control personnel entry to building	1/building
		HEPA filter	Periodically trap particles on exhaust for radiation monitoring	1/building
		HVAC	Periodically heat/cool building during inspection; maintain temperature for computer during operation	1/building

Table A-6. Equipment for All Chemical Forms Specific to Vault Storage

Building	Area	Equipment	Use/Explanation	Number
Storage vault	Storage area	Mobile crane, 10 ton	Load drums on pallets from trucks to storage area or vice versa; remove roof sections of vault for access	2 (total for all vaults)
		Hand-held bar coding equipment with computer link	Track receipt/shipment of drums from/to Receiving Warehouse or Repackaging Building	4 (total for all vaults)
		Computer attached to LAN	Record inventory movements	1/vault
		Radiation monitoring station	Measure radiation in ambient air, on received drums, and on workers at entry/exit	1/vault
		HEPA filter	Periodically trap particles on exhaust for radiation monitoring	1/vault
		HVAC	Periodically heat/cool vault during inspection; maintain temperature for computer during operation	1 lot/ vault

Table A-7. Equipment for All Chemical Forms Specific to Mined Cavity Storage

Building	Area	Equipment	Use/Explanation	Number
Surface to underground access	Access shafts	Elevator, 20 ton	Move depleted uranium in cylinders/drums to/from vaults; remove mined rock	2
		Emergency power supply	Maintain elevator power, lighting to underground area during power outtages	1
		Radiation monitor station	Monitor radioactivity on cylinders/drums entering/exiting underground area; monitoring workers on entry/exit underground area	2
		Scales	Monitor cylinder/drum weight on entry/exit to underground area	4
		Hand-held bar coding equipment with computer link	Record transfers of cylinders/ drums to/from underground area; record condition of drums	2
		Computer attached to LAN	Record transfers of cylinders/ drums to container database	2
		Fire sensors/alarms; sprinkler system	Fire protection	1
		Security station (automated)	Control access to underground area	1
	Ventilation shafts	Compressor	Feed clean air to underground areas; exhaust dirty air	4
		Radiation monitor station	Monitor ambient air in underground facility	4
		Emergency power supply	Maintain air flow during power outtages	4
	Underground area	Straddle carrier, 25 ton (UF_6), 10 ton (UO_2, U_3O_8)	Move cylinders/drums from access shaft to storage areas and vice versa	6

APPENDIX B

Radiation Exposure and Manpower Distribution Estimating Data

BUILDING STORAGE FACILITY (UF6 CYLINDERS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 6)	Source	Distance (ft)	Material (Note 7)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving cylinder	2	0.5	2,322	1	3	Steel	1/4"	2322
Inspect arriving cylinder	1	0.5	2,322	1	3	Steel	1/4"	1161
Transfer undamaged cylinder to warehouse storage	2	0.5	2,319	1	6	Steel	1/4"	2319
Transfer damaged cylinder to repackaging area (5)	2	2	15	1	6	Steel	1/4"	60
Unload failed cylinder	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to repackaging area	2	0.5	1	1	6	Steel	1/4"	1
Load damaged/failed cylinder into autoclave	1	0.5	16	1	3	Steel	1/4"	8
Autoclave pressure test	2	1	16	1	15	Steel	1/4"+ 1/4"	32
Unload autoclave	1	0.5	16	1	3	Steel	1/4"	8
Transfer repackaged cylinder to warehouse storage	2	0.5	16	1	6	Steel	1/4"	16
Transfer damaged/failed empty cylinder to wash bldg	2	0.5	16	2	6	Steel	1/4"	16
Transfer new cylinders into repackaging area	2	0.5	16	1,2	15	Steel	1/4"+ 1/4"	16
Transfer cylinder from warehouse storage to loading bay	2	0.5	2,335	1	6	Steel	1/4"	2335
Load cylinder on truck	2	0.5	2,335	1	3	Steel	1/4"	2335
Transfer cylinder to storage building	1	0.5	1168	1	6	Steel	1/4"	584
Warehouse Storage Surveillance	1	1	520	3	3	Steel	1/4"	520
Autoclave Surveillance	1	0.25	260	1,2	3	Steel	1/4"	65
Building Management	2	8	260	3	10	Steel	1/4"	4160
Security	1	2	1095	3	15	Steel	1/4"	2190
CYLINDER WASHING BUILDING								
Unload damaged/failed cylinder	2	0.5	16	2	3	Steel	1/4"	16
Load cylinder into wash area	2	0.5	16	2	3	Steel	1/4"	16
Remove clean cylinder from wash area	2	0.5	16	2	10	Steel	1/4"	16
Building Operations	4	8	260	2	3	Steel	1/4"	8320
Security	1	2	1095	2	40	Steel	1/4"	2190

WORKSHOP								
Building Operations	4	8	260	4	80	Steel	1/4"	8320
Security	1	2	1095	4	80	Steel	1/4"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	4	160	Steel	1/4"	18720
Security	2	8	1095	4	160	Steel	1/4"	17520
STORAGE BUILDINGS - 17 Buildings								
Unload transferred cylinder	2	0.5	2,335	1	3	Steel	1/4"	2335
Transfer cylinder to storage position	1	0.5	2,335	1	6	Steel	1/4"	1167.5
Unload cylinder into position	2	0.5	2,335	4	3	Steel	1/4"	2335
Load failed cylinder from storage position (5)	2	2	1	4	3	Steel	1/4"	4
Transfer failed cylinder to bay	1	0.5	1	4	6	Steel	1/4"	0.5
Load failed cylinder onto truck	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to warehouse	1	0.5	1	1	6	Steel	1/4"	0.5
Monitor HEPA filtration/air monitor	1	2	260	4	10	Steel	1/4"	520
Storage area/container integrity surveillance	8	8	260	4	3	Steel	1/4"	16640
Building Management	1	8	260	4	10	Steel	1/4"	2080
Security	1	2	1095	4	15	Steel	1/4"	2190

1) Single full UF6 cylinder.
2) Single empty UF6 cylinder.
3) Up to 275 full UF6 cylinders in receiving warehouse.
4) Cumulative inventory of a storage building.
5) Includes handling of damaged/failed cylinder.
6) 2,322 cylinders received per year (46,422 cylinders received over 20 years).
   2 damaged full UF6 cylinders are received per year (0.1% failure rate/year).
   120* failed UF6 cylinders per year (0.5% failure rate sum averaged over 20 years).
   2,442 received and repackaged cylinders per year.
   1,221* on-site transfers per year (2,442 cylinders/2 cylinders per transfer).
   * does not account for 20 year maintenance life of facility which would average 232 failures per year.
   365 days per year x 3 shifts per day = 1095 per year.
7) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UF6 CYLINDERS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 5)	Number of Components	Source	Distance (ft)	Material (Note 6)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	1/4"	208
Autoclave	2	26	1	2,3	3	Steel	1/4"+ 1/4"	52
Autoclave compressor	2	52	1	2,3	3	Steel	1/4"+ 1/4"	104
Air lock system (2 per building)	2	52	2	1	20	Steel	1/4"	208
HVAC	2	520	1	1	10	Steel	1/4"	1040
HEPA	2	26	1	1	10	Steel	1/4"	52
CYLINDER WASHING FACILITY								
Rinse equipment	2	104	2	3	1	Steel	1/4"	416
Evaporating System	2	104	2	3	3	Steel	1/4"	416
U3O8 Conversion Equipment	2	104	2	3	1	Steel	1/4"	416
HVAC	2	520	1	3	20	Steel	1/4"	1040
WORKSHOP								
HVAC	2	520	1	4	80	Steel	1/4"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	4	160	Steel	1/4"	1040
STORAGE BUILDING — 17 Buildings								
Humidity Control System	2	104	17	4	10	Steel	1/4"	3536
HVAC	2	520	17	4	10	Steel	1/4"	17680
HEPA	2	26	17	4	10	Steel	1/4"	884
Air Monitoring Equipment	2	52	17	4	10	Steel	1/4"	1768

1) Up to 275 full UF6 cylinders in receiving warehouse.
2) Single full UF6 cylinder.
3) Single empty UF6 cylinder.
4) Cumulative inventory of a storage building.
5) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (compressors, air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (autoclaves, HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
6) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UF6 CYLINDERS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 5)	Source	Distance (ft)	Material (Note 6)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed cylinder	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to repackaging area	2	0.5	1	1	6	Steel	1/4"	1
Load damaged/failed cylinder into autoclave	1	0.5	1	1	3	Steel	1/4"	0.5
Autoclave pressure test	2	1	1	1	15	Steel	1/4" + 1/4"	2
Unload autoclave	1	0.5	1	1	3	Steel	1/4"	0.5
Transfer repackaged cylinder to warehouse storage	2	0.5	1	1	6	Steel	1/4"	1
Transfer damaged/failed empty cylinder to wash bldg	2	0.5	1	2	6	Steel	1/4"	1
Transfer new cylinders into repackaging area	2	0.5	1	1,2	15	Steel	1/4" + 1/4"	1
Transfer cylinder from warehouse storage to loading bay	2	0.5	1	1	6	Steel	1/4"	1
Load cylinder on truck	2	0.5	1	1	3	Steel	1/4"	1
Transfer cylinder to storage building	1	0.5	1	1	6	Steel	1/4"	0.5
Autoclave Surveillance	1	0.25	260	1,2	3	Steel	1/4"	65
Building Management	1	8	260	1	10	Steel	1/4"	2080
Security	1	2	1095	1	15	Steel	1/4"	2190
CYLINDER WASHING FACILITY								
Unload damaged/failed cylinder	2	0.5	1	2	3	Steel	1/4"	1
Load cylinder into wash area	2	0.5	1	2	3	Steel	1/4"	1
Remove clean cylinder from wash area	2	0.5	1	2	10	Steel	1/4"	1
Building Operations	4	8	260	2	3	Steel	1/4"	8320
Security	1	2	1095	2	40	Steel	1/4"	2190
WORKSHOP								
Building Operations	4	8	260	3	80	Steel	1/4"	8320
Security	1	2	1095	3	80	Steel	1/4"	2190

ADMINISTRATION BUILDING								
Building Operations	9	8	260	3	160	Steel	1/4"	18720
Security	2	8	1095	3	160	Steel	1/4"	17520
						Steel	1/4"	0
STORAGE BUILDING — 17 Buildings								
Unload transferred cylinder	2	0.5	1	1	3	Steel	1/4"	1
Transfer cylinder to storage position	1	0.5	1	1	6	Steel	1/4"	0.5
Unload cylinder into position	2	0.5	1	3	3	Steel	1/4"	1
Load failed cylinder from storage position (4)	2	2	1	3	3	Steel	1/4"	4
Transfer failed cylinder to bay	1	0.5	1	3	6	Steel	1/4"	0.5
Load failed cylinder onto truck	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to warehouse	1	0.5	1	1	6	Steel	1/4"	0.5
Monitor HEPA filtration/air monitor	1	2	260	3	10	Steel	1/4"	520
Storage area/container integrity surveillance	7	8	260	3	3	Steel	1/4"	14560
Building Management	1	8	260	3	10	Steel	1/4"	2080
Security	1	2	1095	3	15	Steel	1/4"	2190

1) Single full UF6 cylinder.
2) Single empty UF6 cylinder.
3) Cumulative inventory of a storage building.
4) Includes handling of damaged/failed cylinder.
5) 46,422 cylinders in storage.
   232 failed UF6 cylinders per year (0.5% failure rate/year).
   365 days per year x 3 shifts per day = 1095 per year.
6) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UF6 CYLINDERS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	1/4"	208
Autoclave	2	26	1	1,2	3	Steel	1/4"+ 1/4"	52
Autoclave compressor	2	52	1	1,2	3	Steel	1/4"+ 1/4"	104
Air lock system (2 per building)	2	52	2	1	20	Steel	1/4"	208
HVAC	2	520	1	1	10	Steel	1/4"	1040
HEPA	2	26	1	1	10	Steel	1/4"	52
CYLINDER WASHING FACILITY								
Rinse equipment	2	104	2	2	1	Steel	1/4"	416
Evaporating System	2	104	2	2	3	Steel	1/4"	416
U3O8 Conversion Equipment	2	104	2	2	1	Steel	1/4"	416
HVAC	2	520	1	2	20	Steel	1/4"	1040
WORKSHOP								
HVAC	2	520	1	3	80	Steel	1/4"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	160	Steel	1/4"	1040
STORAGE BUILDING — 17 Buildings								
Humidity Control System	2	104	17	3	10	Steel	1/4"	3536
HVAC	2	520	17	3	10	Steel	1/4"	17680
HEPA	2	26	17	3	10	Steel	1/4"	884
Air Monitoring Equipment	2	52	17	3	10	Steel	1/4"	1768

1) Single full UF6 cylinder.
2) Single empty UF6 cylinder.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (compressors, air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (autoclaves, HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 8)	Source	Distance (ft)	Material (Note 9)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving pallet	2	0.25	5250	1	3	Steel	0.053"	2625
Inspect arriving pallet	1	0.25	5250	1	3	Steel	0.053"	1312.5
Transfer undamaged pallet to warehouse storage	2	0.25	5239	1	6	Steel	0.053"	2619.5
Transfer damaged pallet to repackaging area (7)	2	2	11	1	6	Steel	0.053"	44
Unload failed drum pallet	2	0.25	71	1	3	Steel	0.053"	35.5
Transfer failed drum to repackaging area	2	0.25	142	2	6	Steel	0.053"	71
Repackage damaged/failed drum contents	2	0.5	142	2	1	Steel	0.053"	142
Transfer repackaged drum to warehouse storage	2	0.25	142	2	6	Steel	0.053"	71
Decontaminate used drum	2	0.1	142	3	1	Steel	0.053"	28.4
Transfer new drums into repackaging area	2	0.25	142	2,3	15	Steel	0.053"	71
Transfer pallet from warehouse storage to loading bay	2	0.25	5310	1	6	Steel	0.053"	2655
Load pallet on truck	2	0.25	5310	1	3	Steel	0.053"	2655
Transfer pallet to storage building	1	0.25	1328	4	6	Steel	0.053"	332
Warehouse Storage Surveillance	1	1	520	5	3	Steel	0.053"	520
Building Management	2	8	260	5	10	Steel	0.053"	4160
Security	1	2	1095	5	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	6	80	Steel	0.053"	8320
Security	1	2	1095	6	80	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	6	270	Steel	0.053"	18720
Security	2	8	1095	6	270	Steel	0.053"	17520

STORAGE BUILDINGS - 9 Buildings								
Unload transferred pallet	2	0.25	5310	1	3	Steel	0.053"	2655
Transfer pallet to storage position	1	0.25	5310	6	6	Steel	0.053"	1327.5
Unload pallet into position	2	0.25	5310	6	3	Steel	0.053"	2655
Load failed drum pallet from storage position (7)	2	2	4	6	3	Steel	0.053"	16
Transfer failed pallet to bay	1	0.25	4	6	6	Steel	0.053"	1
Load failed pallet onto truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed pallet to warehouse	1	0.25	4	1	6	Steel	0.053"	1
Monitor HEPA filtration/air monitor	1	1	260	6	10	Steel	0.053"	260
Storage area/container integrity surveillance	9	8	260	6	3	Steel	0.053"	18720
Building Management	1	8	260	6	10	Steel	0.053"	2080
Security	1	2	1095	6	15	Steel	0.053"	2190

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Single empty UO2 drum.
4) Four pallets (16 UO2 drums).
5) Up to 729 UO2 drum pallets in receiving warehouse.
6) Cumulative inventory of a storage building.
7) Includes handling of damaged/failed drum.
8) 21,000 drums received per year (420,000 drums received over 20 years).
   5,250 UO2 drum pallets (21,000 UO2 drums/4 drums per pallet).
   21 damaged UO2 drums are received per year (0.1% failure rate/year).
   1,764* failed UO2 drums per year (0.8% failure rate sum averaged over 20 years).
   7,014* received and repackaged drum pallets per year.
   1,754* on-site transfers per year (7,014 pallets/4 pallets per transfer).
   * does not account for 20 year maintenance life of facility which would average 3,360 failures per year.
   365 days per year x 3 shifts per day = 1095 per year.
9) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	80	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	270	Steel	0.053"	1040
STORAGE BUILDING — 9 Buildings								
HVAC	2	520	9	3	10	Steel	0.053"	9360
HEPA	2	26	9	3	10	Steel	0.053"	468
Air Monitoring Equipment	2	52	9	3	10	Steel	0.053"	936

1) Up to 729 UO2 drum pallets in receiving warehouse.
2) Single UO2 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed drum pallet	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed drum to repackaging area	2	0.25	4	2	6	Steel	0.053"	2
Repackage damaged/failed drum contents	2	0.5	8	2	1	Steel	0.053"	8
Transfer repackaged drum to warehouse storage	2	0.25	8	2	6	Steel	0.053"	4
Decontaminate used drum	2	0.1	8	3	1	Steel	0.053"	1.6
Transfer new drums into repackaging area	2	0.25	8	2,3	15	Steel	0.053"	4
Transfer pallet from warehouse storage to loading bay	2	0.25	4	1	6	Steel	0.053"	2
Load pallet on truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer pallet to storage building	1	0.25	4	4	6	Steel	0.053"	1
Building Management	1	8	260	4	10	Steel	0.053"	2080
Security	1	2	1095	4	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	5	80	Steel	0.053"	8320
Security	1	2	1095	5	80	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	5	270	Steel	0.053"	18720
Security	2	8	1095	5	270	Steel	0.053"	17520

STORAGE BUILDINGS - 9 Buildings								
Unload transferred pallet	2	0.25	4	1	3	Steel	0.053"	2
Transfer pallet to storage position	1	0.25	4	5	6	Steel	0.053"	1
Unload pallet into position	2	0.25	4	5	3	Steel	0.053"	2
Load failed drum pallet from storage position (7)	2	2	4	5	3	Steel	0.053"	16
Transfer failed pallet to bay	1	0.25	4	5	6	Steel	0.053"	1
Load failed pallet onto truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed pallet to warehouse	1	0.25	4	1	6	Steel	0.053"	1
Monitor HEPA filtration/air monitor	1	1	260	5	10	Steel	0.053"	260
Storage area/container integrity surveillance	9	8	260	5	3	Steel	0.053"	18720
Building Management	1	8	260	5	10	Steel	0.053"	2080
Security	1	2	1095	5	15	Steel	0.053"	2190

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Single empty UO2 drum.
4) Four pallets (16 UO2 drums).
5) Cumulative inventory of a storage building.
6) Includes handling of failed drum.
7) 420,000 drums in storage.
   3,360 failed UO2 drums per year (0.8% failure rate year).
   840 on-site transfers per year (4 pallets/1 pallets per transfer).
   365 days per year x 3 shifts per day = 1,095 per year.
8) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	80	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	270	Steel	0.053"	1040
STORAGE BUILDING — 9 Buildings								
HVAC	2	520	9	3	10	Steel	0.053"	9360
HEPA	2	26	9	3	10	Steel	0.053"	468
Air Monitoring Equipment	2	52	9	3	10	Steel	0.053"	936

1) Up to four pallets (16 UO2 drums).
2) Single UO2 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 8)	Source	Distance (ft)	Material (Note 9)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving pallet	2	0.25	8921	1	3	Steel	0.053"	4460.5
Inspect arriving pallet	1	0.25	8921	1	3	Steel	0.053"	2230.25
Transfer undamaged pallet to warehouse storage	2	0.25	8910	1	6	Steel	0.053"	4455
Transfer damaged pallet to repackaging area (7)	2	2	18	1	6	Steel	0.053"	72
Unload failed drum pallet	2	0.25	121	1	3	Steel	0.053"	60.5
Transfer failed drum to repackaging area	2	0.25	242	2	6	Steel	0.053"	121
Repackage damaged/failed drum contents	2	0.5	242	2	1	Steel	0.053"	242
Transfer repackaged drum to warehouse storage	2	0.25	242	2	6	Steel	0.053"	121
Decontaminate used drum	2	0.1	242	3	1	Steel	0.053"	48.4
Transfer new drums into repackaging area	2	0.25	242	2,3	15	Steel	0.053"	121
Transfer pallet from warehouse to loading bay	2	0.25	9031	1	6	Steel	0.053"	4515.5
Load pallet on truck	2	0.25	9031	1	3	Steel	0.053"	4515.5
Transfer pallet to storage building	1	0.25	2258	4	6	Steel	0.053"	564.5
Warehouse Storage Surveillance	1	1	520	5	3	Steel	0.053"	520
Building Management	2	8	260	5	10	Steel	0.053"	4160
Security	1	2	1095	5	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	6	75	Steel	0.053"	8320
Security	1	2	1095	6	75	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	6	150	Steel	0.053"	18720
Security	2	8	1095	6	150	Steel	0.053"	17520

STORAGE BUILDINGS - 20 Buildings								
Unload transferred pallet	2	0.25	9031	1	3	Steel	0.053"	4515.5
Transfer pallet to storage position	1	0.25	9031	6	6	Steel	0.053"	2257.75
Unload pallet into position	2	0.25	9031	6	3	Steel	0.053"	4515.5
Load failed drum pallet from storage position (7)	2	2	6	6	3	Steel	0.053"	24
Transfer failed pallet to bay	1	0.25	6	6	6	Steel	0.053"	1.5
Load failed pallet onto truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed pallet to warehouse	1	0.25	6	1	6	Steel	0.053"	1.5
Monitor HEPA filtration/air monitor	1	1	260	6	10	Steel	0.053"	260
Storage area/container integrity surveillance	10	8	260	6	3	Steel	0.053"	20800
Building Management	1	8	260	6	10	Steel	0.053"	2080
Security	1	2	1095	6	15	Steel	0.053"	2190

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Single empty U3O8 drum.
4) Seven pallets (23 U3O8 drums).
5) Up to 625 U3O8 drum pallets in receiving warehouse.
6) Cumulative inventory of a storage building.
7) Includes handling of damaged/failed drum.
8) 35,683 drums received per year (713,660 drums received over 20 years).
   8,921 U3O8 drum pallets (35,683 U3O8 drums/4 drums per pallet).
   36 damaged U3O8 drums are received per year (0.1% failure rate/year).
   3,000* failed U3O8 drums per year (0.8% failure rate sum averaged over 20 years).
   11,921* received and repackaged drum pallets per year.
   1,703* on-site transfers per year (11,921 pallets/7 pallets per transfer).
   *does not account for 20 year maintenance life of facility which would average 5,710 failures per year.
   38, 683 received and repackaged drums per year.
   365 days per year x 3 shifts per day = 1095 per year.
9) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	75	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	150	Steel	0.053"	1040
STORAGE BUILDING — 20 Buildings								
HVAC	2	520	20	3	10	Steel	0.053"	20800
HEPA	2	26	20	3	10	Steel	0.053"	1040
Air Monitoring Equipment	2	52	20	3	10	Steel	0.053"	2080

1) Up to 625 U3O8 drum pallets in receiving warehouse.
2) Single U3O8 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed drum pallet	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed drum to repackaging area	2	0.25	6	2	6	Steel	0.053"	3
Repackage damaged/failed drum contents	2	0.5	12	2	1	Steel	0.053"	12
Transfer repackaged drum to warehouse storage	2	0.25	12	2	6	Steel	0.053"	6
Decontaminate used drum	2	0.1	12	3	1	Steel	0.053"	2.4
Transfer new drums into repackaging area	2	0.25	12	2,3	15	Steel	0.053"	6
Transfer pallet from warehouse storage to loading bay	2	0.25	6	1	6	Steel	0.053"	3
Load pallet on truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer pallet to storage building	1	0.25	6	4	6	Steel	0.053"	1.5
Building Management	1	8	260	4	10	Steel	0.053"	2080
Security	1	2	1095	4	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	5	75	Steel	0.053"	8320
Security	1	2	1095	5	75	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	5	150	Steel	0.053"	18720
Security	2	8	1095	5	150	Steel	0.053"	17520

STORAGE BUILDINGS - 20 Buildings								
Unload transferred pallet	2	0.25	6	1	3	Steel	0.053"	3
Transfer pallet to storage position	1	0.25	6	5	6	Steel	0.053"	1.5
Unload pallet into position	2	0.25	6	5	3	Steel	0.053"	3
Load failed drum pallet from storage position (6)	2	2	6	5	3	Steel	0.053"	24
Transfer failed drum pallet to bay	1	0.25	6	5	6	Steel	0.053"	1.5
Load failed drum pallet onto truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed pallet to warehouse	1	0.25	6	1	6	Steel	0.053"	1.5
Monitor HEPA filtration/air monitor	1	1	260	5	10	Steel	0.053"	260
Storage area/container integrity surveillance	14	8	260	5	3	Steel	0.053"	29120
Building Management	1	8	260	5	10	Steel	0.053"	2080
Security	1	2	1095	5	15	Steel	0.053"	2190

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Single empty U3O8 drum.
4) Four pallets (28 U3O8 drums).
5) Cumulative inventory of a storage building.
6) Includes handling of failed drum.
7) 713,660 drums in storage.
   5,710 failed U3O8 drums per year (0.8% failure rate year).
   816 on-site transfers per year (5,710 pallets/7 pallets per transfer).
   365 days per year x 3 shifts per day = 1,095 per year.
8) Materials do not include walls between operating areas.

BUILDING STORAGE FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	75	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	150	Steel	0.053"	1040
STORAGE BUILDING — 20 Buildings								
HVAC	2	520	20	3	10	Steel	0.053"	20800
HEPA	2	26	20	3	10	Steel	0.053"	1040
Air Monitoring Equipment	2	52	20	3	10	Steel	0.053"	2080

1) Up to seven pallets (28 U3O8 drums).
2) Single U3O8 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 8)	Source	Distance (ft)	Material (Note 9)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving pallet	2	0.25	5250	1	3	Steel	0.053"	2625
Inspect arriving pallet	1	0.25	5250	1	3	Steel	0.053"	1312.5
Transfer undamaged pallet to warehouse storage	2	0.25	5239	1	6	Steel	0.053"	2619.5
Transfer damaged drum pallet to repackaging area (7)	2	2	11	1	6	Steel	0.053"	44
Unload failed drum pallet	2	0.25	71	1	3	Steel	0.053"	35.5
Transfer failed drum to repackaging area	2	0.25	142	2	6	Steel	0.053"	71
Repackage damaged/failed drum contents	2	0.5	142	2	1	Steel	0.053"	142
Transfer repackaged drum to warehouse storage	2	0.25	142	2	6	Steel	0.053"	71
Decontaminate used drum	2	0.1	142	3	1	Steel	0.053"	28.4
Transfer new drums into repackaging area	2	0.25	142	2,3	15	Steel	0.053"	71
Transfer pallet from warehouse storage to loading bay	2	0.25	5310	1	6	Steel	0.053"	2655
Load pallet on truck	2	0.25	5310	1	3	Steel	0.053"	2655
Transfer pallet to storage building	1	0.25	1328	4	6	Steel	0.053"	332
Warehouse Storage Surveillance	1	1	520	5	3	Steel	0.053"	520
Building Management	2	8	260	5	10	Steel	0.053"	4160
Security	1	2	1095	5	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	6	75	Steel	0.053"	8320
Security	1	2	1095	6	75	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	6	250	Steel	0.053"	18720
Security	2	8	1095	6	250	Steel	0.053"	17520

STORAGE VAULT AREA - 35 Vaults								
Unload transferred pallet	2	0.25	5310	1	3	Steel	0.053"	2655
Transfer pallet to storage position	1	0.25	5310	6	6	Steel	0.053"	1327.5
Unload pallet into position	2	0.25	5310	6	3	Steel	0.053"	2655
Load failed drum pallet from storage position (7)	2	2	4	6	3	Steel	0.053"	16
Transfer failed pallet to bay	1	0.25	4	6	6	Steel	0.053"	1
Load failed pallet onto truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed pallet to warehouse	1	0.25	4	1	6	Steel	0.053"	1
Monitor HEPA filtration/air monitor	1	1	260	6	10	Steel	0.053"	260
Storage area/container integrity surveillance	9	8	260	6	3	Steel	0.053"	18720
Building Management	1	8	260	6	10	Steel	0.053"	2080
Security	1	2	1095	6	15	Steel	0.053"	2190

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Single empty UO2 drum.
4) Four pallets (16 UO2 drums).
5) Up to 729 UO2 drum pallets in receiving warehouse.
6) Cumulative inventory of a storage building.
7) Includes handling of damaged/failed drum.
8) 21,000 drums received per year (420,000 drums received over 20 years).
   5,250 UO2 drum pallets (21,000 UO2 drums/4 drums per pallet).
   21 damaged UO2 drums are received per year (0.1% failure rate/year).
   1,764* failed UO2 drums per year (0.8% failure rate sum averaged over 20 years).
   7,014* received and repackaged drum pallets per year.
   1,754* on-site transfers per year (7,014 pallets/4 pallets per transfer).
   * does not account for 20 year maintenance life of facility which would average 3,360 failures per year.
   365 days per year x 3 shifts per day = 1,095 per year.
9) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	75	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	250	Steel	0.053"	1040
STORAGE VAULT AREA — 35 Vaults								
HVAC	2	260	35	3	10	Steel	0.053"	18200
HEPA	2	13	35	3	10	Steel	0.053"	910
Air Monitoring Equipment	2	26	35	3	10	Steel	0.053"	1820

1) Up to 729 UO2 drum pallets in receiving warehouse.
2) Single UO2 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
   Storage vault area systems are operated 50% of the time.
5) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed drum pallet	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed drum to repackaging area	2	0.25	4	2	6	Steel	0.053"	2
Repackage damaged/failed drum contents	2	0.5	8	2	1	Steel	0.053"	8
Transfer repackaged drum to warehouse storage	2	0.25	8	2	6	Steel	0.053"	4
Decontaminate used drum	2	0.1	8	3	1	Steel	0.053"	1.6
Transfer new drums into repackaging area	2	0.25	8	2,3	15	Steel	0.053"	4
Transfer pallet from warehouse storage to loading bay	2	0.25	4	1	6	Steel	0.053"	2
Load pallet on truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer pallet to storage building	1	0.25	4	4	6	Steel	0.053"	1
Building Management	1	8	260	4	10	Steel	0.053"	2080
Security	1	2	1095	4	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	5	75	Steel	0.053"	8320
Security	1	2	1095	5	75	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	5	250	Steel	0.053"	18720
Security	2	8	1095	5	250	Steel	0.053"	17520

STORAGE VAULT AREA — 35 Vaults								
Unload transferred pallet	2	0.25	4	1	3	Steel	0.053"	2
Transfer pallet to storage position	1	0.25	4	5	6	Steel	0.053"	1
Unload pallet into position	2	0.25	4	5	3	Steel	0.053"	2
Load failed drum pallet from storage position (6)	2	2	4	5	3	Steel	0.053"	16
Transfer failed pallet to bay	1	0.25	4	5	6	Steel	0.053"	1
Load failed pallet onto truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed pallet to warehouse	1	0.25	4	1	6	Steel	0.053"	1
Monitor HEPA filtration/air monitor	1	1	260	5	10	Steel	0.053"	260
Storage area/container integrity surveillance	4	8	260	5	3	Steel	0.053"	8320
Building Management	1	8	260	5	10	Steel	0.053"	2080
Security	1	2	1095	5	15	Steel	0.053"	2190

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Single empty UO2 drum.
4) Four pallets (16 UO2 drums).
5) Cumulative inventory of a storage building.
6) Includes handling of failed drum.
7) 420,000 drums in storage.
   3,360 failed UO2 drums per year (0.8% failure rate year).
   840 on-site transfers per year (3,360 pallets/4 pallets per transfer).
   365 days per year x 3 shifts per day = 1,095 per year.
8) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	75	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	250	Steel	0.053"	1040
STORAGE VAULT AREA — 35 Vaults								
HVAC	2	260	35	3	10	Steel	0.053"	18200
HEPA	2	13	35	3	10	Steel	0.053"	910
Air Monitoring Equipment	2	26	35	3	10	Steel	0.053"	1820

1) Up to four pallets (16 UO2 drums).
2) Single UO2 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
   Storage vault area systems are operated 50% of the time.
5) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 8)	Source	Distance (ft)	Material (Note 9)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving pallet	2	0.25	8921	1	3	Steel	0.053"	4460.5
Inspect arriving pallet	1	0.25	8921	1	3	Steel	0.053"	2230.25
Transfer undamaged pallet to warehouse storage	2	0.25	8910	1	6	Steel	0.053"	4455
Transfer damaged pallet to repackaging area (7)	2	2	18	1	6	Steel	0.053"	72
Unload failed drum pallet	2	0.25	121	1	3	Steel	0.053"	60.5
Transfer failed drum to repackaging area	2	0.25	242	2	6	Steel	0.053"	121
Repackage damaged/failed drum contents	2	0.5	242	2	1	Steel	0.053"	242
Transfer repackaged drum to warehouse storage	2	0.25	242	2	6	Steel	0.053"	121
Decontaminate used drum	2	0.1	242	3	1	Steel	0.053"	48.4
Transfer new drums into repackaging area	2	0.25	242	2,3	15	Steel	0.053"	121
Transfer pallet from warehouse to loading bay	2	0.25	9031	1	6	Steel	0.053"	4515.5
Load pallet on truck	2	0.25	9031	1	3	Steel	0.053"	4515.5
Transfer pallet to storage building	1	0.25	2258	4	6	Steel	0.053"	564.5
Warehouse Storage Surveillance	1	1	520	5	3	Steel	0.053"	520
Building Management	2	8	260	5	10	Steel	0.053"	4160
Security	1	2	1095	5	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	6	220	Steel	0.053"	8320
Security	1	2	1095	6	220	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	6	280	Steel	0.053"	18720
Security	2	8	1095	6	280	Steel	0.053"	17520

STORAGE VAULT AREA - 79 Vaults								
Unload transferred pallet	2	0.25	9031	1	3	Steel	0.053"	4515.5
Transfer pallet to storage position	1	0.25	9031	6	6	Steel	0.053"	2257.75
Unload pallet into position	2	0.25	9031	6	3	Steel	0.053"	4515.5
Load failed drum pallet from storage position (7)	2	2	6	6	3	Steel	0.053"	24
Transfer failed pallet to bay	1	0.25	6	6	6	Steel	0.053"	1.5
Load failed pallet onto truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed pallet to warehouse	1	0.25	6	1	6	Steel	0.053"	1.5
Monitor HEPA filtration/air monitor	1	1	260	6	10	Steel	0.053"	260
Storage area/container integrity surveillance	10	8	260	6	3	Steel	0.053"	20800
Building Management	1	8	260	6	10	Steel	0.053"	2080
Security	1	2	1095	6	15	Steel	0.053"	2190

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Single empty U3O8 drum.
4) Seven pallets (28 U3O8 drums).
5) Up to 625 U3O8 drum pallets in receiving warehouse.
6) Cumulative inventory of a storage vault.
7) Includes handling of damaged/failed drum.
8) 35,683 drums received per year (713,660 drums received over 20 years).
   8,921 U3O8 drum pallets (35,683 U3O8 drums/4 drums per pallet).
   36 damaged U3O8 drums are received per year (0.1% failure rate/year).
   3,000* failed U3O8 drums per year (0.8% failure rate sum averaged over 20 years).
   11,921* received and repackaged drum pallets per year.
   1,703* on-site transfers per year (11,921 pallets/7 pallets per transfer).
   * does not account for 20 year maintenance life of facility which would average 5,710 failures per year.
   38, 683 received and repackaged drums per year.
   365 days per year x 3 shifts per day = 1,095 per year.
9) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	220	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	280	Steel	0.053"	1040
STORAGE VAULT AREA — 79 Vaults								
HVAC	2	130	79	3	10	Steel	0.053"	20540
HEPA	2	6	79	3	10	Steel	0.053"	948
Air Monitoring Equipment	2	13	79	3	10	Steel	0.053"	2054

1) Up to 625 U3O8 drum pallets in receiving warehouse.
2) Single U3O8 drum.
3) Cumulative inventory of a storage building.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
   Storage vault area systems are operated 25% of the time.
5) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed drum pallet	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed drum to repackaging area	2	0.25	6	2	6	Steel	0.053"	3
Repackage damaged/failed drum contents	2	0.5	12	2	1	Steel	0.053"	12
Transfer repackaged drum to warehouse storage	2	0.25	12	2	6	Steel	0.053"	6
Decontaminate used drum	2	0.1	12	3	1	Steel	0.053"	2.4
Transfer new drums into repackaging area	2	0.25	12	2,3	15	Steel	0.053"	6
Transfer pallet from warehouse storage to loading bay	2	0.25	6	1	6	Steel	0.053"	3
Load pallet on truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer pallet to storage building	1	0.25	6	4	6	Steel	0.053"	1.5
Building Management	1	8	260	4	10	Steel	0.053"	2080
Security	1	2	1095	4	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	9	8	260	5	220	Steel	0.053"	18720
Security	1	2	1095	5	220	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	4	8	260	5	280	Steel	0.053"	8320
Security	2	8	1095	5	280	Steel	0.053"	17520

STORAGE VAULT AREA - 79 Vaults								
Unload transferred pallet	2	0.25	6	1	3	Steel	0.053"	3
Transfer pallet to storage position	1	0.25	6	5	6	Steel	0.053"	1.5
Unload pallet into position	2	0.25	6	5	3	Steel	0.053"	3
Load failed drum pallet from storage position (6)	2	2	6	5	3	Steel	0.053"	24
Transfer failed pallet to bay	1	0.25	6	5	6	Steel	0.053"	1.5
Load failed pallet onto truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed pallet to warehouse	1	0.25	6	1	6	Steel	0.053"	1.5
Monitor HEPA filtration/air monitor	1	1	260	5	10	Steel	0.053"	260
Storage area/container integrity surveillance	14	8	260	5	3	Steel	0.053"	29120
Building Management	1	8	260	5	10	Steel	0.053"	2080
Security	1	2	1095	5	15	Steel	0.053"	2190

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Single empty U3O8 drum.
4) Seven pallets (28 U3O8 drums).
5) Cumulative inventory of a storage vault.
6) Includes handling of damaged/failed drums.
7) 713,660 drums in storage.
   5,710 failed U3O8 drums per year (0.8% failure rate/year).
   816 on-site transfers per year (5,710 pallets/7 pallets per transfer).
   365 days per year x 3 shifts per day = 1,095 per year.
8) Materials do not include walls between operating areas.

VAULT STORAGE FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	3	220	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	3	280	Steel	0.053"	1040
STORAGE VAULT AREA - 79 Vaults								
HVAC	2	130	79	3	10	Steel	0.053"	20540
HEPA	2	6	79	3	10	Steel	0.053"	948
Air Monitoring Equipment	2	13	79	3	10	Steel	0.053"	2054

1) Up to seven pallets (28 U3O8 drums).
2) Single U3O8 drum.
3) Cumulative inventory of a storage vault.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
   Storage vault area systmes are operated 25% of the time.
5) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UF6 CYLINDERS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 6)	Source	Distance (ft)	Material (Note 7)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving cylinder	2	0.5	2,322	1	3	Steel	1/4"	2322
Inspect arriving cylinder	1	0.5	2,322	1	3	Steel	1/4"	1161
Transfer undamaged cylinder to warehouse storage	2	0.5	2,319	1	6	Steel	1/4"	2319
Transfer damaged cylinder to repackaging area (4)	2	2	15	1	6	Steel	1/4"	60
Unload failed cylinder	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to repackaging area	2	0.5	1	1	6	Steel	1/4"	1
Load damaged/failed cylinder into autoclave	1	0.5	16	1	3	Steel	1/4"	8
Autoclave pressure test	2	1	16	1	15	Steel	1/4"+ 1/4"	32
Unload autoclave	1	0.5	16	1	3	Steel	1/4"	8
Transfer repackaged cylinder to warehouse storage	2	0.5	16	1	6	Steel	1/4"	16
Transfer damaged/failed empty cylinder to wash bldg	2	0.5	16	2	6	Steel	1/4"	16
Transfer new cylinders into repackaging area	2	0.5	16	1,2	15	Steel	1/4"+ 1/4"	16
Transfer cylinder from warehouse storage to loading bay	2	0.5	2,335	1	6	Steel	1/4"	2335
Load cylinder on truck	2	0.5	2,335	1	3	Steel	1/4"	2335
Transfer cylinder to storage building	1	0.5	1168	1	6	Steel	1/4"	584
Warehouse Storage Surveillance	1	1	520	3	3	Steel	1/4"	520
Autoclave Surveillance	1	0.25	260	1,2	3	Steel	1/4"	65
Building Management	2	8	260	3	10	Steel	1/4"	4160
Security	1	2	1095	3	15	Steel	1/4"	2190
CYLINDER WASHING BUILDING								
Unload damaged/failed cylinder	2	0.5	16	2	3	Steel	1/4"	16
Load cylinder into wash area	2	0.5	16	2	3	Steel	1/4"	16
Remove clean cylinder from wash area	2	0.5	16	2	10	Steel	1/4"	16
Building Operations	4	8	260	2	3	Steel	1/4"	8320
Security	1	2	1095	2	40	Steel	1/4"	2190

WORKSHOP								
Building Operations	8	8	260	3	200	Steel	1/4"	16640
Security	1	2	1095	3	200	Steel	1/4"	2190
ADMINISTRATION BUILDING								
Building Operations	14	8	260	3	600	Steel	1/4"	29120
Security	2	8	1095	3	600	Steel	1/4"	17520
MINED CAVITY STORAGE AREA								
Unload transferred cylinder at mine shaft	2	0.5	2,335	1	3	Steel	1/4"	2335
Transfer cylinder to mined cavity	1	0.25	2,335	1	6	Steel	1/4"	583.75
Transfer cylinder to storage position	1	0.5	2,335	1	6	Steel	1/4"	1167.5
Unload cylinder into position	2	0.5	2,335	5	6	Steel	1/4"	2335
Return to surface	1	0.75	2,335	5	6	Steel	1/4"	1751.25
Load failed cylinder from storage position (4)	2	2	1	5	6	Steel	1/4"	4
Transfer failed cylinder to mine shaft	1	0.5	1	1	6	Steel	1/4"	0.5
Transfer failed cylinder to surface	1	0.25	1	1	6	Steel	1/4"	0.25
Load failed cylinder onto truck	1	0.5	1	1	3	Steel	1/4"	0.5
Transfer failed cylinder to warehouse	1	0.5	1	1	6	Steel	1/4"	0.5
Monitor HEPA filtration/air monitor	2	2	260	3	400	Steel	1/4"	1040
Storage area/container integrity surveillance	8	8	260	5	3	Steel	1/4"	16640
Building Management	1	8	260	5	10	Steel	1/4"	2080
Security	1	2	1095	5	15	Steel	1/4"	2190

1) Single full UF6 cylinder.
2) Single empty UF6 cylinder.
3) Up to 275 full UF6 cylinders in receiving warehouse.
4) Includes handling of damaged/failed cylinder.
5) Cumulative inventory of a single mine drift.
6) 2,322 cylinders received per year (46,422 cylinders received over 20 years).
   2 damaged full UF6 cylinders are received per year (0.1% failure rate/year).
   120* failed UF6 cylinders per year (0.5% failure rate sum averaged over 20 years).
   2,442* received and repackaged cylinders per year.
   1,221* on-site transfers per year (2,442 cylinders/2 cylinders per transfer).
   *does not account for 20 year maintenance life of facility which would average 232 failures per year.
   365 days per year x 3 shifts per day = 1,095 per year.
7) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UF6 CYLINDERS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 5)	Number of Components	Source	Distance (ft)	Material (Note 6)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	1/4"	208
Autoclave	2	26	1	2,3	3	Steel	1/4"+ 1/4"	52
Autoclave compressor	2	52	1	2,3	3	Steel	1/4"+ 1/4"	104
Air lock system (2 per building)	2	52	2	1	20	Steel	1/4"	208
HVAC	2	520	1	1	10	Steel	1/4"	1040
HEPA	2	26	1	1	10	Steel	1/4"	52
CYLINDER WASHING FACILITY								
Rinse equipment	2	104	2	3	1	Steel	1/4"	416
Evaporating System	2	104	2	3	3	Steel	1/4"	416
U3O8 Conversion Equipment	2	104	2	3	1	Steel	1/4"	416
HVAC	2	520	1	3	20	Steel	1/4"	1040
WORKSHOP								
HVAC	2	520	1	1	200	Steel	1/4"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	600	Steel	1/4"	1040
MINED CAVITY STORAGE AREA								
Humidity Control System	2	104	4	1	400	Steel	1/4"	832
HVAC	2	520	4	1	400	Steel	1/4"	4160
HEPA	2	26	4	1	400	Steel	1/4"	208
Air Monitoring Equipment	2	52	4	1	400	Steel	1/4"	416
Mine Elevator Equipment	2	104	2	1	20	Steel	1/4"	416
Emergency Power System	2	52	1	4	20	Steel	1/4"	104

1) Up to 275 full UF6 cylinders in receiving warehouse.
2) Single full UF6 cylinder.
3) Single empty UF6 cylinder.
4) Cumulative inventory of a single mine drift.
5) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (compressors, air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (autoclaves, HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
6) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UF6 CYLINDERS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 5)	Source	Distance (ft)	Material (Note 6)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed cylinder	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to repackaging area	2	0.5	1	1	6	Steel	1/4"	1
Load failed cylinder into autoclave	1	0.5	1	1	3	Steel	1/4"	0.5
Autoclave pressure test	2	1	1	1	15	Steel	1/4" + 1/4	2
Unload autoclave	1	0.5	1	1	3	Steel	1/4"	0.5
Transfer repackaged cylinder to warehouse storage	2	0.5	1	1	6	Steel	1/4"	1
Transfer failed empty cylinder to wash bldg	2	0.5	1	2	6	Steel	1/4"	1
Transfer new cylinders into repackaging area	2	0.5	1	1,2	15	Steel	1/4" + 1/4	1
Transfer cylinder from warehouse storage to loading bay	2	0.5	1	1	6	Steel	1/4"	1
Load cylinder on truck	2	0.5	1	1	3	Steel	1/4"	1
Transfer cylinder to storae building	1	0.5	1	1	6	Steel	1/4"	0.5
Autoclave Surveillance	1	0.25	260	1,2	3	Steel	1/4"	65
Building Management	2	8	260	1	10	Steel	1/4"	4160
Security	1	2	1095	1	15	Steel	1/4"	2190
CYLINDER WASHING FACILITY								
Unload failed cylinder	2	0.5	1	2	3	Steel	1/4"	1
Load cylinder into wash area	2	0.5	1	2	3	Steel	1/4"	1
Remove clean cylinder from wash area	2	0.5	1	2	10	Steel	1/4"	1
Building Operations	4	8	260	2	3	Steel	1/4"	8320
Security	1	2	1095	2	40	Steel	1/4"	2190

WORKSHOP								
Building Operations	4	8	260	1	200	Steel	1/4"	8320
Security	1	2	1095	1	200	Steel	1/4"	2190
						Steel	1/4"	0
ADMINISTRATION BUILDING								
Building Operations	9	8	260	1	600	Steel	1/4"	18720
Security	2	8	1095	1	600	Steel	1/4"	17520
MINED CAVITY STORAGE AREA								
Unload transferred cylinder at mine shaft	2	0.5	1	1	3	Steel	1/4"	1
Transfer cylinder to mined cavity	1	0.25	1	1	6	Steel	1/4"	0.25
Transfer cylinder to storage position	1	0.5	1	1	6	Steel	1/4"	0.5
Unload cylinder into position	2	0.5	1	3	6	Steel	1/4"	1
Return to surface	1	0.75	1	3	6	Steel	1/4"	0.75
Load failed cylinder from storage position (4)	2	2	1	3	6	Steel	1/4"	4
Transfer failed cylinder to mine shaft	1	0.5	1	1	6	Steel	1/4"	0.5
Transfer failed cylinder to surface	1	0.25	1	1	6	Steel	1/4"	0.25
Load failed cylinder onto truck	2	0.5	1	1	3	Steel	1/4"	1
Transfer failed cylinder to warehouse	1	0.5	1	1	6	Steel	1/4"	0.5
Monitor HEPA filtration/air monitor	2	2	260	1	40	Steel	1/4"	1040
Storage area/container integrity surveillance	8	8	260	3	3	Steel	1/4"	16640
Storage Management	1	8	260	3	10	Steel	1/4"	2080
Security	1	2	1095	3	15	Steel	1/4"	2190

1) Single full UF6 cylinder.
2) Single empty UF6 cylinder.
3) Cumulative inventory of a storage building.
4) Includes handling of failed cylinder.
5) 46,422 cylinders in storage.
   232 failed UF6 cylinders per year (0.5% failure rate/year).
   365 days per year x 3 shifts per day = 1,095 per year.
6) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UF6 CYLINDERS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	1/4"	208
Autoclave	2	26	1	1,2	3	Steel	1/4"+ 1/4"	52
Autoclave compressor	2	52	1	1,2	3	Steel	1/4"+ 1/4"	104
Air lock system (2 per building)	2	52	2	1	20	Steel	1/4"	208
HVAC	2	520	1	1	10	Steel	1/4"	1040
HEPA	2	26	1	1	10	Steel	1/4"	52
CYLINDER WASHING FACILITY								
Rinse equipment	2	104	2	2	1	Steel	1/4"	416
Evaporating System	2	104	2	2	3	Steel	1/4"	416
U3O8 Conversion Equipment	2	104	2	2	1	Steel	1/4"	416
HVAC	2	520	1	2	20	Steel	1/4"	1040
WORKSHOP								
HVAC	2	520	1	1	200	Steel	1/4"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	600	Steel	1/4"	1040
MINED CAVITY STORAGE AREA								
Humidity Control System	2	104	4	1	400	Steel	1/4"	832
HVAC	2	520	4	1	400	Steel	1/4"	4160
HEPA	2	26	4	1	400	Steel	1/4"	208
Air Monitoring Equipment	2	52	4	1	400	Steel	1/4"	416
Mine Elevator Equipment	2	104	2	1	20	Steel	1/4"	416
Emergency Power System	2	52	1	3	20	Steel	1/4"	104

1) Single full UF6 cylinder.
2) Single empty UF6 cylinder.
3) Cumulative inventory of a single mine drift.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (compressors, air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (autoclaves, HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 8)	Source	Distance (ft)	Material (Note 9)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving pallet	2	0.25	5250	1	3	Steel	0.053"	2625
Inspect arriving pallet	1	0.25	5250	1	3	Steel	0.053"	1312.5
Transfer undamaged pallet to warehouse storage	2	0.25	5239	1	6	Steel	0.053"	2619.5
Transfer damaged pallet to repackaging area (7)	2	2	11	1	6	Steel	0.053"	44
Unload failed drum pallet	2	0.25	71	1	3	Steel	0.053"	35.5
Transfer failed drum to repackaging area	2	0.25	142	2	6	Steel	0.053"	71
Repackage damaged/failed drum contents	2	0.5	142	2	1	Steel	0.053"	142
Transfer repackaged drum to warehouse storage	2	0.25	142	2	6	Steel	0.053"	71
Decontaminate used drum	2	0.1	142	3	1	Steel	0.053"	28.4
Transfer new drums into repackaging area	2	0.25	142	2,3	15	Steel	0.053"	71
Transfer pallet from warehouse storage to loading bay	2	0.25	5310	1	6	Steel	0.053"	2655
Load pallet on truck	2	0.25	5310	1	3	Steel	0.053"	2655
Transfer pallet to mine shaft	1	0.25	1328	4	6	Steel	0.053"	332
Warehouse Storage Surveillance	1	1	520	5	3	Steel	0.053"	520
Building Management	2	8	260	5	10	Steel	0.053"	4160
Security	1	2	1095	5	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	8	8	260	5	250	Steel	0.053"	16640
Security	1	2	1095	5	250	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	5	640	Steel	0.053"	24960
Security	2	8	1095	5	640	Steel	0.053"	17520

MINED-CAVITY STORAGE AREA								
Unload transferred pallet at mine shaft	2	0.25	5310	1	3	Steel	0.053"	2655
Transfer pallet to mined cavity	1	0.25	5310	4	6	Steel	0.053"	1327.5
Transfer pallet to storage position	1	0.5	5310	6	6	Steel	0.053"	2655
Unload pallet into position	2	0.25	5310	6	3	Steel	0.053"	2655
Return to surface	1	0.5	5310	6	6	Steel	0.053"	2655
Load failed drum pallet from storage position (7)	2	2	4	6	3	Steel	0.053"	16
Transfer failed drum pallet to mine shaft	1	0.5	4	6	6	Steel	0.053"	2
Transfer failed pallet to surface	1	0.25	4	1	6	Steel	0.053"	1
Load failed pallet onto truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed pallet to warehouse	1	0.25	4	1	6	Steel	0.053"	1
Monitor HEPA filtration/air monitor	2	2	260	5	460	Steel	0.053"	1040
Storage area/container integrity surveillance	9	8	260	6	3	Steel	0.053"	18720
Storage Management	1	8	260	6	10	Steel	0.053"	2080
Security	1	2	1095	6	15	Steel	0.053"	2190

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Single empty UO2 drum.
4) Four pallets (16 UO2 drums).
5) Up to 729 UO2 drum pallets in receiving warehouse.
6) Cumulative inventory of a single mine drift.
7) Includes handling of damaged/failed drum.
8) 21,000 drums received per year (420,000 drums received over 20 years).
 5,250 UO2 drum pallets (21,000 UO2 drums/4 drums per pallet).
 21 damaged UO2 drums are received per year (0.1% failure rate/year).
 1,764* failed UO2 drums per year (0.8% failure rate sum averaged over 20 years).
 7,014* received and repackaged drum pallets per year.
 1,754* on-site transfers per year (7,014 pallets/4 pallets per transfer).
 * does not account for 20 year maintenance life of facility which would average 3,360 failures per year.
 365 days per year x 3 shifts per day = 1,095 per year.
9) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	1	250	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	640	Steel	0.053"	1040
MINED-CAVITY STORAGE AREA								
HVAC	2	520	4	1	460	Steel	0.053"	4160
HEPA	2	26	4	1	460	Steel	0.053"	208
Air Monitoring Equipment	2	52	4	1	460	Steel	0.053"	416
Mine Elevator Equipment	2	104	2	1	20	Steel	0.053"	416
Emergency Power System	2	52	1	3	20	Steel	0.053"	104

1) Up to 729 UO2 drum pallets in receiving warehouse.
2) Single UO2 drum.
3) Cumulative inventory of a single mine drift.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed drum pallet	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed drum to repackaging area	2	0.25	4	2	6	Steel	0.053"	2
Repackage failed drum contents	2	0.5	8	2	1	Steel	0.053"	8
Transfer repackaged drum to warehouse storage	2	0.25	8	2	6	Steel	0.053"	4
Decontaminate used drum	2	0.1	8	3	1	Steel	0.053"	1.6
Transfer new drums into repackaging area	2	0.25	8	2,3	15	Steel	0.053"	4
Transfer pallet from warehouse storage to loading bay	2	0.25	4	1	6	Steel	0.053"	2
Load pallet on truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer pallet to mine shaft	1	0.25	4	4	6	Steel	0.053"	1
Building Management	1	8	260	4	10	Steel	0.053"	2080
Security	1	2	1095	4	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	4	250	Steel	0.053"	8320
Security	1	2	1095	4	250	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	4	640	Steel	0.053"	18720
Security	2	8	1095	4	640	Steel	0.053"	17520

MINED-CAVITY STORAGE AREA								
Unload transferred pallet at mine shaft	2	0.25	4	1	3	Steel	0.053"	2
Transfer pallet to mined cavity	1	0.25	4	4	6	Steel	0.053"	1
Transfer pallet to storage position	1	0.5	4	5	6	Steel	0.053"	2
Unload pallet into position	2	0.25	4	5	3	Steel	0.053"	2
Return to surface	1	0.5	4	5	6	Steel	0.053"	2
Load failed drum pallet from storage position (6)	2	2	4	5	3	Steel	0.053"	16
Transfer failed pallet to mine shaft	1	0.5	4	5	6	Steel	0.053"	2
Transfer failed drum pallet to surface	1	0.25	4	1	6	Steel	0.053"	1
Load failed drum pallet onto truck	2	0.25	4	1	3	Steel	0.053"	2
Transfer failed pallet to warehouse	1	0.25	4	1	6	Steel	0.053"	1
Monitor HEPA filtration/air monitor	2	2	260	4	460	Steel	0.053"	1040
Storage area/container integrity surveillance	6	8	260	5	3	Steel	0.053"	12480
Building Management	1	8	260	5	10	Steel	0.053"	2080
Security	1	2	1095	5	15	Steel	0.053"	2190

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Single empty UO2 drum.
4) Four pallets (16 UO2 drums).
5) Cumulative inventory of a single mine drift.
6) Includes handling of failed drum.
7) 420,000 drums in storage.
   3,360 failed UO2 drums per year (0.8% failure rate year).
   840 on-site transfers per year (3,360 pallets/4 pallets per transfer).
   365 days per year x 3 shifts per day = 1,095 per year.
8) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	1	250	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	640	Steel	0.053"	1040
MINED-CAVITY STORAGE AREA								
HVAC	2	520	4	1	460	Steel	0.053"	4160
HEPA	2	26	4	1	460	Steel	0.053"	208
Air Monitoring Equipment	2	52	4	1	460	Steel	0.053"	416
Mine Elevator Equipment	2	104	2	1	20	Steel	0.053"	416
Emergency Power System	2	52	1	3	20	Steel	0.053"	104

1) Up to four pallets (16 UO2 drums).
2) Single UO2 drum.
3) Cumulative inventory of a single mine drift.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES - PHASE I

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 8)	Source	Distance (ft)	Material (Note 9)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload arriving pallet	2	0.25	8921	1	3	Steel	0.053"	4460.5
Inspect arriving pallet	1	0.25	8921	1	3	Steel	0.053"	2230.25
Transfer undamaged pallet to warehouse storage	2	0.25	8910	1	6	Steel	0.053"	4455
Transfer damaged pallet to repackaging area (7)	2	2	18	1	6	Steel	0.053"	72
Unload failed drum pallet	2	0.25	121	1	3	Steel	0.053"	60.5
Transfer failed drum to repackaging area	2	0.25	242	2	6	Steel	0.053"	121
Repackage damaged/failed drum contents	2	0.5	242	2	1	Steel	0.053"	242
Transfer repackaged drum to warehouse storage	2	0.25	242	2	6	Steel	0.053"	121
Decontaminate used drum	2	0.1	242	3	1	Steel	0.053"	48.4
Transfer new drums into repackaging area	2	0.25	242	2,3	15	Steel	0.053"	121
Transfer pallet from warehouse storage to loading bay	2	0.25	9031	1	6	Steel	0.053"	4515.5
Load pallet on truck	2	0.25	9031	1	3	Steel	0.053"	4515.5
Transfer pallet to mine shaft	1	0.25	2258	4	6	Steel	0.053"	564.5
Warehouse Storage Surveillance	1	1	520	5	3	Steel	0.053"	520
Building Management	2	8	260	5	10	Steel	0.053"	4160
Security	1	2	1095	5	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	8	8	260	5	250	Steel	0.053"	16640
Security	1	2	1095	5	250	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	5	900	Steel	0.053"	24960
Security	2	8	1095	5	900	Steel	0.053"	17520

MINED-CAVITY STORAGE AREA								
Unload transferred pallet at mine shaft	2	0.25	9031	1	3	Steel	0.053"	4515.5
Transfer pallet to mined cavity	1	0.25	9031	4	6	Steel	0.053"	2257.75
Transfer pallet to storage position	1	0.5	9031	6	6	Steel	0.053"	4515.5
Unload pallet into position	2	0.25	9031	6	3	Steel	0.053"	4515.5
Return to surface	1	0.5	9031	6	6	Steel	0.053"	4515.5
Load failed drum pallet from storage position (7)	2	2	6	6	3	Steel	0.053"	24
Transfer failed pallet to mine shaft	1	0.5	6	6	6	Steel	0.053"	3
Transfer failed drum pallet to surface	1	0.25	6	1	6	Steel	0.053"	1.5
Load failed drum pallet onto truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed pallet to warehouse	1	0.25	6	1	6	Steel	0.053"	1.5
Monitor HEPA filtration/air monitor	2	2	260	5	450	Steel	0.053"	1040
Storage area/container integrity surveillance	12	8	260	6	3	Steel	0.053"	24960
Storage Management	1	8	260	6	10	Steel	0.053"	2080
Security	1	2	1095	6	15	Steel	0.053"	2190

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Single empty U3O8 drum.
4) Seven pallets (28 U3O8 drums).
5) Up to 625 U3O8 drum pallets in receiving warehouse.
6) Cumulative inventory of a single mine drift.
7) Includes handling of damaged/failed drum.
8) 35,683 drums received per year (713,660 drums received over 20 years).
   8,921 U3O8 drum pallets (35,683 U3O8 drums/4 drums per pallet).
   36 damaged U3O8 drums are received per year (0.1% failure rate/year).
   3,000* failed U3O8 drums per year (0.8% failure rate sum averaged over 20 years).
   11,921* received and repackaged drum pallets per year.
   1,703* on-site transfers per year (11,921 pallets/7 pallets per transfer).
   * does not account for 20 year maintenance life of facility which would average 5,710 failures per year.
   38, 683 received and repackaged drums per year.
   365 days per year x 3 shifts per day = 1,095 per year.
9) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES - PHASE I

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	1	250	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	900	Steel	0.053"	1040
MINED-CAVITY STORAGE AREA								
HVAC	2	520	4	1	450	Steel	0.053"	4160
HEPA	2	26	4	1	450	Steel	0.053"	208
Air Monitoring Equipment	2	52	4	1	450	Steel	0.053"	416
Mine Elevator Equipment	2	104	2	1	20	Steel	0.053"	416
Emergency Power System	2	52	1	3	20	Steel	0.053"	104

1) Up to 625 U3O8 drum pallets in receiving warehouse.
2) Single U3O8 drum.
3) Cumulative inventory of a single mine drift.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
   Storage vault area systems are operated 25% of the time.
5) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES - PHASE II

Activity	Number of Workers per station	Time per Operation (hr)	Operations Per Year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Unload failed drum pallet	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed drum to repackaging area	2	0.25	6	2	6	Steel	0.053"	3
Repackage failed drum contents	2	0.5	12	2	1	Steel	0.053"	12
Transfer repackaged drum to warehouse storage	2	0.25	12	2	6	Steel	0.053"	6
Decontaminate used drum	2	0.1	12	3	1	Steel	0.053"	2.4
Transfer new drums into repackaging area	2	0.25	12	2,3	15	Steel	0.053"	6
Transfer pallet from warehouse to loading bay	2	0.25	6	1	6	Steel	0.053"	3
Load pallet on truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer pallet to mine shaft	1	0.25	6	4	6	Steel	0.053"	1.5
Building Management	1	8	260	4	10	Steel	0.053"	2080
Security	1	2	1095	4	15	Steel	0.053"	2190
WORKSHOP								
Building Operations	4	8	260	4	250	Steel	0.053"	8320
Security	1	2	1095	4	250	Steel	0.053"	2190
ADMINISTRATION BUILDING								
Building Operations	9	8	260	4	900	Steel	0.053"	18720
Security	2	8	1095	4	900	Steel	0.053"	17520

MINED-CAVITY STORAGE AREA								
Unload transferred pallet at mine shaft	2	0.25	6	1	3	Steel	0.053"	3
Transfer pallets to mined cavity	1	0.25	6	4	6	Steel	0.053"	1.5
Transfer pallet to storage position	1	0.5	6	5	6	Steel	0.053"	3
Unload pallet into position	2	0.25	6	5	3	Steel	0.053"	3
Return to surface	1	0.5	6	5	6	Steel	0.053"	3
Load failed drum pallet from storage position (6)	2	2	6	5	3	Steel	0.053"	24
Transfer failed pallet to mine shaft	1	0.5	6	5	6	Steel	0.053"	3
Transfer failed drum pallet to surface	1	0.25	6	1	6	Steel	0.053"	1.5
Load failed drum pallet onto truck	2	0.25	6	1	3	Steel	0.053"	3
Transfer failed pallet to warehouse	1	0.25	6	1	6	Steel	0.053"	1.5
Monitor HEPA filtration/air monitor	2	2	260	4	450	Steel	0.053"	1040
Storage area/container integrity surveillance	14	8	260	5	3	Steel	0.053"	29120
Storage Management	1	8	260	5	10	Steel	0.053"	2080
Security	1	2	1095	5	15	Steel	0.053"	2190

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Single empty U3O8 drum.
4) Seven pallets (28 U3O8 drums).
5) Cumulative inventory of a single mine drift.
6) Includes handling of damaged/failed drums.
7) 713,660 drums in storage.
   5,710 failed U3O8 drums per year (0.8% failure rate/year).
   816 on-site transfers per year (5,710 pallets/7 pallets per transfer).
   365 days per year x 3 shifts per day = 1,095 per year.
8) Materials do not include walls between operating areas.

MINED-CAVITY FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES - PHASE II

Equipment	Number of Workers per station	Hours per Component per year (Note 4)	Number of Components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING								
Overhead Crane	2	52	2	1	10	Steel	0.053"	208
Electrically Powered Transfer Equipment	2	104	1	2	3	Steel	0.053"	208
Air lock system (2 per building)	2	52	2	1	20	Steel	0.053"	208
HVAC	2	520	1	1	10	Steel	0.053"	1040
HEPA	2	26	1	1	10	Steel	0.053"	52
Generator	2	52	1	1	10	Steel	0.053"	104
UPS	2	26	1	1	10	Steel	0.053"	52
WORKSHOP								
HVAC	2	520	1	1	250	Steel	0.053"	1040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	900	Steel	0.053"	1040
MINED-CAVITY STORAGE AREA								
HVAC	2	520	4	1	450	Steel	0.053"	4160
HEPA	2	26	4	1	450	Steel	0.053"	208
Air Monitoring Equipment	2	52	4	1	450	Steel	0.053"	416
Mine Elevator Equipment	2	104	2	1	20	Steel	0.053"	416
Emergency Power System	2	52	1	3	20	Steel	0.053"	104

1) Up to seven pallets (28 U3O8 drums).
2) Single U3O8 drum.
3) Cumulative inventory of a single mine drift.
4) 2 hours per week (104) for complex systems with multiple active components.
   1 hours per week (52) on active components (air lock systems, cranes) — includes instrumentation.
   1/2 hour per week (26) on passive components (HEPAs) — includes instrumentation.
   10 hours per week (520) on HVAC.
5) Materials do not include walls between operating areas.

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Section 6.13

Disposal Options for Depleted Uranium Management

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A-E	architect-engineer
AEA	Atomic Energy Act
AEC	Atomic Energy Commission
AGEMCV	Above Ground, Earth Mounded Concrete Vault
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
atm	atmosphere
BGV	Below Grade Vault
BNFL	British Nuclear Fuel
BTP	Branch Technical Position
°C	degree centigrade
CAA	Clean Air Act
CAP	Cost Analysis Project
CAR	Cost Analysis Report
CEC	Claiborne Enrichment Center
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter
cm^3	cubic centimeter
CNSI	Chem-Nuclear Systems, Inc.
CRNL	Chalk River Nuclear Laboratory
DAW	Dry Active Waste
DF	decontamination factor
DHS	California Department of Health Services
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EAP	Engineering Analysis Project
EAR	Engineering Analysis Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ES&H	environment, safety, and health

°F	degrees fahrenheit
ft	foot
ft^3	cubic foot
FTE	full-time equivalent
g/L	gram per liter
g/cm^3	gram per cubic centimeter
GCD	Greater Confinement Disposal
GTCC	Greater-Than-Class-C
ha	hectare
HEPA	high-efficiency particulate air
HF	hydrogen fluoride
HLW	high-level waste
HVAC	heat, ventilation, and air conditioning
ILW	intermediate-level waste
in.	inch
INEL	Idaho National Engineering Laboratory
K_d	distribution coefficient
kg	kilogram
km	kilometer
kva	thousand volt amperes
kWh	kilowatt hours
L	liter
LANL	Los Alamos National Laboratory
LAW	low-activity waste
lb	pound
LES	Louisiana Enrichment Services
LLBG	Low-Level Burial Ground
LLRWDF	Low-Level Radioactive Waste Disposal Facility
LLRW	low-level radioactive waste
LLW	low-level waste
LLNL	Lawrence Livermore National Laboratory
m	meter
m^2	square meter
m^3	cubic meter

mi	mile
mg/L	milligram per liter
ML	million liters
MLLW	mixed low-level waste
mm	millimeter
MPC	multi-purpose canister
mrem	millirem
MW	megawatts
NAAQS	National Ambient Air Quality Standards
NEC	National Electric Code
nCi/g	nano-curies per gram
NEC	National Electric Code
NECO	Nuclear Engineering Company Inc.
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Act
NPDES	National Pollutant Discharge Elimination System
NPH	Natural Phenomena Hazard
NPHM	Natural Phenomena Hazard Mitigation
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
PAD	Protective Action Distance
PCB	polychlorinated biphenyl
pH	logarithm (log) of the reciprocal concentration of the hydrogen ion
ppm	parts per million (weight basis)
R	Roentgen
RCA	Radiological Control Area
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RAM	Radioactive Waste Material
RWMC	Radioactive Waste Management Complex
RWMS	Radioactive Waste Management Site
SAR	Safety Analysis Report

SCM	standard cubic meters
SDA	Subsurface Disposal Area
SNF	spent nuclear fuel
SRS	Savannah River Site
SSC	structure, system, and component
SWSA	Solid Waste Storage Area
TA	Technical Area
TAR	Technology Assessment Report
TCP	Toxicity Characteristic Leaching Procedure
te	metric ton
TRU	transuranic
TWh	Tera-watt hours
U_3O_8	triuranium octaoxide
UBC	Universal Building Code
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
UPS	uninterruptible power supply
WAC	Waste Acceptance Criteria
WBS	work breakdown structure
WSRC	Westinghouse Savannah River Company
WVDP	West Valley Demonstration Project

PREFACE

This report presents and evaluates potential disposal options for depleted uranium, using low-level waste (LLW) disposal design parameters current among government agencies and commercial industries. For the purposes of this report, the depleted uranium is assumed to be in an oxide form, either triuranium octaoxide (U_3O_8) or uranium dioxide (UO_2). Preconceptual designs are included for three disposal options: disposal in a vault, disposal in an engineered trench, and disposal in a deep mined cavity.

Description of the facilities associated with the three disposal options are provided, including a wasteform facility for receipt and cementing of the uranium oxide. Personnel staffing estimates for the construction, operation, and maintenance of the facilities are also provided. Wastes and emissions from the facilities during construction, operation, and maintenance have been estimated.

Each disposal option is evaluated for four cases differing by wasteform. The base case considered is cemented U_3O_8, with alternative cases of cemented UO_2, uncemented U_3O_8, and uncemented UO_2.

1.0 DESCRIPTION OF DISPOSAL OPTIONS FOR DEPLETED URANIUM

This section provides information on current practices for low-level radioactive waste (LLRW) disposal, both at Department of Energy (DOE) sites and commercial (domestic and foreign) sites; background on the disposal of depleted uranium; a description of depleted uranium wasteforms; and a brief description of the three disposal options considered in this report. The major assumption throughout is that the depleted uranium wasteforms can be considered as Class A low-level waste (LLW) regulated by the Atomic Energy Act (AEA) and associated regulations, not by the Resource Conservation and Recovery Act (RCRA). Section 9 includes an in-depth discussion of the regulatory status.

1.1 Low-Level Waste Disposal Practices

LLW has been primarily disposed of in near-surface burial facilities for the past half century. This disposal has occurred both in the United States and in foreign countries, by government agencies and private industry. The entire process of LLW disposal, including waste acceptance criteria and disposal operations, as well as public, worker, and environmental protection, is well understood and documented.

Several variations of near-surface disposal techniques have been used by government and industry. These include excavated trenches or pits and "natural" ground depressions [such as subsidence craters at the Nevada Test Site (NTS)], boreholes, buried concrete/steel silos, vaults, and tumulus. Although soil disposal has been the predominant technology, concreted facilities such as vaults and tumulus are being used in some foreign countries and at some U.S. sites in the east. Appendix A describes the ability of existing DOE, commercial, and overseas LLW facilities to accept the depleted uranium.

1.2 Background on the Disposal of Depleted Uranium

1.2.1 The Chemistry of Uranium in a Disposal Environment

The optimum chemical form for the disposal of depleted uranium (a) is the least toxic to man; (b) is the most stable in the proposed disposal environment, and (c) meets all of the regulatory requirements. This section will focus on the chemical properties of uranium compounds that determine their stability in a disposal environment, where the requirements for stability are influenced by toxicity and regulatory factors. To examine the interaction between depleted uranium and the disposal environment, it is assumed that no credit is taken for encapsulation or containment.

The goal is to provide a depleted uranium wasteform that is both chemically and structurally stable in the disposal environment. The general requirements for providing waste that will perform well in a disposal environment are given in the Waste Acceptance Criteria (WAC) for each disposal site (see Appendices E and F for Nevada Test Site WAC and Hanford WAC, respectively). The Nuclear Regulatory Commission (NRC) has defined the characteristics of a LLW form in 10 CFR 61. It is assumed that the wasteform that meets the WAC will be "stable." This means that it will maintain its physical dimensions and form (not flow, crush, degrade), and will not explode, generate toxic gases, or be pyrophoric, etc. Stable also means that it will not be easily transported from the disposal site by air (dispersibility) or water (solubility, distribution coefficient). Thus, in a disposal environment, some of the most desirable properties of the wasteform are minimal reactivity and low mobility.

There are two categories of chemical hazards of concern in depleted uranium disposal. First, some chemical forms of uranium are sufficiently reactive that they can present hazards while handling for storage or disposal. Secondly, for all compounds of uranium, the potential risk from chemical toxicity is equal to or greater than that from radiotoxicity (Hertzler, 1994).

The chemical toxicity of uranium has been a primary concern in establishing occupational and environmental limits for depleted uranium. In occupational situations, uranium is considered only slightly less toxic than lead (Hertzler, 1994).

Uranium hexafluoride (UF_6) is a solid at standard temperature and pressure, but is volatile and sublimes at 56 °C. It reacts with water to form soluble uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF) gas. Finely divided depleted uranium metal is pyrophoric and is restricted from disposal by site-specific WAC. In limited cases, however, "bulk" depleted uranium metal has been accepted for disposal at the NTS as mentioned in appendix B of this report (Hertzler, 1994).

The evaluation of the chemical reactivity between the wasteform and the disposal environment should consider both the equilibrium thermodynamics of the reaction and the kinetics of the reaction. For example, thermodynamics may predict a reaction between a uranium compound and water, but the rate of reaction may be controlled by the rate at which water becomes accessible to the waste. Apparently, there is very little reaction rate data for the reactions of interest. However, for the long time scales involved in disposal, the reactions will probably proceed to completion.

Chemical reactions between depleted uranium and the disposal environment can influence the stability of the waste in several ways. The waste can be converted to a more soluble form, and thus be more mobile and lead to increased offsite exposures. Also, the reaction products can be more reactive and lead to the degradation of containment structures.

The physical properties of selected uranium compounds that have been considered for disposal are listed in table 1.1 (MMES, 1990). The most reactive compound is UF_6, which reacts with water to form soluble UO_2F_2 and HF gas. Uranium tetrafluoride (UF_4) reacts slowly with water to form uranium dioxide (UO_2) and HF. At ambient temperatures, UO_2 will gradually convert to triuranium octaoxide (U_3O_8). Under normal environmental conditions, U_3O_8 is one of the most kinetically and thermodynamically stable forms of uranium.

One of the potential problems with disposing of depleted uranium in the form of UF_6 or UF_4 is the release of HF when these compounds come in contact with water. If the waste was stored in a concrete vault, the HF could degrade the concrete and could lead to the conversion of uranium fluoride to the more soluble uranium carbonates.

It is important to note that U_3O_8 does not exist in solution, but rather speciates to other oxide, hydroxide, and complex forms that are soluble to some extent. U_3O_8 has been reported to be thermodynamically unstable under some groundwater conditions (Kozak, 1992). Thus, it may convert to other oxide (mineral) forms that are dependent on site-specific conditions. For example, schoepite ($UO_3 \bullet 2H_2O$) is favored under oxidizing conditions, and uraninite ($UO_{2-2.67}$) is favored under reducing conditions. Since oxidizing conditions are expected for disposal sites in an unsaturated zone, the behavior of schoepite should be considered.

The assumptions regarding the solubility of uranium in groundwater will significantly affect the dose assessment, since solubility will likely control the release of the uranium into the environment. It is generally assumed that the solubility of uranium in groundwater is a function of the pH, temperature, and ionic content of the groundwater. However, the kinetics of dissolution must also be taken into consideration, and not just the equilibrium thermodynamic solubility. Thus, there is a need for leach testing.

The solubility and ion complexing of uranium compounds is largely dependent on the valence (oxidation) state of the uranium. Of the four valence states in which uranium can exist (+3, +4, +5, +6), only the +4 and +6 states are stable enough to be of practical importance. Uranium compounds with a +6 valence have a much greater solubility ($6x10^{+2}$ mg/L) in neutral pH groundwater than uranium compounds with a +4 valence ($7x10^{-3}$ mg/L) (Hertzler, 1994). The solubility used for uranium (with +4 valence) for the deep geological disposal ($1x10^{-4}$ mg/L) is less than this, as is the solubility used for near-surface disposal ($2.4x10^{-3}$ mg/L) (Kozak, 1992). It is clear that site-specific conditions can produce a wide range of solubility values for uranium oxides and that specifying solubility on a generic basis is subject to large uncertainties.

The solubility of uranium in groundwater has been examined under conditions that ignore the presence of other mineral species that might influence the solubility (Kozak, 1992). Most uranium oxides are not very soluble in neutral or near neutral solutions, but can be much more soluble in very acidic ($pH < 3$) and very basic ($pH > 10$) solutions.

The influence of the grout on the U_3O_8 solubility in groundwater can be estimated by the effect of grout on the pH of the water adjacent to the wasteform. Grouts are capable of conditioning large quantities of groundwater to strongly alkaline pHs (>10). Therefore, the solubility of the grouted U_3O_8 form can be estimated by looking at the solubility of U_3O_8 at high pHs (10-12). Grouted U_3O_8 with a pH of 10 would have a solubility of approximately 21.5 gram-moles/L (Glasser, 1990).

In the case of UO_2, a degree of oxidation can be tolerated prior to the onset of dissolution of the UO_2 matrix. An electrode potential value between 0 and +50 mV has been determined for the onset of oxidative dissolution. This could be taken as a minimum redox condition, below which UO_2 should be a stable host matrix for radionuclides. Electrochemical results show that the mechanism of oxidative dissolution of UO_2 remains essentially unchanged in the pH range of $5 < pH < 10$, which is the range expected in groundwaters. Therefore, the same argument that was used for grouted U_3O_8 can also be applied here: at pHs greater than 10, the alkalinity of the grout will dominate the solubility rate (Shoesmith, 1985).

It should be noted that these solubilities could be substantially changed if other species that form complexes with uranium are present in the groundwater. An analysis of the solubility of U_3O_8 for a specific site groundwater composition is given in Kozak, 1992. A more detailed discussion of the solubility of uranium and other wasteforms for actual groundwater chemistries at NTS is presented in Chu, 1991. For example, for the water chemistry of Well 5-B at NTS, the mineral form of uranium called haiweeite [$Ca(UO_2)_2Si_6O_{15} \bullet 5H_2O$] is the most insoluble phase. This is primarily due to the availability of the silica in the groundwater to form uranium-silicate precipitates such as haiweeite. The minimum solubility occurs near the neutral value of pH, as was reported above for schoepite. Note also that schoepite will tend to precipitate in groundwater that is initially low in silica or has been depleted of silica due to the precipitation of silicates.

Another measure of environmental mobility is the distribution coefficient (K_d), which is a measure of how tightly a compound binds to a soil particle. A compound with a high K_d for the soils in the disposal area is desirable, since this indicates that the compound will remain bound to the local soil and not migrate through the groundwater system. K_d is largely dependent on soil type. For clay soils, uranium compounds with a +6 valence are more tightly bound than uranium compounds with a +4 valence. This might compensate somewhat for the higher solubility of the +6 compounds with regard to potential mobility in the groundwater.

Encapsulating and/or containing depleted uranium will influence the interaction of the wasteform with the environment. Some forms of containment, such as the standard steel drums, are primarily used for handling purposes, and are not assumed to provide long-term protection of the waste. Other forms of containment are specifically used as a barrier between the waste and the environment. Since the purpose of these barriers is to increase the "stability" of the depleted uranium, reduced reactivity and mobility of the wasteform should exist for some period of time. It is usually assumed that the barriers are no longer effective after a few hundred years.

If credit is taken for encapsulating and containment, then the behavior (chemistry) of the modified depleted uranium wasteform should be calculated or measured for the specific disposal site environment. For example, encapsulating depleted uranium in grout will increase the pH of the wasteform and thus alter properties such as solubility. Using barriers that inhibit migration (diffusion) will affect the kinetics of degradation reactions. Leach testing procedures have been developed by the Environmental Protection Agency (EPA) and the NRC so that the kinetics of dissolution of a specific wasteform in a specific site environment can be measured.

The intrinsic dissolution rate of U_3O_8 in air saturated water (pH=8.1, T=23°C) is approximately 10 mg/m^2/day, which is 2-4 times greater than UO_2 and U_3O_8 under the same conditions. However, the fractional (actual) dissolution rate will be very sensitive to the effective surface area of the U_3O_8 (grain size, particle size).

1.2.2 Prior Analyses of the Disposal of Depleted Uranium

Studies on the disposal of depleted uranium have been performed by DOE (Hertzler, 1994; MMES, 1990) and the NRC (Kozak, 1992). Although these studies covered technical, regulatory, and cost issues, the technical issues will be the focus of the following discussions. The DOE analyses will be covered in this section, while the NRC analyses will be covered in section 1.2.3.

The primary objectives in the disposal of depleted uranium are to protect the health and safety of the workers and the public and to minimize the degradation of the environment. A study performed in 1990 for DOE-Uranium Enrichment (MMES, 1990) concluded that the most important aspect in achieving this objective was the chemical form of the depleted uranium. Based on the technical analysis conducted by the Uranium Enrichment Organization, UF_6 was the acceptable and desirable form for inventory and short-term storage, but chemical conversion to U_3O_8 was recommended for long-term disposal. The preference of the U_3O_8 form of depleted uranium for disposal is also supported by studies outside the United States (Michallet, 1988).

A study of the disposal options for depleted uranium was recently performed for DOE's Office of Environmental Restoration and Waste Management (Hertzler, 1994). This study also recommended U_3O_8 as the best chemical form for the disposal of depleted uranium. The study concluded that disposal of depleted uranium is only technically and economically feasible at the NTS and the Hanford Site. The WAC and/or disposal costs at commercial disposal sites [such as US Ecology's Richland Site, Chem-Nuclear Systems, Inc.'s (CNSI's) Barnwell Site, and Envirocare's Clive Site] effectively eliminated them from consideration. The disposal of depleted uranium as U_3O_8 was considered for two cases: (a) depleted uranium treated as LLW, and (b) depleted uranium treated as RCRA mixed waste.

A disposal analysis includes a site-specific pathway analysis to estimate potential radiation and chemical exposures to intruders and offsite members of the public. A typical analysis calculates release from the disposal facility; transport to the environment by air, water, and the food chain; and exposure to the public from inhalation, ingestion, and external exposure. The time period over which this analysis is made can be very long (1,000 to 10,000 years). At any time during this period, certain radiological and chemical toxicities cannot be exceeded at the disposal site. For example, the annual radiation dose to a member of the general public cannot exceed 25 mrem/year (from all pathways). A disposal site must also meet the atmospheric pathway limit of 10 mrem/year (Clean Air Act). Chemical toxicity limits for uranium have been proposed by the Occupational Safety and Health Administration (OSHA) for continuous air exposure (0.05 mg/m^3), and by EPA for drinking water limits (60μg/L).

The radiological hazards associated with depleted uranium are the consequence of its isotopic composition. The typical concentrations of the three isotopes contained in depleted uranium are: 99.80 percent (U-238); 0.20 percent (U-235); and 0.0005 percent (U-234). Depleted uranium produced by gaseous diffusion is essentially free of daughter products from these isotopes. However, subsequent decay of the depleted uranium produces daughter products that lead to an ingrowth of decay products. It has been reported that the quantity of radon-226 produced by this process is insufficient to produce a significant radiological hazard for tens of thousands of years (Hertzler, 1994). Radionuclides with the short half-lives (Th-234, Pa-234, and Th-231) reach their maximum concentration within a few months after the production of depleted uranium, and this concentration then remains constant.

The radiological hazards from depleted uranium are primarily due to alpha particle emissions. Thus, for most cases, the limiting radiological hazard is the internal radiation dose from ingestion or inhalation. Highly insoluble uranium oxides such as UO_2 and U_3O_8 will be retained in the lungs for much longer times than more soluble uranium compounds such as UF_6. Table 1.1 (MMES, 1990) lists the inhalation classifications for the various compounds of depleted uranium. Although the low solubility of U_3O_8 is a positive factor in groundwater migration (and in kidney take up), it is a negative factor in air pathway considerations.

A comparison of the chemical and radiological toxicity of various forms of depleted uranium is given in table 1.2 (Hertzler, 1994). It should be noted that the chemical and radiological toxicities of the various compounds of uranium are generally of the same order of magnitude. Whether chemical or radiological toxicity will be the limiting factor for a given uranium compound depends on the specific situation. For environmental situations where drinking water is the primary concern, chemical toxicity will be the limiting factor for insoluble compounds such as U_3O_8. This is because highly soluble compounds such as UF_6 will reach the very restrictive EPA radiation dose limit for drinking water before exceeding a chemical toxicity limit.

1.2.3 NRC Analyses and Position

The NRC perspective on the disposal of depleted uranium is given in the NRC Environmental Impact Statement (EIS) for the Claiborne Enrichment Center (CEC) (U.S. NRC, 1994) and in the NRC response to the request for recommendations (LLNL, 1995 and appendix B). The NRC EIS assumes that depleted uranium may be disposed of in "generic" near-surface or deep geologic disposal units. Technologies applicable for near-surface disposal units include lined trenches, above- and below-grade vaults, and tumuli. Since the location of future disposal sites within the Central Interstate Compact (the waste compact group for the CEC) has not been determined, the EIS used the humid southeast site case study presented in appendix E of the Draft EIS for 10 CFR 61. The Central Interstate Compact requires above-grade disposal, and the Louisiana Enrichment Services (LES) Claiborne EIS assumes the near-surface disposal unit would be an earth-mounded bunker (tumulus). Exposure pathways include drinking well water and consumption of crops irrigated with water drawn from the well. The EIS concludes that near-surface disposal would significantly exceed the 25 mrem/year limit specified in 10 CFR 61 and the doses could potentially approach 570 mrem/year.

Analyses were also performed for "generic" deep, geologic disposal, potentially in an abandoned mine. The deep geological disposal unit was assumed to be a pre-existing cavity such as an abandoned mine or a facility engineered for disposal. Two sites whose geological structures had been previously characterized were analyzed for deep disposal - one located in a granite formation and one located in interbedded sandstone and basalt layers. Exposure pathways included a well drilled into the deep aquifer down gradient from the disposal facility and groundwater flow to a river that serves as a source of drinking water, fish, and irrigation. All estimated impacts were below 10 CFR 61 limits. There was no analysis of the chemical toxicity of the uranium. The analyses concluded with a maximum dose of approximately 0.23 mrem/year, and therefore, a deep disposal site is most likely to be selected. However, no specific candidate sites for deep disposal were identified.

Oxide forms were favored for long-term disposal, with U_3O_8 being the preferred form. Since U_3O_8 is thermodynamically unstable in groundwater, the technical analysis supporting the EIS recommended that consideration be given to an alternative wasteform (specifically, schoepite). The original LES proposal to dispose of depleted uranium as UF_4 was dismissed by the NRC for environmental, safety, and health (ES&H) reasons. The uranium fluorides, including UF_4, are less stable than the uranium oxides and produce HF in the presence of water. The HF renders the water acidic and accelerates further degradation and dissolution of the tetrafluoride wasteform. However, much of the analysis in the performance assessment study supporting the EIS (Kozak, 1992) focuses on this tetrafluoride form.

Additional findings that were not discussed in the EIS were made in the performance assessment study:

1. Under certain unspecified site conditions, the schoepite wasteform of uranium may give acceptable offsite doses for near-surface disposal.

2. For UF_4 disposal, the chemical toxicity of the depleted uranium is a greater limitation on the disposal than the radiological doses. Significant toxic effects to the kidneys are observed even for contaminant intake levels that pose negligible radiological risk. Chemical toxicity may be a significant, potentially limiting effect for depleted U_3O_8 disposal as well.

Currently accepted models used in LLW performance assessments were employed in the supporting study for the EIS (Kozak, 1992) to determine near-surface disposal doses. Although not stressed in the assessment or in the EIS, revising any of the assumptions used in the analysis may yield significantly different conclusions, resulting in near-surface disposal being acceptable. For example:

1. <u>Engineered Barriers:</u> No credit was taken for engineered barriers after institution controls were gone (100 years), or for the wasteform. Multiple caps and liners of natural materials would reduce infiltration and migration significantly, long after the institutional control period had expired.

2. <u>Mass Loading Factors:</u> Different values for the mass loading factor of particulates in air or for the bulk density could change doses.

3. <u>Solubility:</u> The assessment assumes that the solubility of uranium in groundwater is a function of the naturally occurring ions in the groundwater and of physical/chemical characteristics such as pH and temperature. This solubility significantly affects the dose assessment. Since solubility controls release of uranium, different values for solubility would affect the doses. Furthermore, the uranium concentration may actually be limited by the kinetics of dissolution, not by the thermodynamic solubility. This would be determined by leach tests, such as the EPA's Toxicity Characteristic Leaching Procedure (TCLP) and the NRC's Branch Technical Position (BTP).

4. <u>Disposal Site:</u> Alternate disposal site locations would profoundly influence dose assessment results. For example, disposal at a drier site would be expected to have significantly lower offsite doses.

5. Wasteform: Alternative wasteforms (e.g., encapsulated in cement, polymer, or glass) may be proposed that would reduce kinetic release rates or the solubility limits of the depleted uranium.

1.3 Depleted Uranium Wasteform for Disposal

The wasteform disposal options for depleted uranium management include (a) the octaoxide of uranium (U_3O_8) in a cemented matrix (grouted), (b) bulk disposal (no cement) of U_3O_8 (c) disposal of a cemented form of UO_2, and (d) bulk disposal of UO_2. The assumed isotopic composition of depleted uranium is: U-234 (0.001%); U-235 (0.25%); and U-238 (99.75%).

1.3.1 General Assumptions

It is assumed that the waste package is a closed-head steel drum with a nominal capacity of either 55 gallons (for U_3O_8) or 30 gallons (for UO_2).

Each disposal option is sized to accommodate the equivalents of 560,000 metric tons of UF_6 tailings, i.e, 447,000 metric tons (te) of U_3O_8, or 430,000 te of UO_2. The physical properties of these wastes, and the loadings of waste containers, are shown in table 1.3. The characteristics of the wasteform containers are provided in table 1.4.

The depleted uranium waste material flows, from depleted UF_6 at the three gaseous diffusion plant sites through drum storage as oxides of uranium, are shown on figure 1.1. This figure reflects the base case and the three process variants.

1.3.2 Base Case

Grouted U_3O_8 is considered the base case because of its chemical stability and low solubility in most environmental conditions. The morphology of U_3O_8, however, is a drawback. It is difficult to control the particle size distribution of the oxide. The compound is friable and not readily formed into hard microspheres that resist fracture. For this reason, and to augment the insolubility of the oxide, the base case incorporates mixing U_3O_8 with cement and sand to produce a grouted, solid product. The ratio of sand, cement, and U_3O_8 is 1:1:2. It is often found that grouted waste includes blast furnace slag and/or flyash. To be conservative, fillers will not be considered for the grouted cases because it has been found that fillers can reduce the leach rate. The composition of the grouted waste as given above provides an upper bounding case with respect to leaching rates. Process flow diagrams for construction and operations are shown in figures 1.2 and 1.3.

It is assumed that U_3O_8 will be subjected to a compacting/screening/fines recycling operation at the point of conversion so that it will satisfy the waste acceptance particle size criteria, thereby eliminating the need for fixation or packaging in lined containers. A benefit of the compaction process would be to increase the depleted uranium bulk density from 1.4 g/cm^3 (out of the kiln) to about 3 g/cm^3, effectively decreasing the disposal volume by a factor of more than two.

1.3.3 Variations

Uncemented U_3O_8, sealed in drums, provides the advantage of reducing the disposal area because of the lower volume of this wasteform compared to the cemented form. The shortcomings of this variation are (a) the potential mobility of the small fragments of the wasteform in the event of an inadvertent rupture of the storage drum, and (b) the solubility of the finely divided wasteform.

Cemented UO_2 has the advantage, in terms of minimizing disposal area, of being much more compact than cemented U_3O_8. The disadvantage is that UO_2 is slightly less stable. The composition of this grouted waste is simply cement and UO_2 in a 1:3 ratio. Again, fillers were not added for reasons given in section 1.3.2.

Uncemented UO_2 provides an advantage in density over U_3O_8 and has the additional benefit of being readily formed into hardened microspheres. It is, therefore, less susceptible to fracturing of the particles and to the formation of mobile or respirable fines.

1.4 Disposal in a Vault

1.4.1 Summary Description

A concrete vault has been suggested as an improved means of LLW disposal (Hertzler, 1994; Shuman, 1989), particularly in the eastern part of the United States. Both above- and below-ground variations have been discussed. The current discussion considers a reinforced concrete vault built just below grade, with the excavated material mounded above the vault and the original grade as a water/intrusion resistant cap. Section 2 provides the dimensions and a specific description of the vault.

1.4.2 Assumptions and Bases

The following assumptions and bases were made regarding the vault as a disposal option:

(a) Generic, flat site with adequate size (approximately 60 ha maximum);

(b) Minimal clearing and grubbing requirements;

(c) The site has met the regulatory requirements for offsite doses, and is licensed and permitted;

(d) The site has no unusual subsurface features, mineral values, springs, aquifers, or meteorology;

(e) Adequate concrete and material supply; and

(f) Adequate local workforce.

1.4.3 Flow Diagrams and Material and Energy Balances

Figures 1.4 and 1.5 display the process flow per vault for construction and operations for the base case of grouted U_3O_8 disposal. Materials are required for the vault itself, while the energy is consumed by construction activities. Once filled, the vault only uses energy to monitor equipment (approximately 2 kW per vault). 169 vaults are required for the base case.

1.4.4 Variations

The effects of the variations are summarized in table 1.5. The variations all require fewer vaults than the base case due to the higher uranium density of the wasteform.

1.5 Disposal in an Engineered Trench

1.5.1 Summary Description

Standard engineered trenches are used for low-specific-activity waste and other LLW. Near-surface disposal of radioactive waste involves disposal in the uppermost portion of the earth, approximately 75 meters (m) (250 ft). The actual length of the trench is usually limited by site conditions, the volume of wastes received per unit time, and the degree of facility space required. Trench width may be dictated by the amount of radiation the workers may be exposed to, stability of the trench walls, the volume and/or size of the waste to be buried, types and weights of excavating and compacting machinery, and site conditions such as topographic relief. Engineered trenches are feasible primarily in drier parts of the country, such as the western desert area. Factors influencing the depth include the physical aspects of the waste size, stability of the soil slopes, depth to bedrock, water-bearing sand lenses, permissible proximity of the top of the waste to the ground surface, and the type and amount of cover and liner required. The most important depth-limiting factor for LLW disposal in the unsaturated zone is the water table. The bottom of the trench should be a distance away from the water table so as not to disturb its activity. The trench floor generally slopes gently to one side and to one end in order to collect infiltrated water, if any, at one corner of the trench. Trench design processes are discussed in NUREG/CR-3144; NUREG/CR-4938 (U.S. NRC, 1983 and U.S. NRC, 1987, respectively).

It is assumed that wastes are placed three pallets high in the trenches by a fork lift, and the remainder of the trench is occupied by backfill. Initially, waste packages are emplaced at the higher end of the trench, which is gradually filled toward the lower end. Drums with higher radiation levels should routinely be placed in the deeper levels of the trenches, with drums of lesser activity being stacked over them as soon as is practical. This would provide additional shielding and would minimize personnel exposure with little or no loss in efficiency (U.S. NRC, 1987).

Wastes must be emplaced in a manner that maintains the package integrity, minimizes the void spaces between packages, and permits the void spaces to be filled. Void spaces between waste packages must be filled with earth, sand, gravel, or other material as each waste layer is placed. This will make eventual trench subsidence easier to repair and less likely to temporarily expose the wastes when subsidence occurs. The backfill should extend to a maximum of 1 m (3 ft) above the local grade and is sloped.

1.5.2 Assumptions and Bases

A cornerstone of the system is stability — stability of the waste and the trench so that once emplaced and covered, access to the waste can be minimized. Migration of radionuclides is thus minimized, long-term active maintenance can be avoided, and potential exposures to intruders reduced. In choosing a disposal site, site characteristics should be considered in terms of the indefinite future and evaluated assuming at least a 500 year timeline.

Another issue regarding stability is the use of steel pallets vs. some other handling material. Pallets create a 10-centimeter (cm) (4 in.) void space under the drums, which is cause for concern for future stability. Some other material such as plywood would eliminate the void space, but it would require some other method to get the drums into the trench.

Ideally, precipitation at the potential site should be low, the distance to any aquifers should be long, aquifer flows and utilization should be low, and underlying strata should be neither highly fractured nor contain voids and flow channels. The site should be selected so that projected population growth and future developments are not likely to affect the ability of the trench to meet performance objectives. The site should be well drained and free of areas of flooding or frequent ponding. Waste disposal shall not take place in a 100-year flood plain, coastal high-hazard area, or wetland. Upstream drainage areas must be minimized to decrease the amount of runoff that could erode or inundate trench units. Depth of frost penetration should also be considered (U.S. NRC, 1983).

1.5.3 Flow Diagrams and Material and Energy Balances

Figures 1.6 and 1.7 present the process flow per year for trench construction and operations. All water shown is for personnel, as detailed in section 4.3.2.2.

1.5.4 Variations

The effects of variations are discussed in section 3.5 and are summarized in table 1.6. The variations all require less land than the base case due to higher uranium density in the wasteform.

1.6 Disposal in a Mined Cavity

The disposal of depleted uranium in a mined cavity was considered in the Final EIS for the tailings resulting from enrichment operations at the proposed CEC, Homer, Louisiana (U.S. NRC, 1994). Near-surface disposal was also considered in that EIS. The wasteform, in both cases, was depleted U_3O_8.

1.6.1 Summary Description

The CEC EIS does not provide any descriptive details of the mined repository for depleted U_3O_8 disposal other than the depth of waste emplacement [290 m (957 ft) in a granite formation, and 635 m (2,096 ft) in a sandstone layer]. Conceptually, the design could be similar to that of the Yucca Mountain repository (U.S. DOE, 1988), in that it would consist of (a) surface facilities that provide space for waste receiving and inspection, and shafts and ramps for access to and ventilation of the underground portion of the repository; and (b) tunnels ("drifts") underground for the transport of waste for underground emplacement, and tunnels for the removal of excavated rock and for servicing the area; (c) a waste ramp to permit transport of the waste containers from the surface facilities to the underground emplacement facilities; and (d) a tuff ramp that would be used for excavating and constructing the underground facility and for removing excavated tuff. There would also be shafts for the movement of workers and materials between the two areas, for the access of utilities, and for the ventilation of emplacement areas, underground shops and support areas, and decontamination areas.

Yucca Mountain was chosen as a conceptual analog for two reasons: (a) it is a rock repository, and the NRC analysis of CEC tailings disposal chose rock as the preferred emplacement medium and ruled out near-surface disposal; and (b) tuff formations represent a conservative choice in terms of support and spacing to be provided.

Beyond these conceptual similarities between a depleted uranium repository and Yucca Mountain are some very significant differences, which indicate that the magnitude of a depleted uranium repository effort would be much smaller. The underground layout of Yucca Mountain, though designed to accommodate 70,000 te (150 million lb) of uranium (U.S. DOE, 1988) as compared to the depleted uranium inventory of 379,000 te (840 million lb) of uranium, covers 566.6 ha (1,400 acres) and requires 500,000 linear feet of emplacement drifts, 6.5 m (22 ft) in diameter. The principal reason for the expanse of the Yucca Mountain underground area is the low density of waste emplacement (in terms of uranium) for reasons of shielding, heat transfer, and criticality safety. None of these constraints apply to depleted uranium disposal. Thus, depleted uranium oxides, for example, could be packaged in steel drums and stacked within a smaller number of more closely spaced tunnels in palletized storage, without any need for additional drilling to emplace these waste packages. Emplacement drifts are spaced 41.7 m (125 ft) on centers, which is consistent with tunneling in other mine media, but the walls or the floors of the emplacement drifts are drilled at an average borehole spacing of 2.3 m (7.5 ft) for vertical or horizontal emplacement of waste containers, with less than 3 te (6,600 lb) of uranium per container.

1.6.2 Assumptions and Bases

The assumed layouts of 55-gallon and 30-gallon drum containers in a repository tunnel or "drift" are shown in figures 1.9a and 1.9b. Assumptions are made by analogy to experience with the construction of the Yucca Mountain repository, and the details of such assumptions will be discussed at appropriate intervals of this analysis.

1.6.3 Flow Diagrams and Material and Energy Balances

Material flows and energy balances for the mined cavity are shown in figures 1.8 and 1.9. It should be noted that during the construction phase (which as indicated in section 10, largely coincides with the 20-year period during which the depleted UF_6 is converted to oxides), the principal output of the repository is material excavated to provide underground access, as well as the auxiliary emplacement tunnels or "drifts" in which the waste drums will be stacked in palletized storage. Major inputs include steel-reinforced concrete to both line the tunnels and provide for ramps, roadways, and foundations. In addition, major services such as potable water supply, air conditioning, and ventilation must be provided. The construction phase is the most energy-intensive due to the power consumption of excavating equipment. In the operating phase, power consumption is driven by materials-handling equipment, principally fork lifts, conveyors, and elevators.

1.6.4 Variations

The effects of variations are summarized in table 1.6. The variations all require less land than the base case due to higher uranium density in the wasteform.

Table 1.1 Physical Properties of Selected Uranium Compounds (MMES, 1990)

Chemical Compound	Melting point (°C)	Density (g/cm^3) Bulk	Solubility in Water, Neutral pH	Inhalation Solubility Class[a]
UF_6	64	4.6	Soluble, Decomposes to UO_2F_2	Class "D"
U_3O_8	Decomposes to UO_2 at 1300	3.0	Insoluble	Class "W"[b]
UO_2 (pellets)	2878	5.9	Insoluble	Class "W"[b]
UO_2 (microspheres)	2878	9.0	Insoluble	Class "Y"[c]

a. "D", "W", and "Y" are inhalation solubility classes established by the International Commission on Radiological Protection. Class "D" material is very soluble; lung retention time is days. Class "W" material is moderately soluble; lung retention time is weeks. Class "Y" material is relatively insoluble; lung retention time is years.

b. The solubility of uranium oxides is very dependent on heat treatment.

c. High-fired uranium dioxide.

Table 1.2 Chemotoxicity Versus Radiotoxicity for Various Chemical Forms of Depleted Uranium (Hertzler, 1994)

Chemical Compound	Limiting Air Concentration			Limiting Water Concentration		
	Chemotoxicity[a] (mg/m^3)	Radiotoxicity[b]		Chemotoxicity[c] (μg/L)	Radiotoxicity[d]	
		(pCi/m^3)	(mg/m^3)		(pCi/L)	(μg/L)
U_3O_8	0.68	189	0.47	60	220	550
UO_2	0.68	189	0.47	60	220	550
UF_6	0.07	540	1.35	60	22	55

a. Air concentration at which constant exposure results in a steady state kidney burden of 0.330 mg (about 1 μg/g of kidney tissue). The OSHA occupational limit for continuous exposure is 0.05 mg/m^3 based on chemical toxicity.

b. Air concentration at which constant exposure results in a radiation dose equal to the annual occupational limit of 5 rem/year. Conversion from pCi/m^3 to mg/m^3 is based on a depleted uranium specific activity of 4 x 10^{-7} Ci/g.

c. Proposed EPA standard for naturally occurring uranium in drinking water based on chemical toxicity.

d. Drinking water concentration that would result in an annual dose equaling the EPA drinking water standard of 4 mrem/year. Conversion from pCi/L to μg/L is based on a depleted uranium specific activity of 4 x 10^{-7} Ci/g.

Table 1.3 Distribution of Various Wasteforms

	U_3O_8 (55-gallon drums)		UO_2 (30-gallon drums)	
	grouted	**ungrouted**	**grouted**	**ungrouted**
Density	2.88 g/cc (180 lb/ft^3)	3.0 g/cc (187 lb/ft^3)	8.0 g/cc (500 lb/ft^3)	9.0 g/cc (562 lb/ft^3)
Weight of drum contents	0.598 te (1,320 lb)	0.625 te (1,380 lb)	0.907 te (2,000 lb)	1.024 te (2,260 lb)
Amount of U per drum	0.254 te 560 lb	0.530 te 1,170 lb	0.600 te 1,320 lb	0.902 te 1,990 lb
Number of drums	1.494 million	0.715 million	0.632 million	0.420 million

Table 1.4 Characteristics of Wasteform Containers

Container/ Contents	Height	Outside Diameter	Gauge/wall thickness	Weight (empty)
55 gallon drum for U_3O_8	88.3 cm (34.75 in.)	57.15 cm (22.5 in.)	40.6 cm/0.135 cm (16 in./0.053 in.)	34.0 kg (75 lb)
30 gallon drum for UO_2 microspheres	74.0 cm (29.125 in.)	46.4 cm (18.25 in.)	30.5 cm/0.241 cm (12 in./0.095 in.)	45.4 kg (100 lb)

Table 1.5 Number of Disposal Vaults (Base Case and Variations)

Disposal Case	Number of Vaults Annually	Total Number of Vaults	Site Land Area (Acres)
U_3O_8, grouted (Base Case)	8.45	169	56.4
U_3O_8, ungrouted	4.04	81	28.6
UO_2, grouted	1.73	35	12.9
UO_2, ungrouted	1.15	23	9.8

Table 1.6 Required Area for Trench and Underground Mined-Cavity Disposal (Base Case and Variations)

Disposal Case	Trench Disposal Site Area (hectares)	Underground Mined-Cavity	
		Area (hectares)	Emplacement Drift Length (m)
U_3O_8, grouted (Base Case)	30.6	187.0	45,628
U_3O_8, ungrouted	16.8	92.2	21,888
UO_2, grouted	12.1	58.0	13,452
UO_2, ungrouted	9.5	39.5	8,940

Figure 1.1: Material Flow Diagram

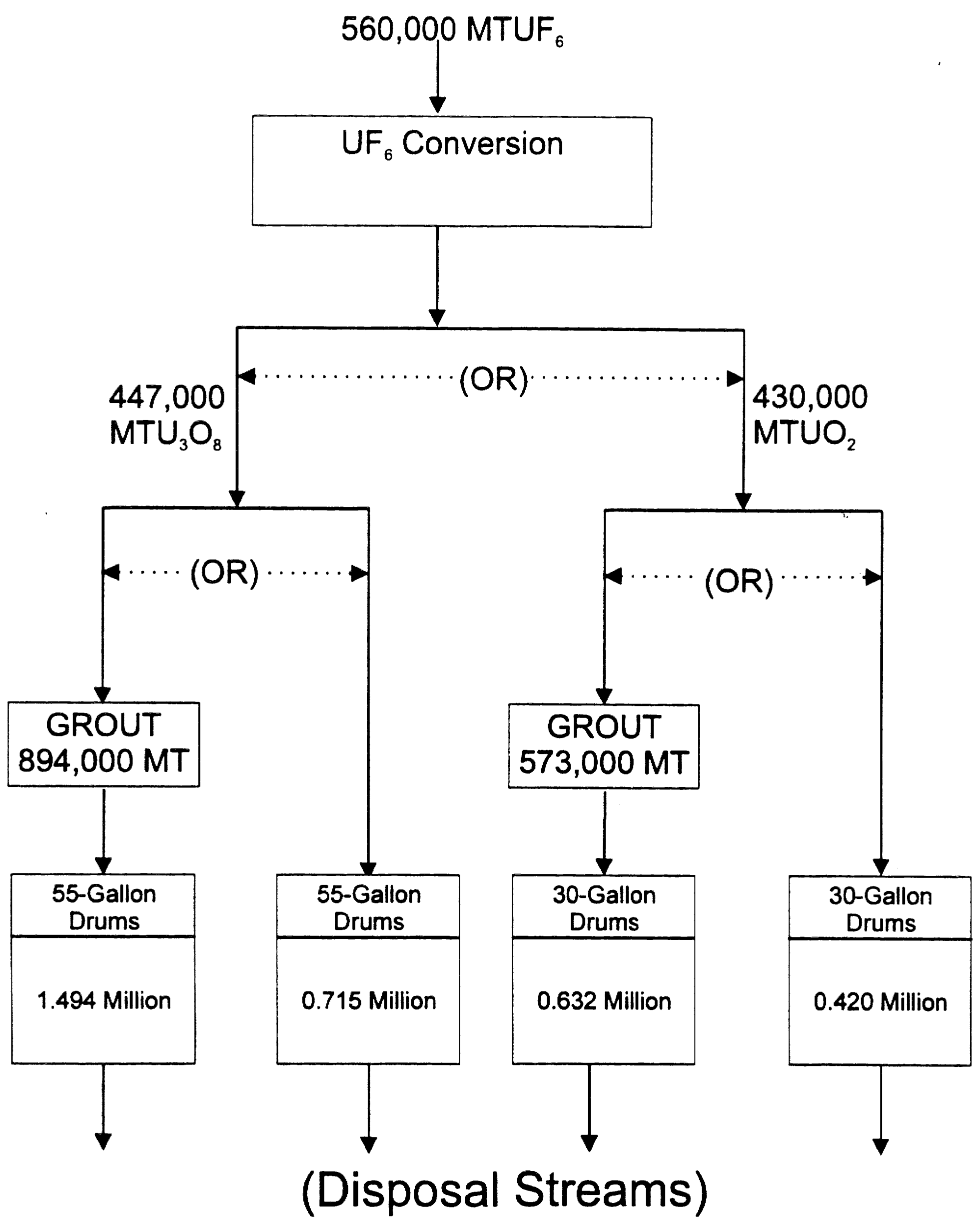


Figure 1.2: Wasteform Facility Process Flow Diagram for Construction: Grouted U_3O_8 (Base Case)

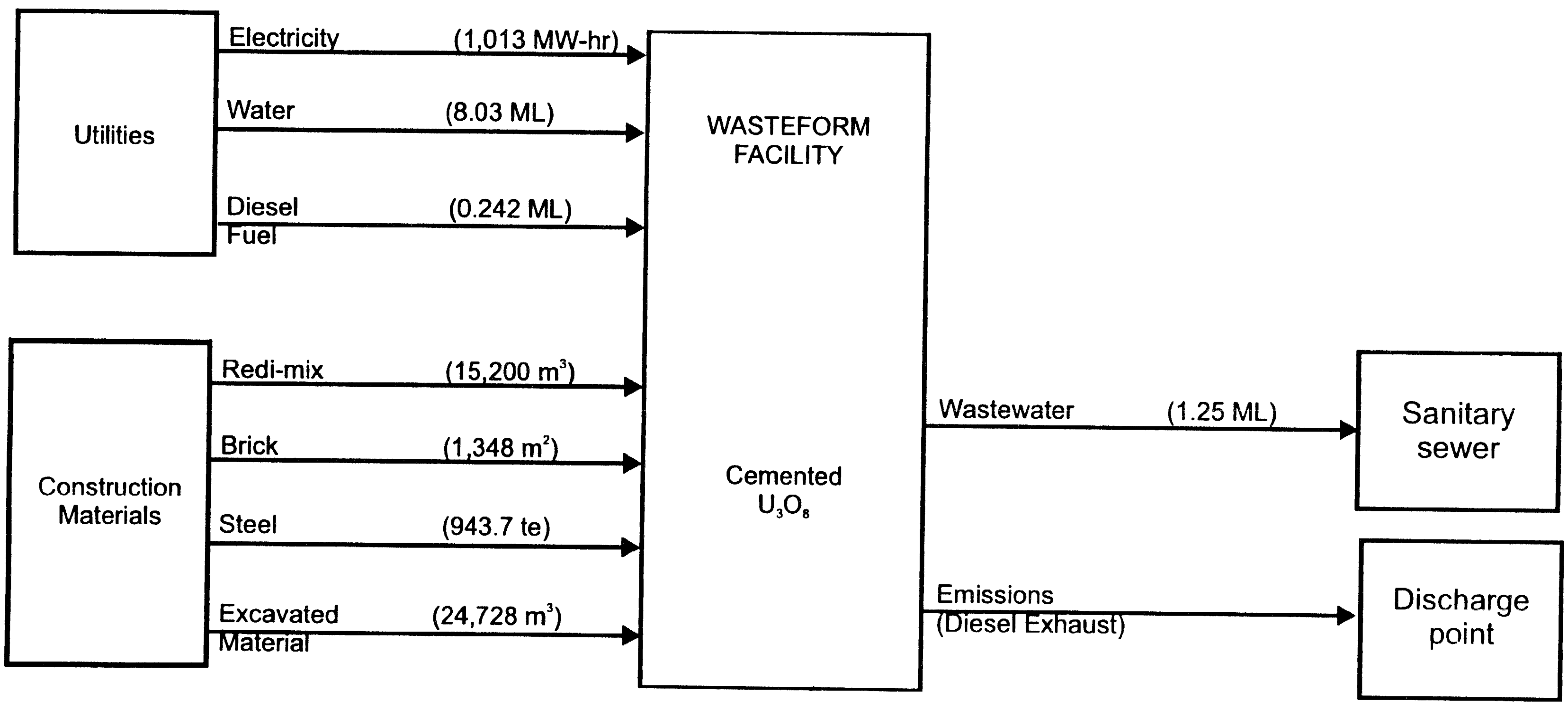


Figure 1.3: Wasteform Facility Process Flow Diagram for Operations (Annual Basis): Grouted U_3O_8 (Base Case)

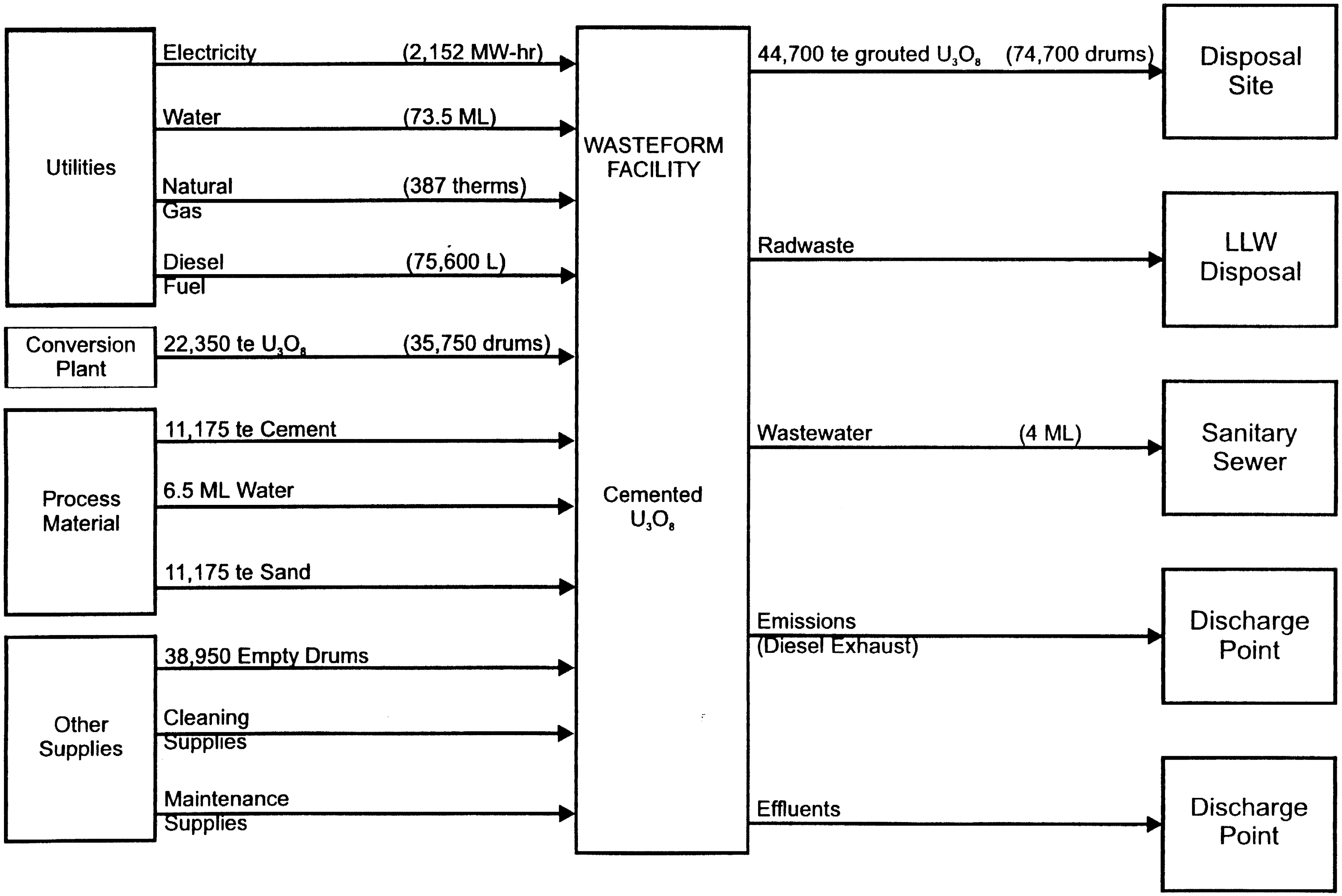


Figure 1.4: Vault Process Flow Diagram for Construction (per Vault): Grouted U_3O_8 (Base Case)

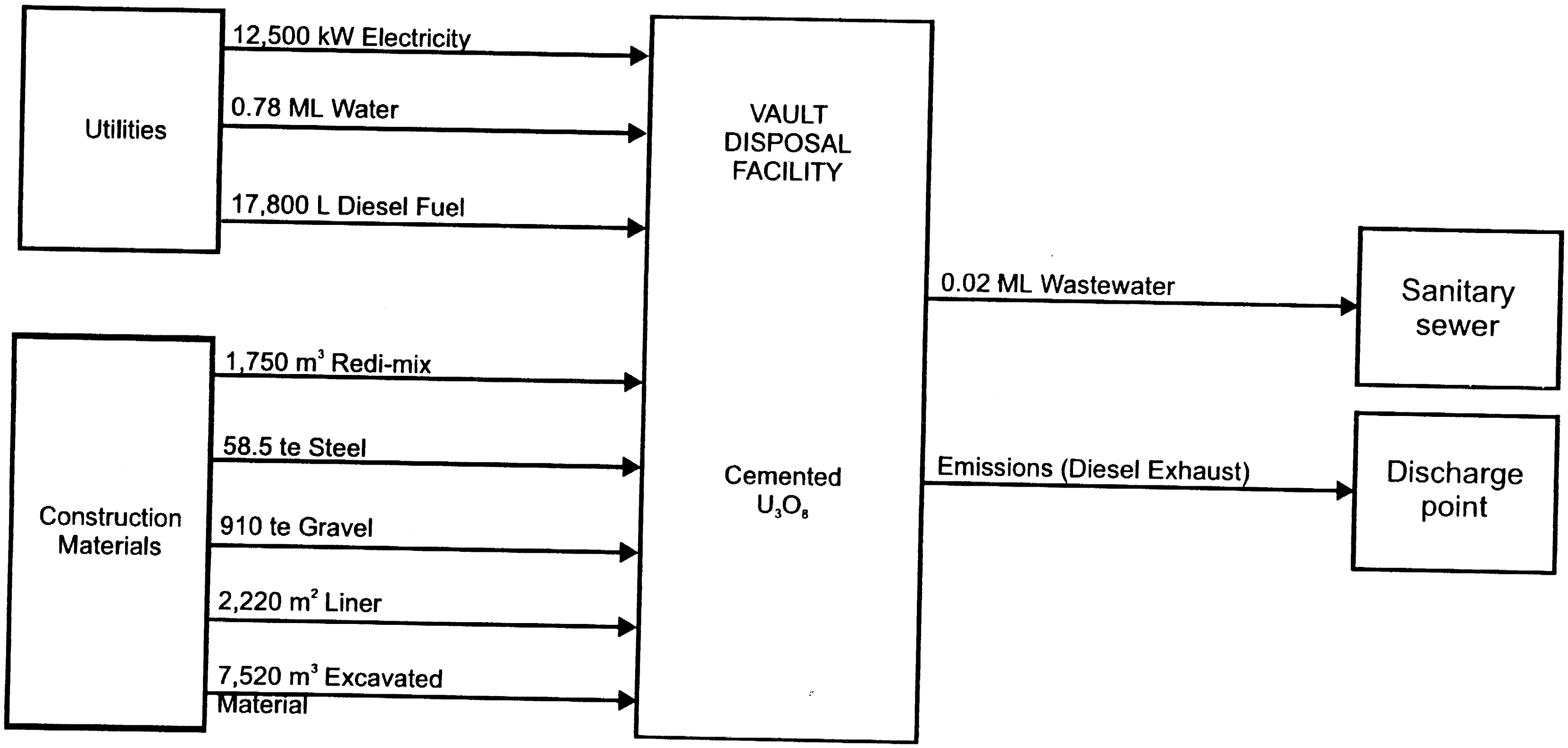


Figure 1.5: Vault Process Flow Diagram for Operations (per Vault): Grouted U_3O_8 (Base Case)

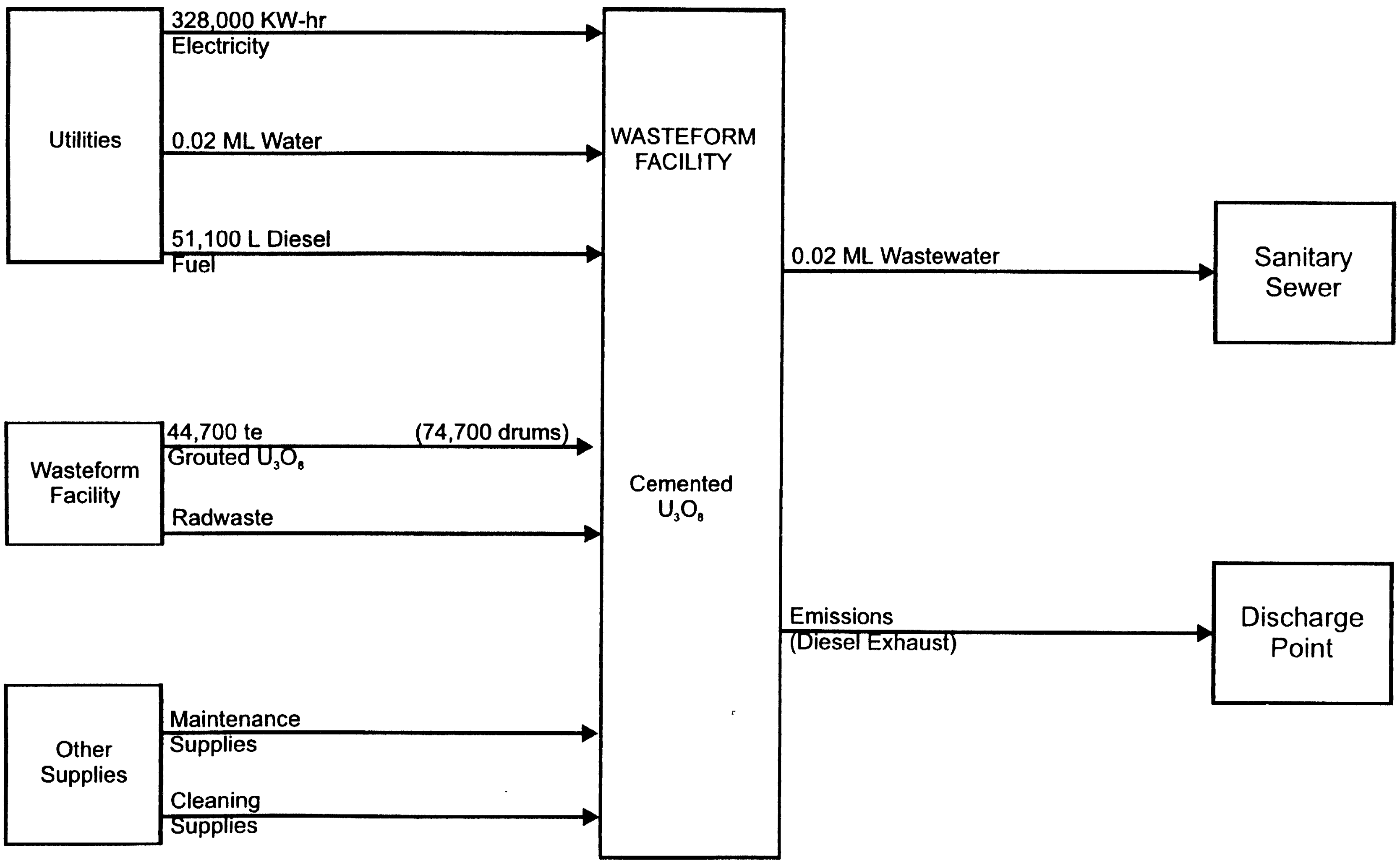


Figure 1.6: Trench Process Flow Diagram for Construction (per Trench): Grouted U_3O_8 (Base Case)

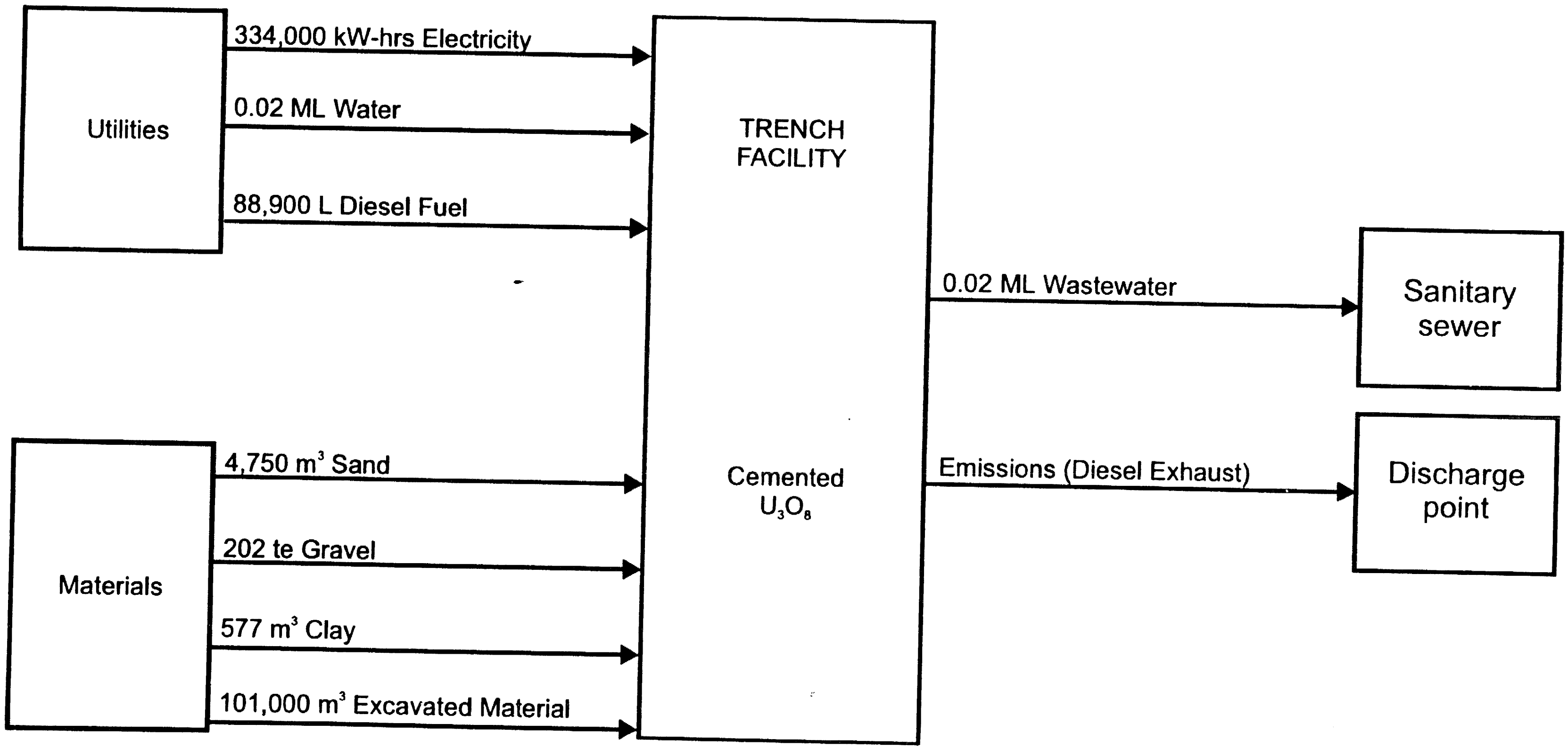


Figure 1.7: Trench Process Flow Diagram for Operations (per Trench): Grouted U_3O_8 (Base Case)

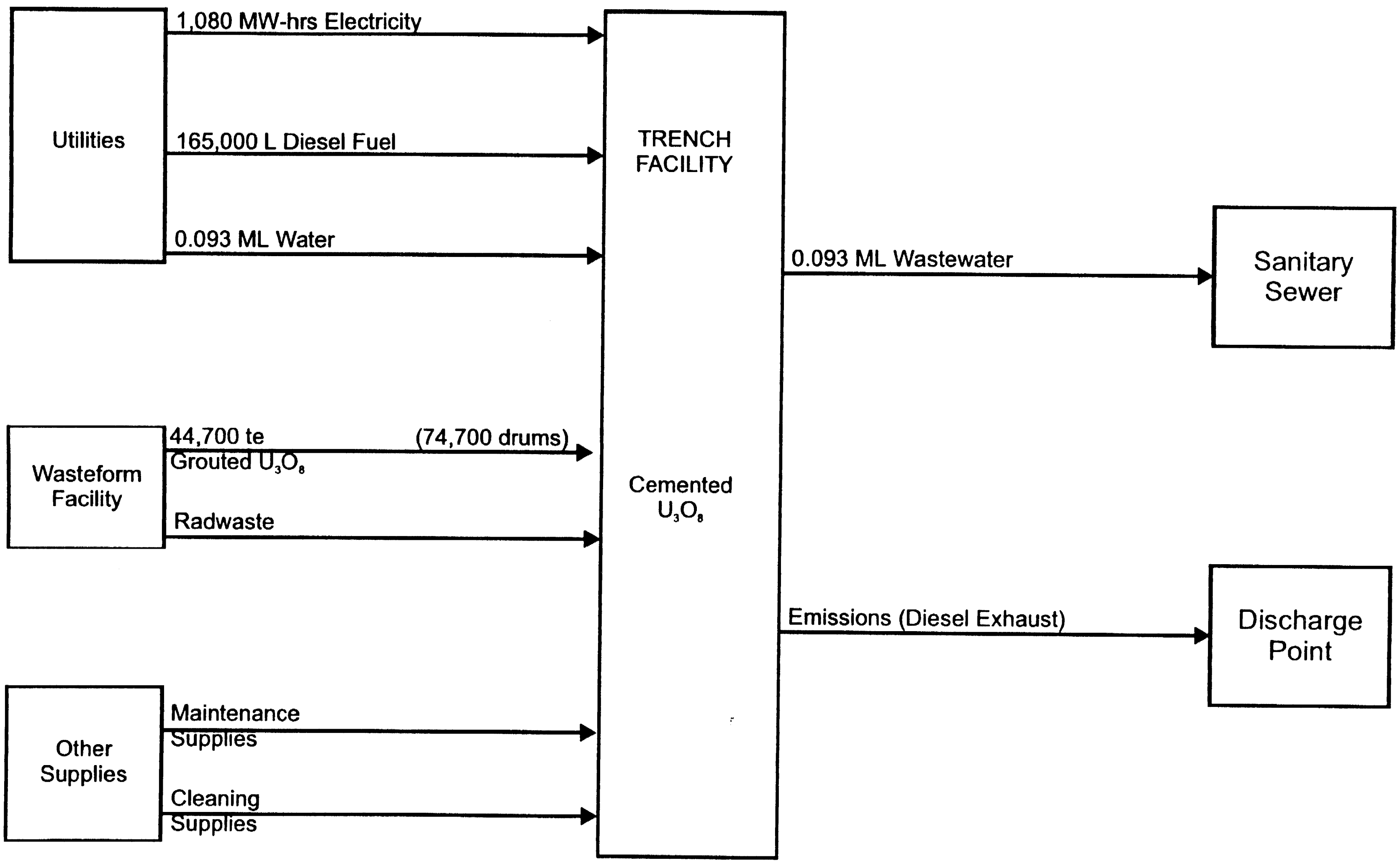


Figure 1.8: Mined Cavity Process Flow Diagram for Construction: Grouted U_3O_8 (Base Case)

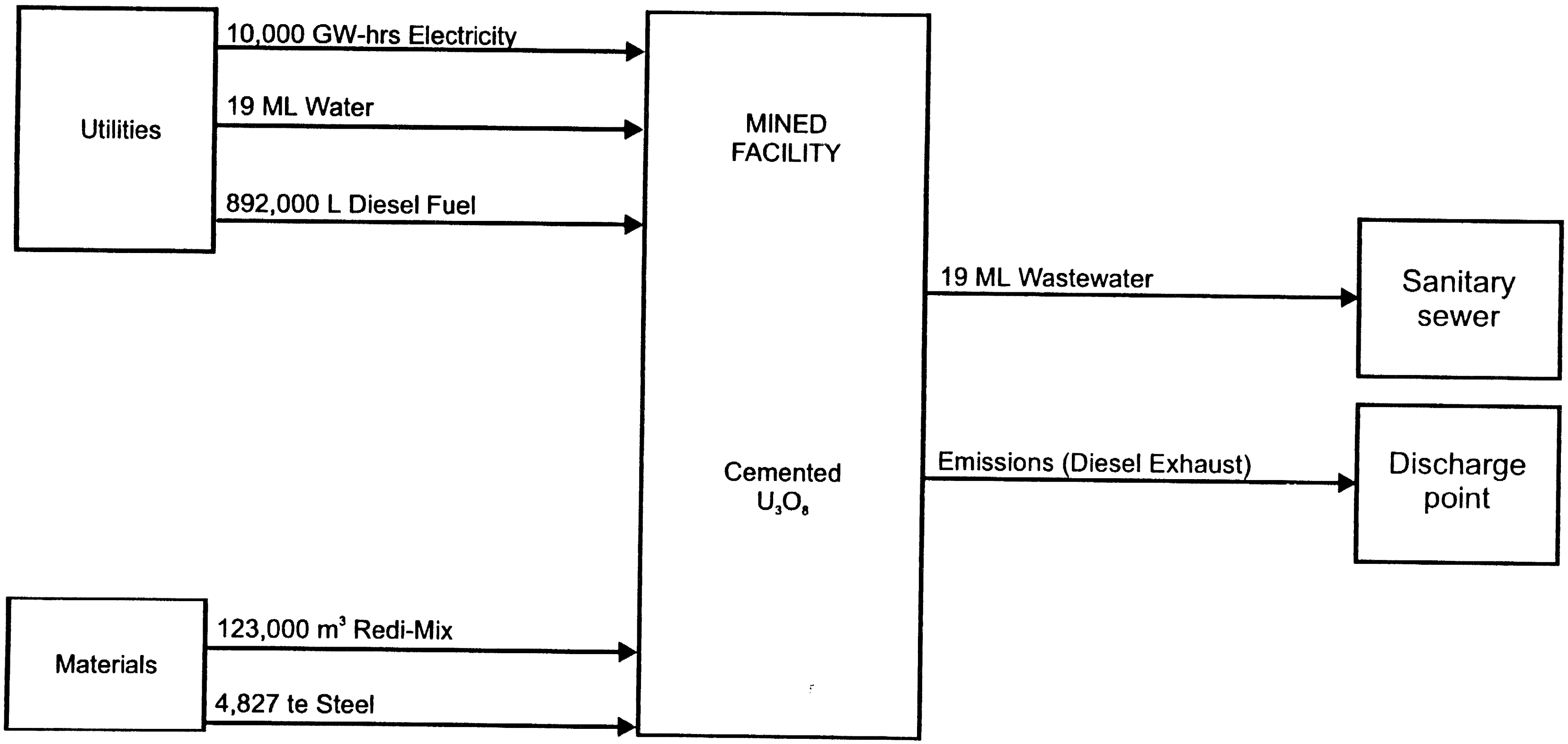


Figure 1.9: Mined Cavity Process Flow Diagram for Operations (Annual Basis): Grouted U_3O_8 (Base Case)

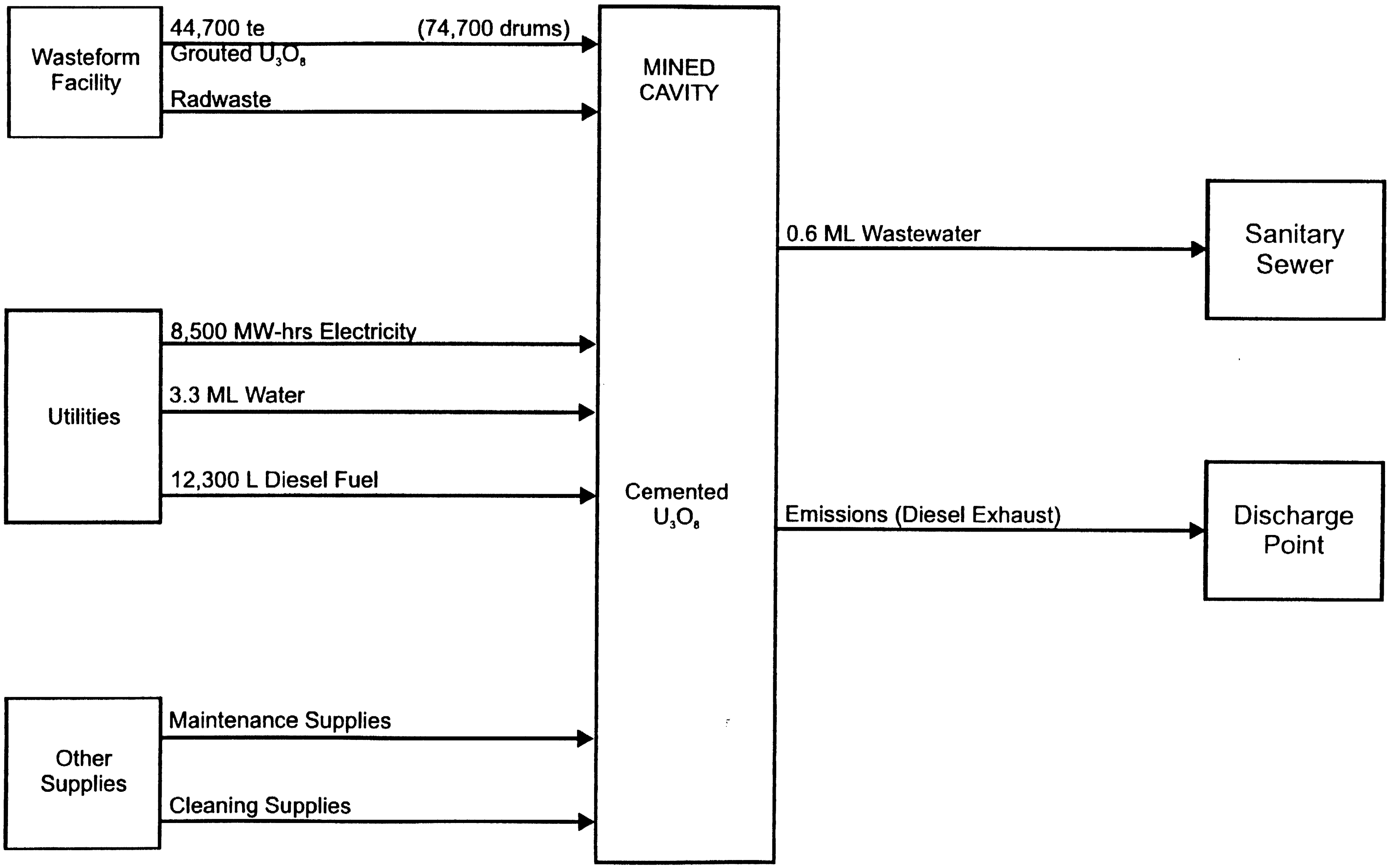


Figure 1.9a: U_3O_8 Palletized, 55-Gallon Drum Storage Within a 21-Foot-Wide Mined Repository Drift

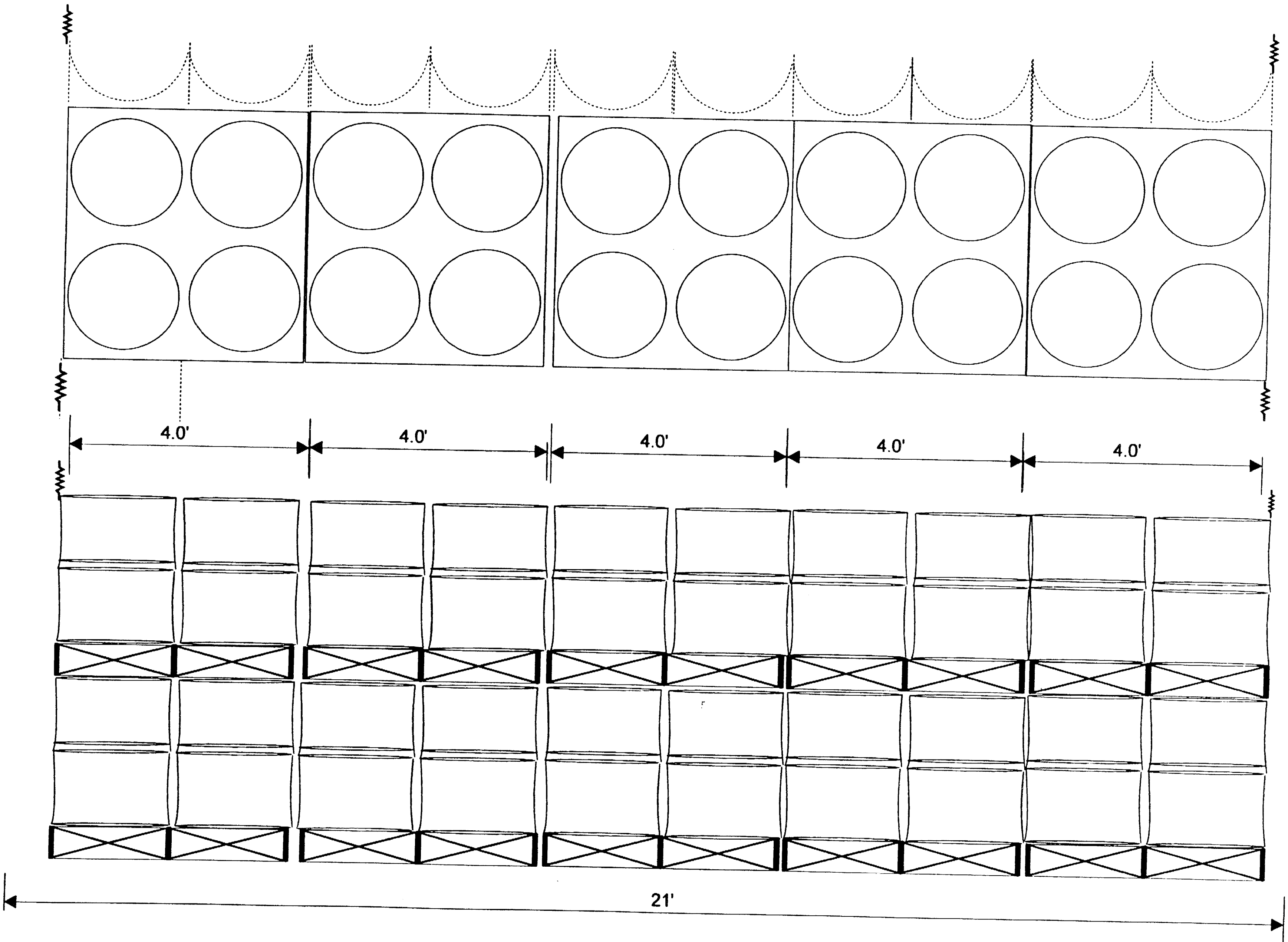
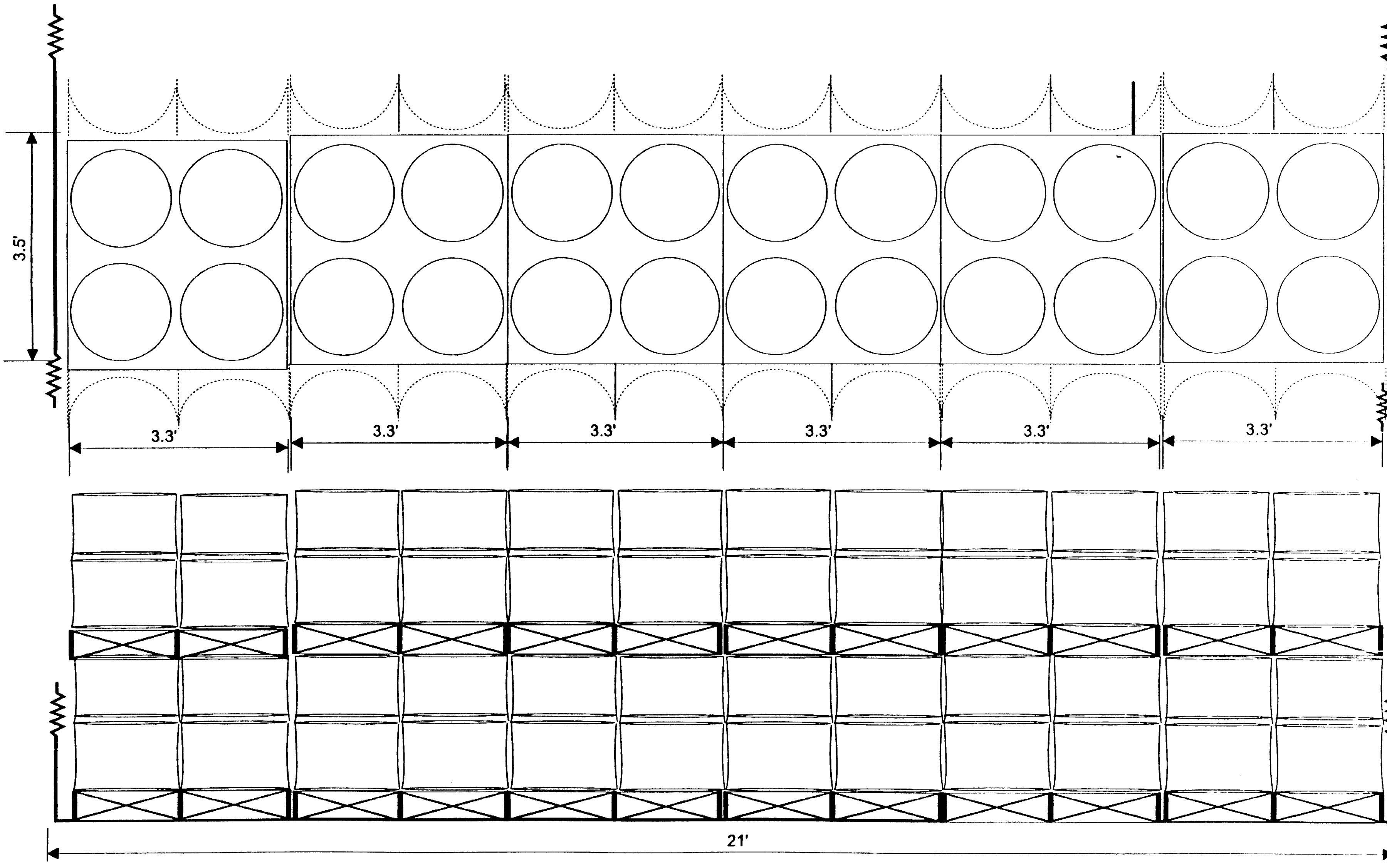


Figure 1.9b: UO_2 in Palletized, 30-Gallon Drum Storage Within a 21-Foot-Wide Mined Repository Drift



2.0 DESCRIPTION OF THE FACILITIES

This section contains the description of the wasteform facility and the disposal facility alternatives, based on grouted octaoxide as the wasteform product. Ungrouted U_3O_8 and grouted and ungrouted versions of UO_2 are treated in sections 2.1.2, 2.2.2, 2.3.2, and 2.4.2. The approach assumes collocation of the wasteform and disposal facilities to minimize transportation requirements. In operation, the U_3O_8 would be received at the facility in steel-drum containers.

There is some overlap in facilities needed by Wasteform Facility personnel and Disposal Facility personnel. It should be assumed that the buildings and structures described in the Wasteform Facility sections would be present regardless of the disposal option selected. The respective Disposal Facility sections will address only those facilities unique to that option.

There are two secondary waste streams generated by the facilities described in this section. The inorganic spray solution used to decontaminate the drum exteriors is treated as an aqueous liquid, and the cotton waste wipes used to decontaminate the drum exteriors are treated as combustible debris. Table 2.1 provides treatability categories of secondary waste streams.

2.1 Wasteform Facility

The Depleted Uranium Wasteform Facility is the interface between the UF_6 conversion facility and disposal of the depleted uranium oxide, or other conversion product form. Several forms of depleted uranium oxide are considered as the disposal form. The base case wasteform is cemented U_3O_8. Three alternative forms being considered are (a) U_3O_8 in containers, (b) cemented UO_2, and (c) UO_2 in containers.

The Wasteform Facility provides space and equipment for the following functions:

- Receiving depleted UF_6 conversion product (U_3O_8 in the base case) from the conversion plant
- Lag storage of conversion product prior to wasteform processing or disposal
- Processing to convert depleted uranium oxide products to a cemented form (only for the base case or alternative b)
- Storage of cemented depleted uranium oxide prior to disposal
- Storage of processing supplies

- Access to the wasteform for transportation for local disposal (the Wasteform Facility is assumed to be collocated with the disposal site). Transportation will be provided by the disposal facility.

- Facility support (Administration, Health Physics, Maintenance, Security)

Brief descriptions and layouts of the Wasteform Facility structures are provided for the proposed configuration of the facility.

2.1.1 Major Structures

The following structures compose the Wasteform Facility:

- Administration Building

- Product Receiving Warehouse

- Cementing Building

- Curing Building

- Supply and Shipping Warehouse

The buildings are described in the subsections that follow. The site layout is depicted in figure 2.1. With the benign nature of the materials to be handled, there is not likely to be any significant radiological or other hazard associated with the Wasteform Facility operations. The evaluation of potential hazards and the accident analyses will quantify the risk and will dictate specific design and construction requirements of the DOE and the NRC. It is possible that standard industrial practices for building design and materials usage may be employed.

2.1.1.1 Administration Building

Figure 2.2 represents the layout of the Administration Building. This building is located on the fenced perimeter of the site. The Security offices and foyer are located in the entrance to the building and adjacent to the vehicle gate so that both vehicle and personnel entry can be controlled from one station.

In addition to the security function, the Administration Building provides office space for the Site Manager, and the Operations, Health Physics, Plant Engineering, and Maintenance supervisors and their staffs. It is important that the Administration Building be a structurally sound facility because this is where all of the records will be kept and where the medical facility will be located.

2.1.1.2 Product Receiving Warehouse

Figure 2.3 represents the layout of the Product Receiving Warehouse. The receiving area incorporates four truck bays and one rail bay for receipt of conversion product (depleted uranium oxide). The depleted uranium oxide drums are unloaded using electrically powered fork lifts and other standard equipment.

Space is provided for storing depleted uranium oxide in its original shipping containers [assumed to be 208 L (55-gallon) drums containing a maximum of 625 kg U_3O_8 (1,380 lb) per drum]. The storage area is sized to accommodate 3 months of production from the depleted UF_6 conversion plant (8,940 drums). Daily receipts average 137 drums. Using a 60 cm (2 ft) square as the effective footprint of a drum, 1 day's receipts require 49.3 m^2 (530 ft^2). The total storage area required (footprint) for double-stacked pallets of four drums each is 1,610 m^2 (17,300 ft^2). A bridge crane with a capacity of 10 to 15 te (22,050 to 33,075 lb) will service the product storage area in order to minimize the spacing required for aisles.

After a receiving inspection for drum damage and external smearable contamination, clean drums will be stored double-stacked in the storage area. Damaged or contaminated drums will be stored in an impound area to await resolution of claims. Heat, ventilation, and air conditioning (HVAC) demands for the storage area of the Product Receiving Warehouse are minimal, requiring only what is necessary for the health and well-being of the workers in the area.

2.1.1.3 Cementing Building

Figures 2.4a and 2.4b depict the layout of the Cementing Building. This is a two-story building that houses the facilities for formulating, mixing, and pouring the cemented depleted uranium oxide product. The building includes facilities for receiving depleted uranium oxide containers from the Product Receiving Warehouse, new wasteform containers from the Supply and Shipping Warehouse, and recycled wasteform containers emptied during transfer. Cement and sand is made available from bulk storage hoppers located outside the building.

Processing features include:

- a drum elevator to convey U_3O_8 to the upper level of the building.

- a means for dust-controlled transfer of the depleted uranium oxide from drums into metering hoppers.

- a system for settling and metering the formulation of depleted uranium oxide, sand, cement, and any additives.

- a means for transferring the formulation to the high shear mixers.

- a means for decontaminating emptied depleted uranium drums which are not recycled. [The decontamination line consists of a vacuuming station, a monitoring station, and (if additional cleaning is found to be necessary) a dilute acid spray, rinse, and drying station. It is assumed that this treatment string will clean at least 95 percent of the drums to releasable limits.]

The formulation of grouted depleted uranium oxide for the purposes of this report is 1:1:2 cement to sand to depleted U_3O_8. The formulation will be measured and mixed using commercially available metering equipment. Cement and sand are conveyed from outdoor bulk storage hoppers into sand and cement metering hoppers in the Cementing Building. Depleted uranium oxide drums will be conveyed from the Product Receiving Warehouse into the Cementing Building and dumped under isolated ventilation control conditions into depleted uranium oxide metering hoppers. The grout mixture of cement, sand, and metered water will be initiated and the depleted uranium oxide added to the liquid slurry.

Wasteform drums (new and recycled) are conveyed into position to receive the wet cement from the mixer. The pouring stations are equipped with vibrators to eliminate air pockets. The filled drums are conveyed to firm, level, conveyor stands where the concrete is allowed to set (initial solidification). One to two days may be required for the product to achieve adequate solidification and strength before the drum can be moved to the curing unit.

Sections of the Cementing Building are individually partitioned, and the ventilation system is designed and balanced to isolate and provide radioactive contamination control for the handling of the dry, crystalline depleted uranium oxide, and the pouring of the wet cement depleted uranium oxide mixture (grout).

The production rate of 288 drums per day at 0.598 te (1,320 lb) per drum can be maintained with four, 3.82 m^3 capacity (5 yd^3) high shear mixers. Three mixers will be operated on a two-shift (16 hr), 5-day-per-week basis. A fourth mixer will be available for backup. The charge-mix-pour-prepare cycle time is estimated at 130 minutes assuming an 80 percent total overall efficiency factor.

After the filled drums are capped, and prior to their transfer to the Curing Building, the exterior of the drums will be monitored for decontamination and, if necessary, decontaminated using inorganic spray solutions and cotton waste wipes. The cotton waste will be accumulated and treated with other LLW.

The emptied drums will be visually examined to determine their suitability for recycling. Drums that pass the visual inspection will be returned to the Cementing Building for storage, while drums that have not maintained their structural integrity will be washed thoroughly and be sent to a scrap metal yard.

The Cementing Building includes the sampling and testing station for process control and verification. Test cylinders of the cement mixture will be poured and analyzed in accordance with the accepted process sampling plan.

2.1.1.4 Curing Building

Figure 2.5 represents the layout of the Curing Building. After the depleted uranium is cemented and poured into a drum, a curing period is provided to allow the cemented product to reach the physical characteristics required by the disposal WAC. It takes 1 month or more for the pour to reach 90 percent of its ultimate strength. The Curing Building provides a controlled environment for the curing to take place. Periodic inspection and monitoring of the cement temperature is conducted during this curing period. After each drum is certified to meet the criteria, it is transferred from the Curing Building to the Supply and Shipping Warehouse for pre-disposal storage (Mullkeff, 1995).

2.1.1.5 Supply and Shipping Warehouse

Figure 2.6 represents the layout of the Supply and Shipping Warehouse. This warehouse provides storage for site and process supplies and provides short-term lag storage for the cemented product prior to disposal.

2.1.2 Variations

Aside from the base case of cemented U_3O_8 discussed in the foregoing description of the facility structures, other possible variations include ungrouted U_3O_8, and grouted and ungrouted UO_2. Table 2.2 contains comparisons of the variations, all based on converting depleted UF_6 at an annual rate of 28,000 te/year (62 million lb/yr). The base case and the grouted UO_2 case would require new drums, as well as recycled drums for disposal, due to the increase in mass from grouting. However, either U_3O_8 or UO_2 in the ungrouted form would be disposed of in its original container.

2.2 Vault Disposal Facility

Vault disposal encompasses the use of an enclosed, engineered structure built for the purpose of near-surface disposal of LLW (Hertzler, 1994; Shuman, 1989). The vault may be at-grade, below-grade, or above-grade. Frequently, the design includes an earth cover and capping materials. In the United States, vaults have not been used for the disposal of commercial LLW.

The Savannah River Site (SRS) uses aboveground vaults for disposal of LLW arising from the treatment of high-level waste (HLW). The Hanford Site has also used vaults for LLW disposal. Vaults of varying designs have also been proposed for LLW disposal in several State compacts. To date, none have been approved and built. Vaults have been used for LLW storage at Chalk River and Whiteshell in Canada. These structures are cylindrical [around 6 m (20 ft) in diameter by 4 to 5 m (13 to 16.4 ft) high], but early versions were rectangular [61 m (200 ft) long by 4.9 m (16 ft) wide by 2.4 m (7.8 ft) tall]. Canada also uses storage vaults at two nuclear power plant sites in Ontario and New Brunswick. France has also used variations on the vault design for LLW disposal.

2.2.1 Major Buildings

2.2.1.1 The Vault

The disposal vault can be either below-grade [Below Grade Vault (BGV)] or above-grade [Above Ground, Earth Mounded Concrete Vault (AGEMCV)]. This approach uses a standard design for a BGV, modified for the circumstances of depleted uranium disposal. Figure 2.7 displays the conceptual approach for the vault, figure 2.8 provides dimensions, and figure 2.9 presents a vertical cross section. The design considers the individual vault to consist of five bays, each approximately 20 m (66 ft) long by 8 m (26 ft) wide by 4 m (13 ft) tall. This represents a maximum stacking of approximately four full-size or six half-size (30 gal) drums. The total loading per bay is around 1,800 full-size or 3,840 half-size drums. Thus, the total capacity per vault becomes 9,000 full-size or 19,200 half-size drums. As shown in figures 2.8 and 2.9, the floor of the facility consists of a 60-cm-thick (2 ft) reinforced concrete floor over a gravel subfloor of comparable thickness. The gravel rests upon a low permeability membrane that slopes and directs infiltrated water toward a drain. Drains within the vault also lead toward this main drain. The main drain subsequently flows toward a sump on one corner of the vault for leachate collection and treatment as necessary. Monitoring pipes can be installed at 30 m intervals for future sampling capabilities. Reinforced concrete, 30 cm thick (1 ft), comprises the outer walls of the vault. The inner walls between the bays are fabricated from normal concrete block.

Operationally, a crane fills each bay with drums from the top. Side entry is not an option due to the expected weight of the waste packages and the resultant size of equipment for moving more than one drum at a time. Once a level within a bay is filled, the interstitial spaces between the drums are filled with gravel and compacted. A temporary liner covers each bay until the entire vault is filled. Then, operations cast a nominal 1-m-thick (3 ft) top slab over the entire filled vault. This top slab slopes gently toward the sides with about a 1 percent grade. Additional operations place several membrane barriers and engineered features in place, prior to grading and planting of vegetation. Figure 2.10 depicts a closed, filled vault. For the base case of grouted U_3O_8, about 169 vaults are required.

2.2.1.2 Other Buildings

The wasteform buildings discussed in section 2.1.1 constitute the other major buildings at the Vault Disposal Facility.

2.2.2 Variations

The three variations reduce the number of vaults in the facility. Ungrouted U_3O_8 requires 81 vaults, grouted UO_2 uses approximately 35 vaults, and ungrouted UO_2 requires 23 vaults.

2.3 Engineered Trench Disposal Facility

2.3.1 Major Structures

Other than the facilities described in the Wasteform Facility section, the only other structure for this option will be the trenches themselves. Prior to excavation of an engineered burial trench, the top sandy layer of soil is completely removed from the area. Clay is then brought to the area and compacted to high density to construct an upper barrier wall. The compacted clay serves two purposes: it prevents the walls from collapsing or caving in, and it ensures that the waste is surrounded by a relatively impermeable barrier. The trench is excavated to a depth of 8 m (26 ft) (this holds true regardless of the wasteform used). Along the floor's lower side, a 0.6-m French drain is constructed and filled with small stones. Monitoring pipes can be installed at 30-m intervals for future sampling capabilities. Two sumps, 1.2 m by 1.2 m (3.8 ft by 3.8 ft) and extending 1.2 m (3.8 ft) below the trench floor, are constructed at 152-m (500 ft) intervals, filled with stone, and serve as collection points for water. Pervious sand is added to the trench floor for several reasons: (a) to provide a firm and level base for the waste up to 1 m (3.3 ft) thick, (b) to provide a porous medium for rainfall (into the open trench) to move easily to the French drain and sumps, and (c) to provide a buffer zone for the unlikely rise of the water table. Figure 2.11 illustrates the trench elements (U.S. NRC, 1983; U.S. NRC, 1982).

The current plan requires that one trench be opened and closed every year for 20 years, resulting in 20 trenches. A distance of 4.9 m (16 ft) should separate each trench to ensure stability of the trench walls and to allow room for equipment and machinery.

After the trench is full, a minimum of 0.6 m (2 ft) of clay is added and a 4,536-kg vibrating compactor is used to accelerate the settling process. Topsoil overburdened of at least 1 m (3.3 ft) is added over the clay. To minimize infiltration of precipitation, all new trench cappings are overlapped and sloped, and topped with a clay cover. To the extent practical, covers must be designed to minimize water infiltration, direct percolating or surface water away from the disposed waste, and resist degradation by surface geologic processes and biotic activity. Surface features must direct surface water drainage away from disposal units at velocities and gradients that will not result in erosion which will require ongoing active maintenance in the future (U.S. NRC, 1983).

Improvements can be made in the trench design to isolate the buried wastes from the environment and minimize any radionuclide migration of LLW. Possible features that could be included are as follows:

- Incline the trench bottom to facilitate drainage toward one end and incorporate an appropriately sized sump or drain to allow eventual removal of water that may accumulate in the trench.

- If the soil comprising the trench bottom has a low ion-exchange capacity, a minimum of 5 cm (2 in.) of clay may be mixed in the bottom to provide increased ion-exchange capacity. This can probably be accomplished without increasing the tendency of the trench to retain water in the waste region.

- Provide a drainage ditch at least 0.3 m (1 ft) square along the bottom of one or both walls of the burial trench filled with crushed rock. This will help prevent contact with any water that may infiltrate the trench walls.

- Provide a sump or drain at the lower end of the trench with a means for sampling and pumping out any accumulated trench water.

- Process all trench water that has been removed from the sump or drain. This can be done by passing it through an ion-exchange column to remove radionuclides before discharging the water to the environment or by evaporation to prevent its acting as a means of transporting radioactive materials (U.S. NRC, 1979).

2.3.2 Variations

The basic layout of the trench would remain the same for each of the variations; however, all three variations would reduce the size of each trench and the resulting size of the disposal site. These details are discussed later in section 3.5.

2.4 Mined Cavity Disposal Facility

For the base case of depleted U_3O_8 grouted and packaged in 55-gallon drums, a 1.2-m (4 ft) repeating section in a 6.5-wide-m (21 ft) drift will accommodate 40 55-gallon drums, containing about 10 te (22,000 lb) of uranium. Thus, the depleted uranium mined repository would have a vastly denser emplacement of uranium, and consequently, much greater economy in use of space and tunneling than the Yucca Mountain repository, as discussed in section 1.6. Table 1.6 in

Chapter 1 summarizes the drift tunneling lengths and total underground acreage required for the base case and three variations. It is based upon the foregoing data and observations, and the further assumption that drift tunnel spacing is maintained at 38.5 m (125 ft), as in Yucca Mountain.

Thus, it may be seen that the underground area and drilling requirements for a mined repository for depleted uranium need only be 7 to 30 percent as large as these requirements for the Yucca Mountain repository despite the fact that over five times as much uranium (by weight) must be accommodated.

2.4.1 Major Buildings

The surface site of the mine cavity repository will include all of the major structures described in section 2.1.1 as Wasteform Facility structures. These include an Administration Building for performing security functions; for housing administrative, operations, and maintenance management and staff; and for training, health physics, and decontamination functions.

In addition to the Administration Building, there will be a facility for waste product receiving and inspection, grouting and curing, and a supply and shipping warehouse.

The surface site should also include a general facilities support area, fashioned after the Yucca Mountain central surface facilities area, with the following major buildings/facilities: (a) fire station, (b) motor pool and service station, (c) surface and underground ventilation air conditioning and handling, (d) shops, and (e) medical center. Figure 2.12 illustrates a conceptual layout of the mined cavity.

2.4.2 Variations

The major structures described in section 2.4.1 would be required in all four cases considered in this report (i.e., the base case and the three variations).

Because of the differences in wasteform and in packaging among the four cases, however, the extent of tunneling required for underground emplacement drifts would be different in each case. These variations were noted earlier in Chapter 1, table 1.6. Although no "major structures" as such would be required underground, it should be noted that all tunnels, whether they are excavated for the purpose of access between the surface and underground facilities or for waste emplacement, are lined with 15 cm (6 in.) of reinforced concrete and are provided with paved roadways.

2.5 General Design and Safety Criteria

The approach presented for the disposal facilities constitutes a pre-conceptual design level, and as such, specific design features, safety criteria, and hazards mitigation are not possible. However, the following general design and safety criteria would be applicable to either DOE or NRC-licensed facilities:

- Double confinement
- Use of high-integrity components, including welded piping
- Logical integration of process operations
- Full sprinkler and fire protection in the buildings
- Application of As Low As Reasonably Achievable (ALARA), including automated operation

DOE and NRC regulations generally require double confinement of radioactive materials, including depleted uranium. This means that there exists at least two barriers between the uranium and the environment. The design accomplishes this primarily by placing all piping, equipment, and operations within buildings. Hence, the piping represents the first level of confinement, and the building constitutes the second level. Potential emissions and effluents are treated (at least filtration) at least twice prior to discharge. Chemicals are also stored with double confinement.

The design applies proven, high-integrity components and materials. Welded piping is used as much as possible; the few joints are for anticipated maintenance requirements, and are primarily flanged. Specific materials of construction would be identified during more detailed design efforts. However, this design identifies materials with proven service in the expected operating environments.

The design integrates the process operations where it appears logical. This does not represent process optimization. However, the design incorporates recycle streams for water, thus eliminating some resource utilization and waste generation.

The buildings have full fire protection. The design achieves this by having sprinklers, separate compartments, and other systems in all of the buildings.

The design applies the ALARA concept as much as possible at this preconceptual design level. Most of the operations are assumed to be automatic and operated from central control rooms. Purging and decontamination are required prior to maintenance. The site arrangement and layout (see section 3) incorporate a separate, Radiological Control Area (RCA) for the processing of uranium, with distances between the processing areas and the site boundaries that mitigate the effects of potential accidents.

The three subsections that follow discuss other aspects of general design and safety criteria.

2.5.1 Natural Phenomena Hazards Mitigation

It is DOE policy to design, construct, and operate its facilities so that workers, the general public, and the environment are protected from the impacts of natural phenomena hazards. DOE Order 5480.28, Natural Phenomena Hazards Mitigation (NPHM), identifies the responsibilities and requirements to execute this policy in a consistent manner.

The overall strategy for NPHM should be consistent with the graded approach illustrated in the Safety Analysis Report (SAR). The selection of structures, systems, and components (SSCs) that require NPHM design should be based on the safety classifications developed for the SSCs as established by the SAR. Mission importance and economic considerations should also be used in selecting these components. Once these SSCs are assessed, DOE Order 5480.28 specifies the hazard requirements to ensure that the components are adequately designed to resist natural phenomena hazards.

The natural phenomena hazard standard DOE-STD-1020-94 was developed from UCRL-15910, and provides criteria to follow for design of new SSCs so that DOE can evaluate and upgrade SSCs against the effects of such hazards as earthquakes, flooding, and extreme wind. DOE-STD-1020-94 is used consistently throughout all DOE sites and provides the means to implement DOE Order 5480.28 for all NPHM and to comply with DOE's safety policy, SEN-35-91.

DOE-STD-1020-94 essentially replaces the four category hazard ranking system of UCRL-15910 with five performance categories (see table 2.3).

The design and evaluation criteria for SSCs in Performance Categories 0, 1, and 2 are similar to those given in model building codes. Performance Category 0 recognizes that for certain lightweight equipment items, furniture, etc., and for other special circumstances where there is little or no potential impact on safety, mission, or cost, design or evaluation for natural phenomena hazards may not be needed. Assignment of an SSC to Performance Category 0 is intended to be consistent with, and not take exception to, model building code natural phenomena hazard (NPH) provisions. Performance Category 1 criteria include no extra conservatism against natural phenomena hazards beyond that in model building codes that include earthquake, wind, and flood considerations. Performance Category 2 criteria are intended to maintain the capacity to function and to keep the SSC operational in the event of natural phenomena hazards. Model building codes would treat hospitals, fire and police stations, and other emergency handling facilities in a similar manner to DOE-STD-1020 Performance Category 2 NPH design and evaluation criteria.

Performance Categories 3 and 4 SSCs handle significant amounts of hazardous materials or have significant programmatic impact. Damage to these SSCs could potentially endanger worker and public safety and the environment or interrupt a significant mission. As a result, it is very important for these SSCs to continue to function in the event of a natural phenomena hazard, such that the hazardous materials may be controlled and confined. For these categories, there must be a very small likelihood of damage due to natural phenomena hazards. DOE-STD-1020 NPH criteria for Performance Category 3 and higher SSCs are more conservative than requirements found in model building codes and are similar to DOD criteria for high risk buildings and NRC criteria for various applications as illustrated in table 2.4. Table 2.4 illustrates how DOE-STD--1020 criteria for the performance categories defined in DOE 5480.28 compare with NPH criteria from other sources.

For Performance Category 1 SSCs, the primary concern is preventing major structural damage or collapse that would endanger personnel. A performance goal annual probability of exceedance of about 10^{-3} of the onset of significant damage is appropriate for this category. This performance is considered to be consistent with model building codes at least for earthquake and wind considerations. The primary concern of model building codes is preventing major structural failure and maintaining life safety under major or severe earthquakes or winds. Repair or replacement of the SSC or the ability of the SSC to continue to function after the occurrence of the hazard is not considered.

Performance Category 2 SSCs are of greater importance due to mission-dependent considerations. In addition, failure of these SSCs may pose a greater danger to onsite personnel than Performance Category 1 SSCs because of operations or materials involved. The performance goal is to maintain both capacity to function and occupant safety. Performance Category 2 SSCs should allow relatively minor structural damage in the event of natural phenomena hazards. This is damage that results in minimal interruption to operations and that can be easily and readily be repaired following the event. A reasonable performance goal is judged to be an annual probability of exceedance of between 10^{-3} and 10^{-4} of structure or equipment damage, with the SSC being able to function with minimal interruption. This performance goal is slightly more severe than that corresponding to the design criteria for essential facilities (e.g., hospitals, fire and police stations, centers for emergency operations) in accordance with model building codes.

Performance Category 3 and higher SSCs pose a potential hazard to public safety and the environment because radioactive or toxic materials are present. Design considerations for these categories are to limit SSC damage so that hazardous materials are controlled and confined, occupants are protected, and functioning of the SSC is not interrupted. The performance goal for Performance Category 3 and higher SSCs is to limit damage such that DOE safety policy is achieved. For these categories, damage must typically be limited in confinement barriers (e.g., buildings, gloveboxes, storage canisters, vaults), ventilation systems and filtering, and monitoring and control equipment in the event of an occurrence of severe earthquakes, winds, or floods. In addition, SSCs can be placed in Performance Categories 3 and 4 if improved performance is needed due to cost or mission requirements.

A quantitative assessment has been performed of the hazard ranking and performance category for the base cases of the wasteform facility and the three proposed disposal facilities (vault, engineered trench, and mined cavity). Table 2.5 summarizes the results of this assessment.

2.5.2 Design Engineering

The intent of design engineering is to ensure the application of sound engineering principles, and to ensure that appropriate consideration is given to the expected period of use, sound construction practices, quality assurance, energy conservation, decontamination and decommissioning requirements, and the appearance of completed facilities. Whenever feasible, these facilities shall be planned and a layout developed on the basis of relative discrete processing steps, grouped according to facility services, and shall be contained in process rooms to the extent practical. The engineering quality process involved to accomplish these characteristics include achieving minimum construction costs consistent with programmatic, environmental, security, and safety requirements; achieving technical adequacy; and achieving optimum economy in operation and maintenance in the design of the proposed facilities. State, municipal, county, and other local building codes should be reviewed for possible conflicts with these criteria. The design professional is encouraged to cooperate with local officials to accommodate the intent and requirements of local codes and regulations.

Flexibility is considered a major design requirement for all facilities, even those with specialized functions. The design shall provide sufficient flexibility to accommodate possible programmatic changes or operational modifications to the maximum extent practicable. The layouts and type of architectural, structural, mechanical, and electrical elements of all facilities shall address anticipated future needs. The placement of columns and beams shall be coordinated with the initial and estimated future equipment installations, utility services, and operational requirements. Design solutions shall demonstrate methods for modifications and expansion including modularity, additional capacities, and other techniques when justified as a functional requirement.

The design inspection process ensures that all activities during the construction process are constructed in accordance with plans and specifications, and that the quality of materials and workmanship remains consistent with the requirements of this project. The structures will be designed to meet the requirements of DOE Orders 4700.1, 6430.1A, and 5480.28; the Universal Building Code (UBC); and DOE-STD-1020-94.

2.5.3 Site Preparation, Structure, and Appurtenances

Design shall include any required improvements to the land, site preparation for surveying and mapping, clearing and excavating, and backfill/compacting.

Selection of the exterior wall systems should provide minimally acceptable requirements for facility design. However, the selection may be dictated by the governmental policy regarding various architectural environmental guidelines that require similar architectural elements be present on all buildings in a complex. Consideration shall be given to energy, heat loss, natural light requirements, and economics during the selection process.

Building concrete includes concrete on or below-grade, major concrete slabs, floors above-grade, equipment foundations, and miscellaneous concrete (i.e., thresholds, stairs, lintels, walks). Specifically it covers materials for forming, placing, and waterproofing concrete for building foundations, piers, grade beams, walls, columns, and slabs. Building concrete also includes all work associated with reinforcing steel, concrete encasement of structural steel columns, and any precast concrete requirements.

The structural design process will incorporate elements of risk assessment related to the level of risk associated with the operation of these facilities. Specific guidance should be obtained from DOE Order 5480.28. Erection of structural metals shall cover all materials for building superstructure steel, including crane rails and all steel members framed directly into the superstructure. This section is to include fabrication handling, hauling, erecting, and setting of base plates required to completely install the structural steel. It also includes materials required for process piping, structural steel supports and hangers, related base plates, operating platforms, ladders, interior and exterior metal door frames, toe plates, door and window lintels, metal sleeves in the building structure, and other miscellaneous structural steel and iron.

The conservation of energy will be considered in the design of all new mechanical systems. The architect-engineer (A-E) shall select equipment and/or the type of installation that provides the most cost-effective HVAC system (if applicable) that meets all requirements for a non-reactor processing facility. Mechanical equipment includes systems such as heating systems, ventilation systems, fire protection systems, and plumbing equipment, along with all associated piping, valves, controls, and instrumentation. Materials for filtration systems in connection with an environmental control system should also be considered.

Electrical design and installation will comply with applicable provisions of the National Fire Protection Association (NFPA) 70-1993, National Electric Code (NEC), DOE Order 6430.1A, and the American National Standards Institute (ANSI). Building electrical lighting systems will include the installation of the electrical lighting system for the various buildings from the low-voltage side of the unit substation or at the service entrance to the structures. The equipment will include lighting transformers, panels, circuits, fixtures, conduit, wire, and the complete installation of the emergency lighting system. The electrical power system will cover the installation from the building wall through the primary building substation and include equipment such as switchgear and transformers. Building instrumentation lines run from the point of connection at the equipment within the building up to and including the control room or equivalent.

Table 2.1 Treatability Categories of Secondary Waste Streams

Description of Secondary Waste Streams	Treatability Category
inorganic spray solution used to decontaminate exterior of drums	aqueous liquid
cotton waste wipes used to decontaminate exterior of drums	combustible debris

Table 2.2 Variations for the Wasteform Facility

	Quantity/Basis	Number of Depleted Uranium Oxide Containers Received	Depleted Uranium Oxide Storage Footprint - Double Tiered -	Number of Product (Output) Containers	Grouted Product Storage Footprint - Double Tiered -
Grouted U_3O_8 - **base case**	44,700 te/yr based on a formulation of 1:1:2 cement:sand:U_3O_8 @ 2.88 g/cm^3 (180 lb/ft^3)	715,000 55-gallon containers (35,750/yr)	1610 m^2 (17,300 ft^2) 3 months production of depleted UF_6 processing = 8940 drums one drum = 0.36 m^2	1,494,000 55-gallon containers (74,700/yr)	1120 m^2 (12,000 ft^2) 1 month production of U_3O_8 - grout = 6225 drums one drum = 0.36m^2
U_3O_8	22,350 te/yr based on 447,000 te	715,000 55-gallon containers (35,750/yr)	same as grouted U_3O_8 (above)	715,000 55-gallon containers (35,750/yr)	N/A
Grouted UO_2	28,670 te/yr based on a formulation of 1:3 cement:UO_2 @ 8.0 g/cm^3 (500 lb/ft^3)	420,000 30-gallon containers (21,000/yr)	656 m^2 (7060 ft^2) 3 months of production of depleted UF_6 processing = 5250 drums one drum= 0.25m^2	632,000 30-gallon containers (31,600/yr)	330 m^2 (3,540 ft^2) 1 month production of UO_2 - grout = 2634 drums one drum = 0.25m^2
UO_2	21,500 te/yr based on 430,000 te	420,000 30-gallon containers (21,000/yr)	same as grouted UO_2 (above)	420,000 30-gallon containers (21,000/yr)	N/A

Table 2.3 Structure, System, or Component Natural Phenomena Hazard Performance Goals for Various Performance Categories

Performance Category	Performance Goal Description[1]	NPH Performance Goal Annual Probability of Exceeding Acceptable Behavior Limits, P_F
0	No Safety, Mission, or Cost Considerations	No Requirements
1	Maintain Occupant Safety	$\sim 10^{-3}$ of the onset of SSC[2] damage to the extent that occupants are endangered
2	Occupant Safety, Continued Operation	$\sim 5 \times 10^{-4}$ of SSC damage to the extent that the component cannot perform its function
3	Occupant Safety, Continued Operation, Hazard Confinement	$\sim 10^{-5}$ of SSC damage to the extent that the component cannot perform its function
4	Occupant Safety, Continued Operation, Confidence of Hazard Confinement	$\sim 10^{-5}$ of SSC damage to the extent that the component cannot perform its function

(1) These performance goals are for each natural phenomena hazard (earthquake, wind, and flood).

(2) SSC refers to structure, distribution system, or component (equipment).

Table 2.4 Comparison of Performance Categories from Various Sources

Source	SSC Categorization			
DOE-STD-1020 - DOE Natural Phenomena Hazard Criteria	1	2	3	4
Uniform Building Code	General Facilities	Essential Facilities	--	--
DOD Tri-Service Manual for Seismic Design of Essential Buildings	--	--	High Risk	--
Nuclear Regulatory Commission	--		Evaluation of NRC Fuel Facilities	Evaluation of Existing Reactors
DOE UCRL-15910	None/ General	Low Hazard	Moderate Hazard	High Hazard

Table 2.5 Qualitative Assessment of Hazard Ranking for Wasteform Facility and Three Proposed Disposal Facilities (Base Cases)

Building/Area	Hazard Ranking/Category*	Qualitative Rationale
Wasteform Facility		
Administration Building	Low/Performance Category 2	Facilities must continue to function after a seismic event or an accident
Product Receiving Warehouse	Low/Performance Category 2	No offsite, minimal onsite consequences from non-radioactive materials
Cementing Building	Low/Performance Category 2	No offsite, minimal onsite consequences from non-radioactive materials
Curing Building	Low/Performance Category 2	No releases with consequences; facility must continue to function after a seismic event or an accident
Supply and Shipping Warehouse	None - General Construction Performance Category 0-1	Release fractions effectively zero
Disposal Facilities		
Vault	Low/Performance Category 2	No offsite, minimal onsite releases essential to mission
Trench	Low/Performance Category 2	No offsite, minimal onsite releases essential to mission
Mined Cavity	Low/Performance Category 2	No offsite releases, minimal onsite releases with consequences; essential to mission

*Appropriate hazard ranking per UCRL-15910 and approximate performance category per DOE-STD-1020-94.

Figure 2.1: Wasteform Facility Site Plan: Grouted U_3O_8 (Base Case)

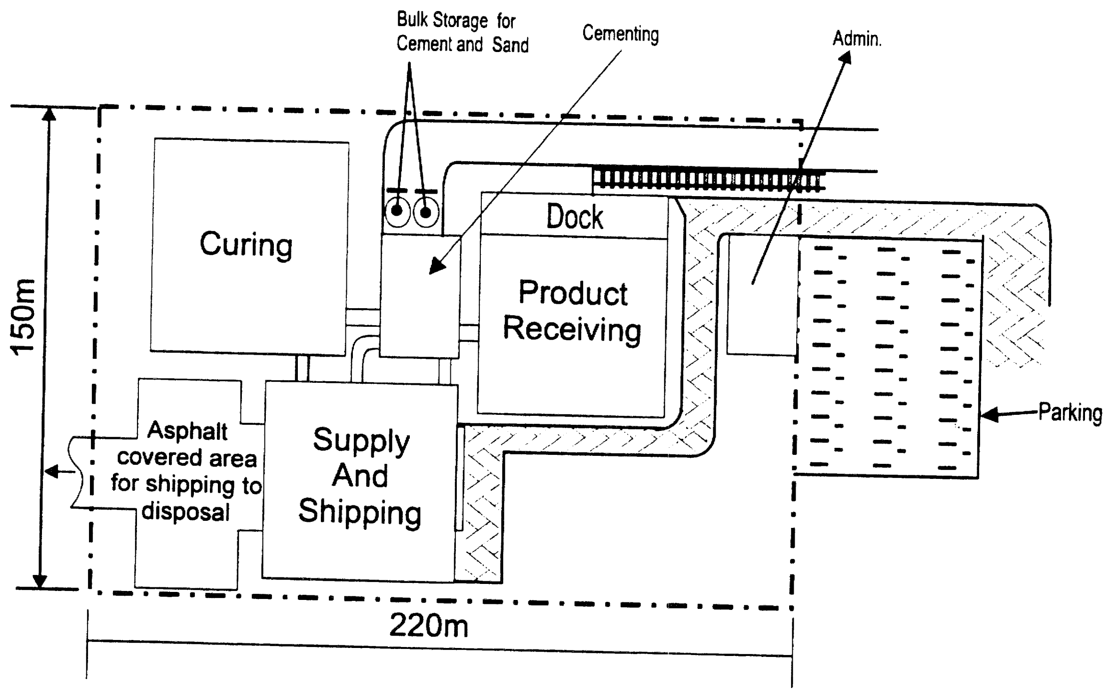


Figure 2.2: Layout of the Administration Building

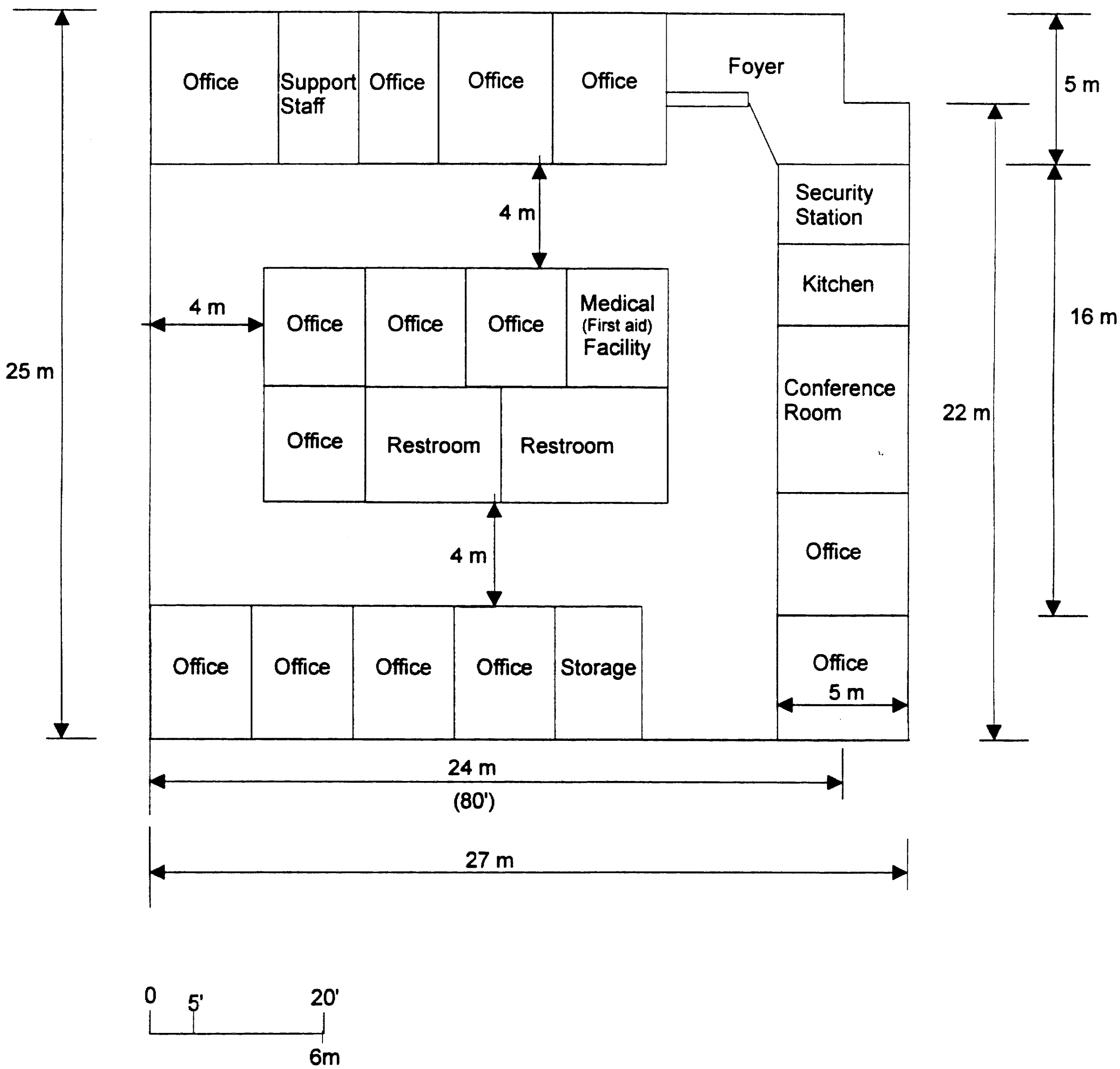


Figure 2.3: Layout of the Product Receiving Warehouse: Grouted U_3O_8 - (Base Case)

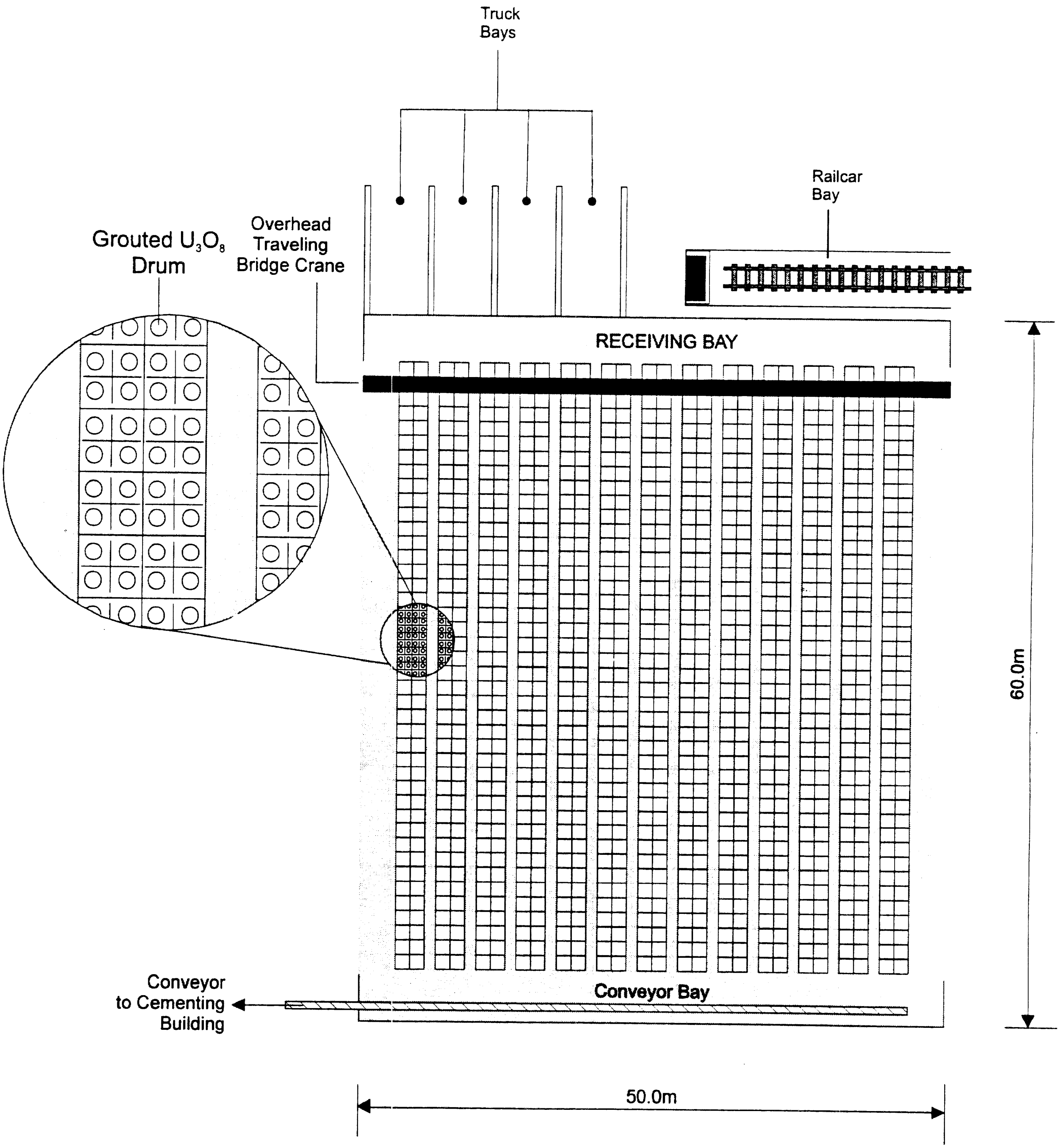


Figure 2.4a: Layout of the Cementing Building-First Floor: Grouted U_3O_8 (Based Case)

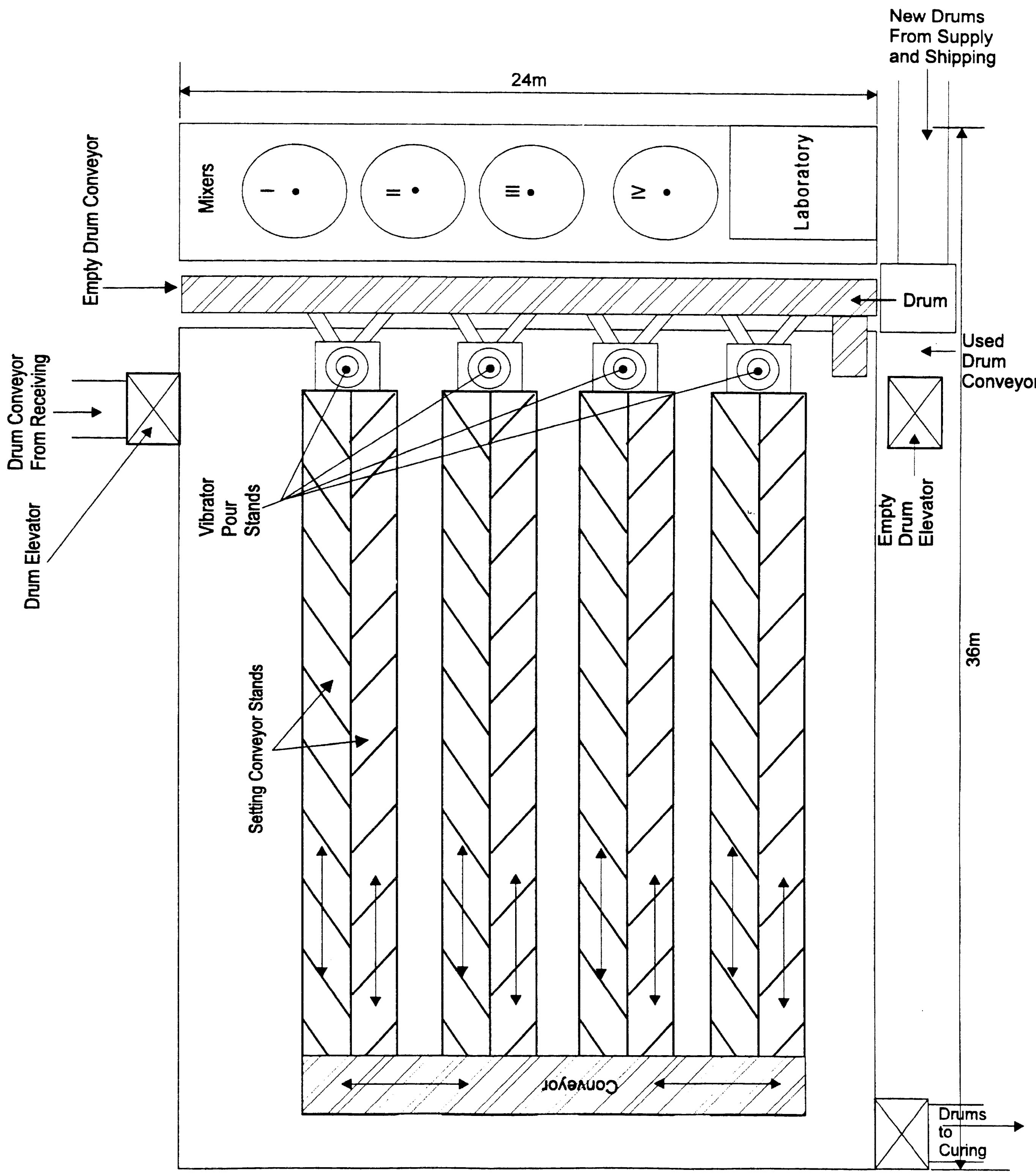


Figure 2.4b: Layout of the Cementing Building-Second Floor: Grouted U_3O_8 (Based Case)

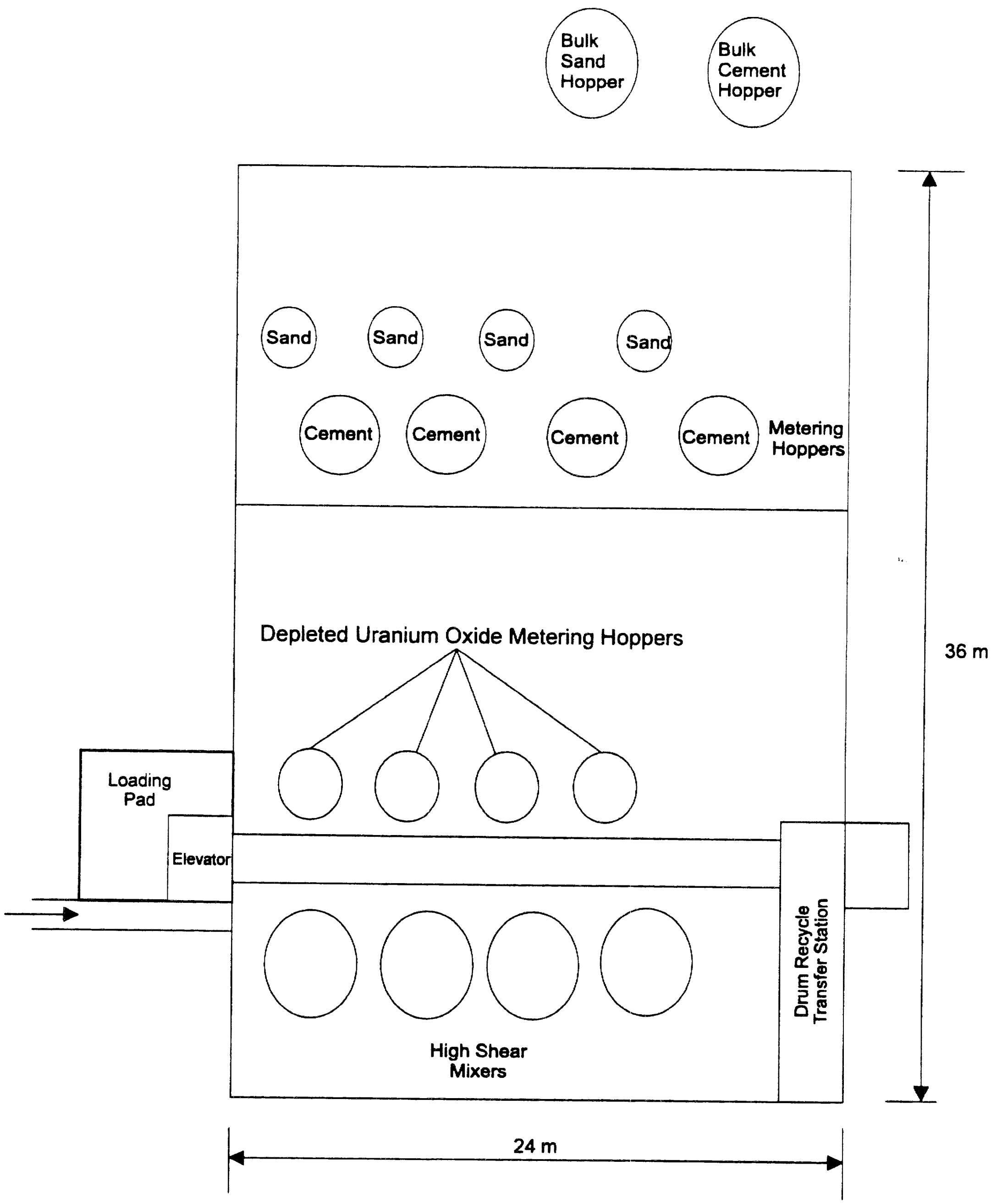


Figure 2.5: Layout of the Curing Building: Grouted U_3O_8 (Base Case)

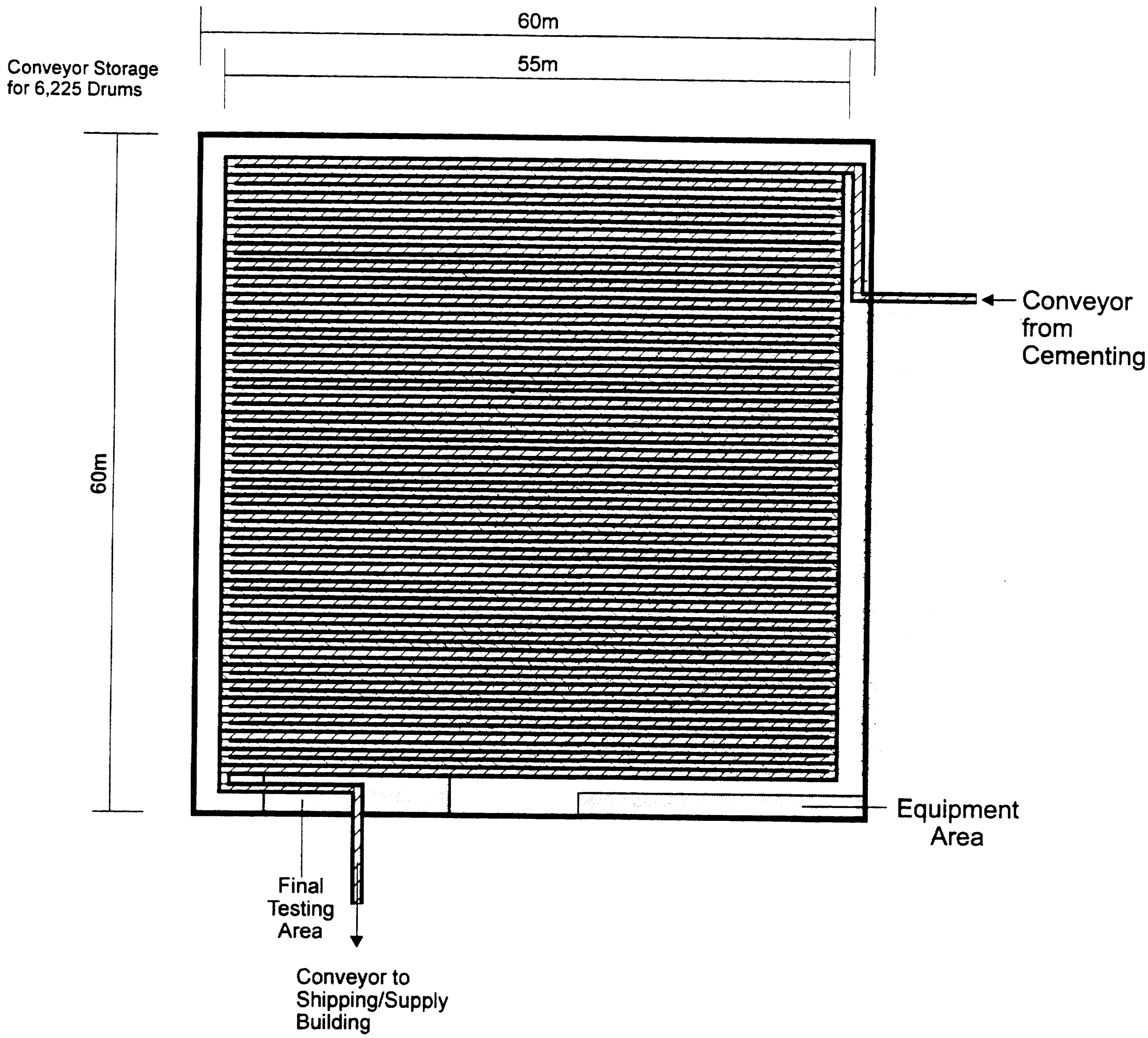


Figure 2.6: Layout of the Supply and Shipping Warehouse

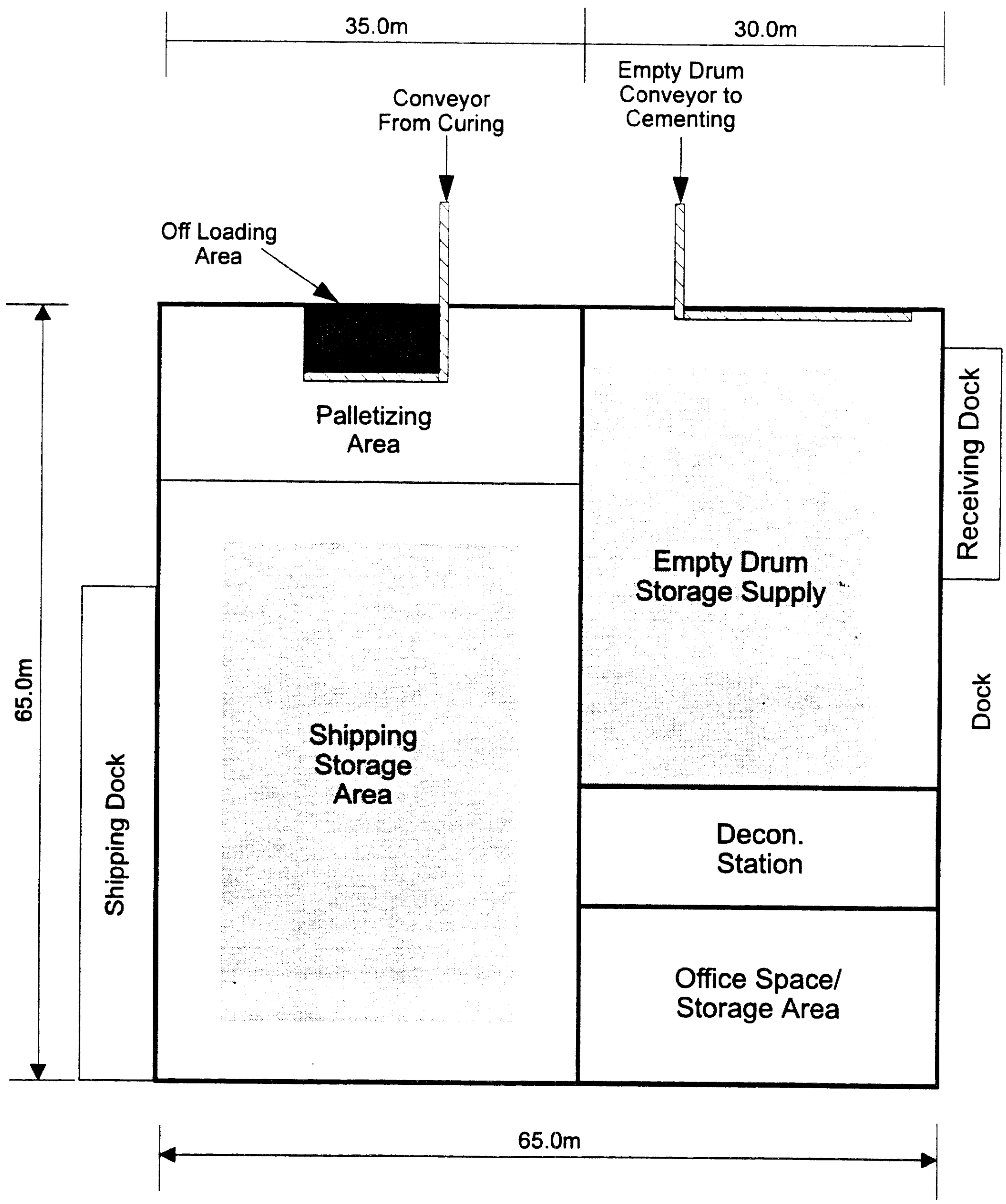


Figure 2.7 Conceptual Approach for Vault Disposal of Depleted Uranium

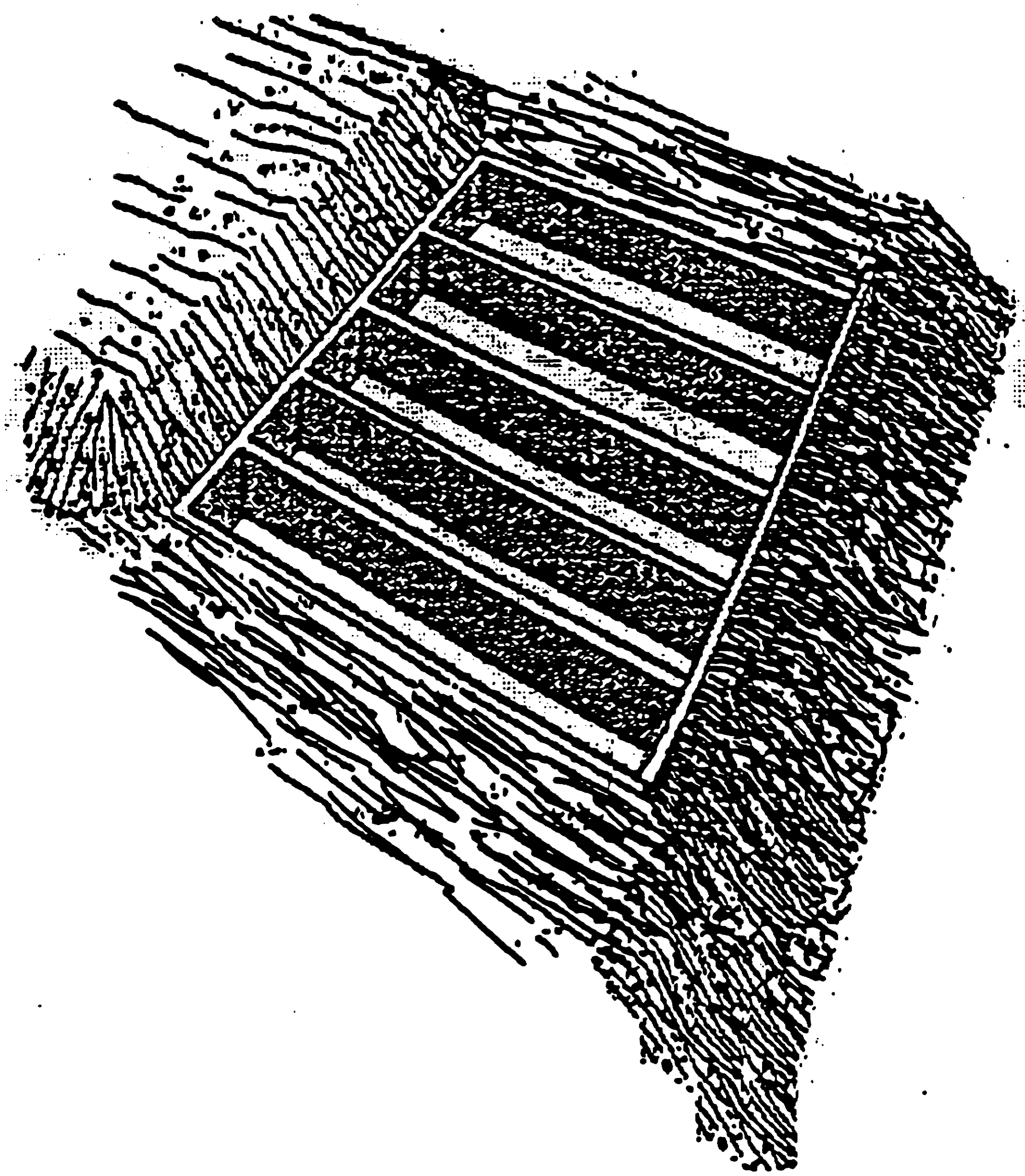


Figure 2.8: Horizontal Layout of an Individual Vault

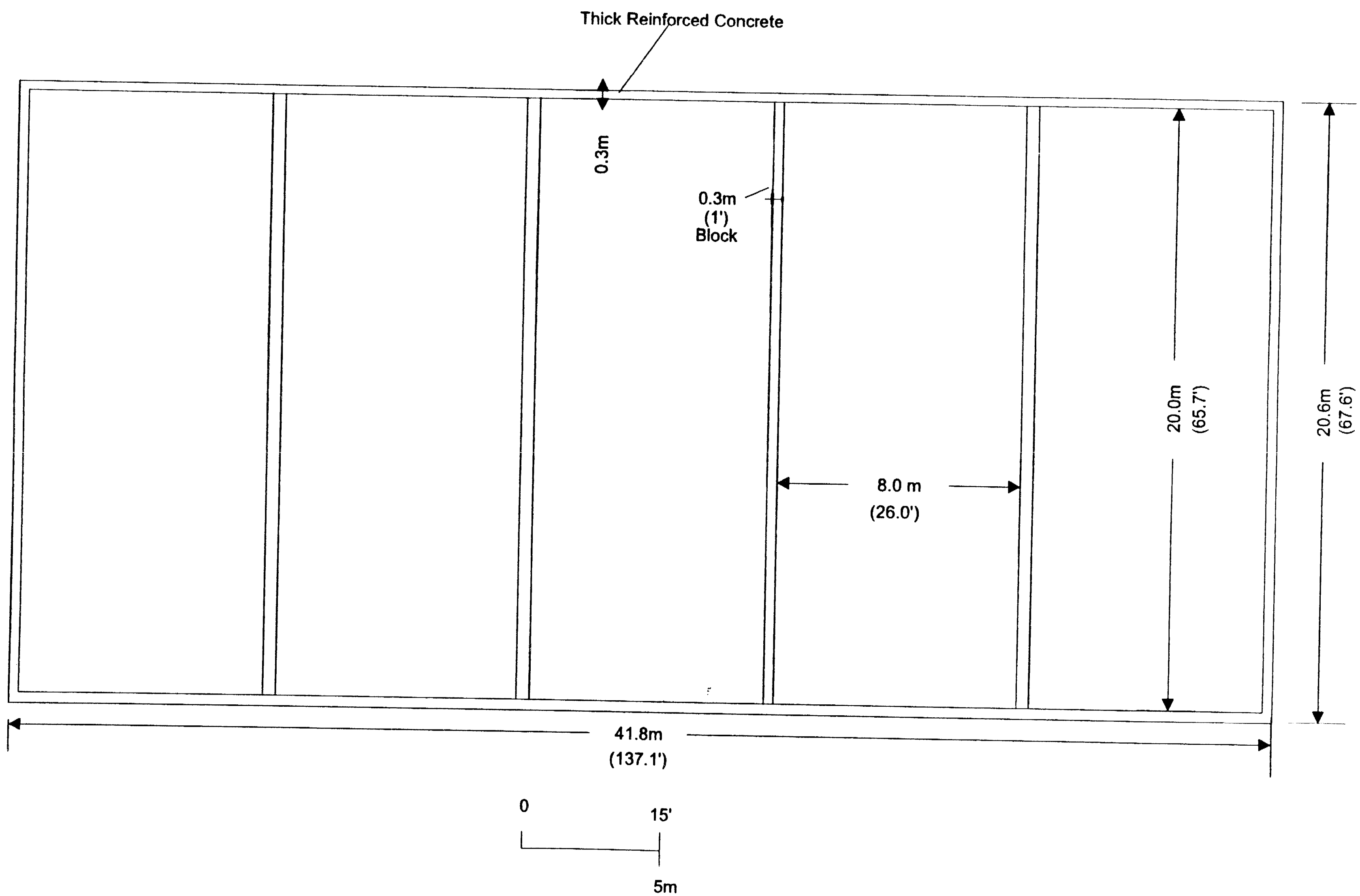


Figure 2.9: Vertical Section through the Disposal Vault

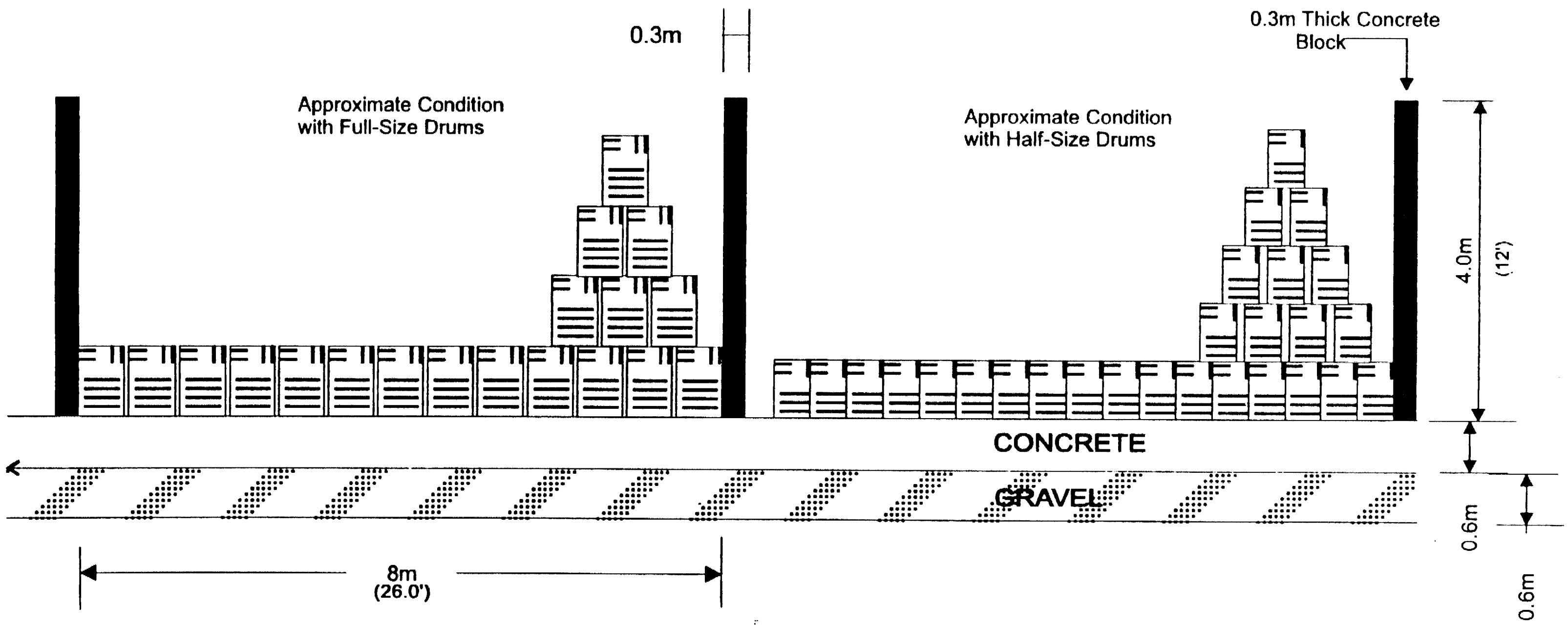


Figure 2.10: Vertical Cross Section of a Completed, Filled Vault

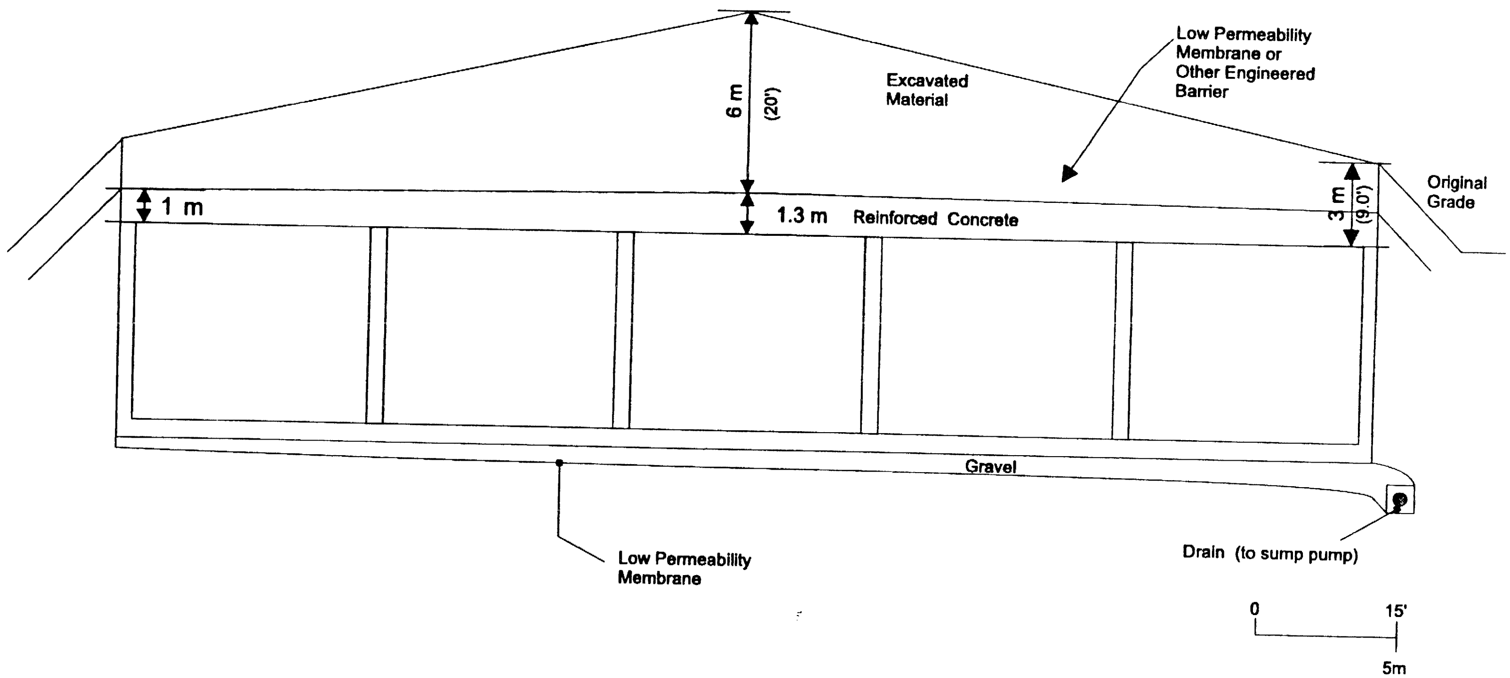


Figure 2.11: Trench Elements

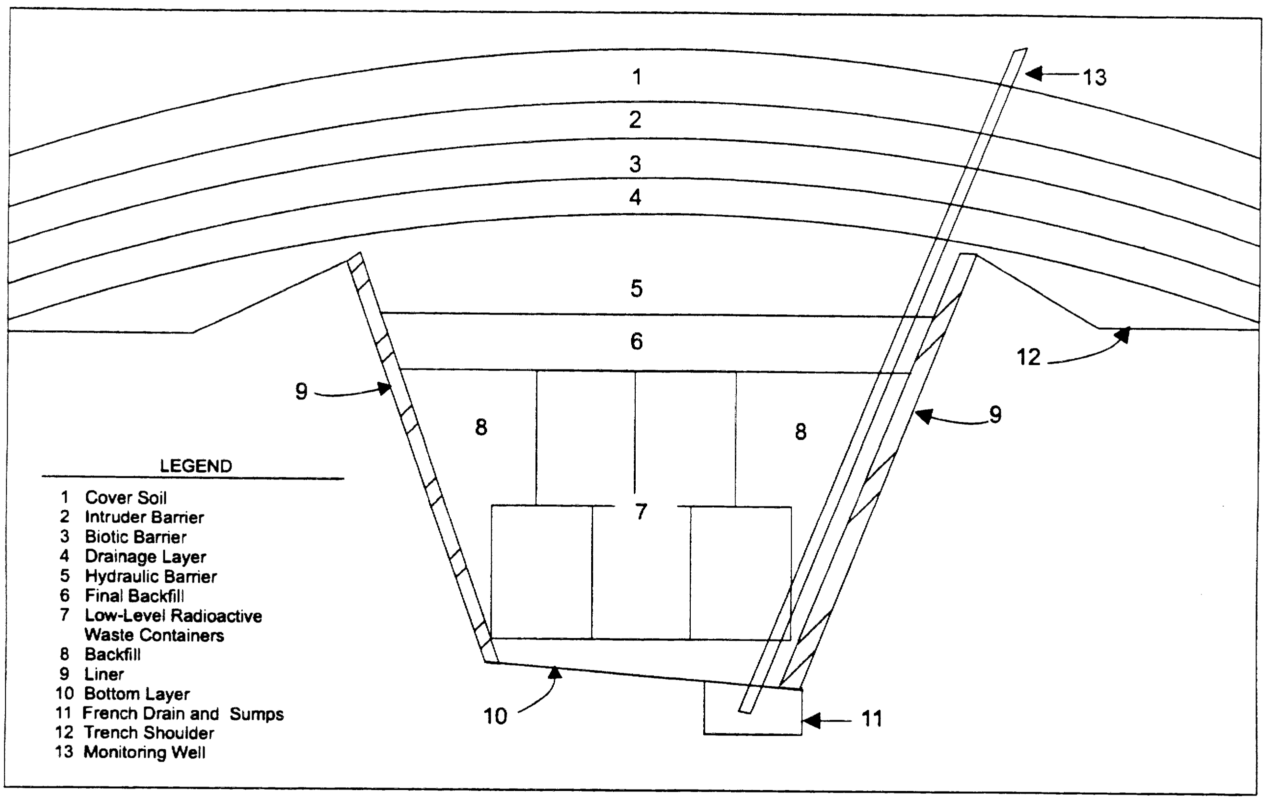
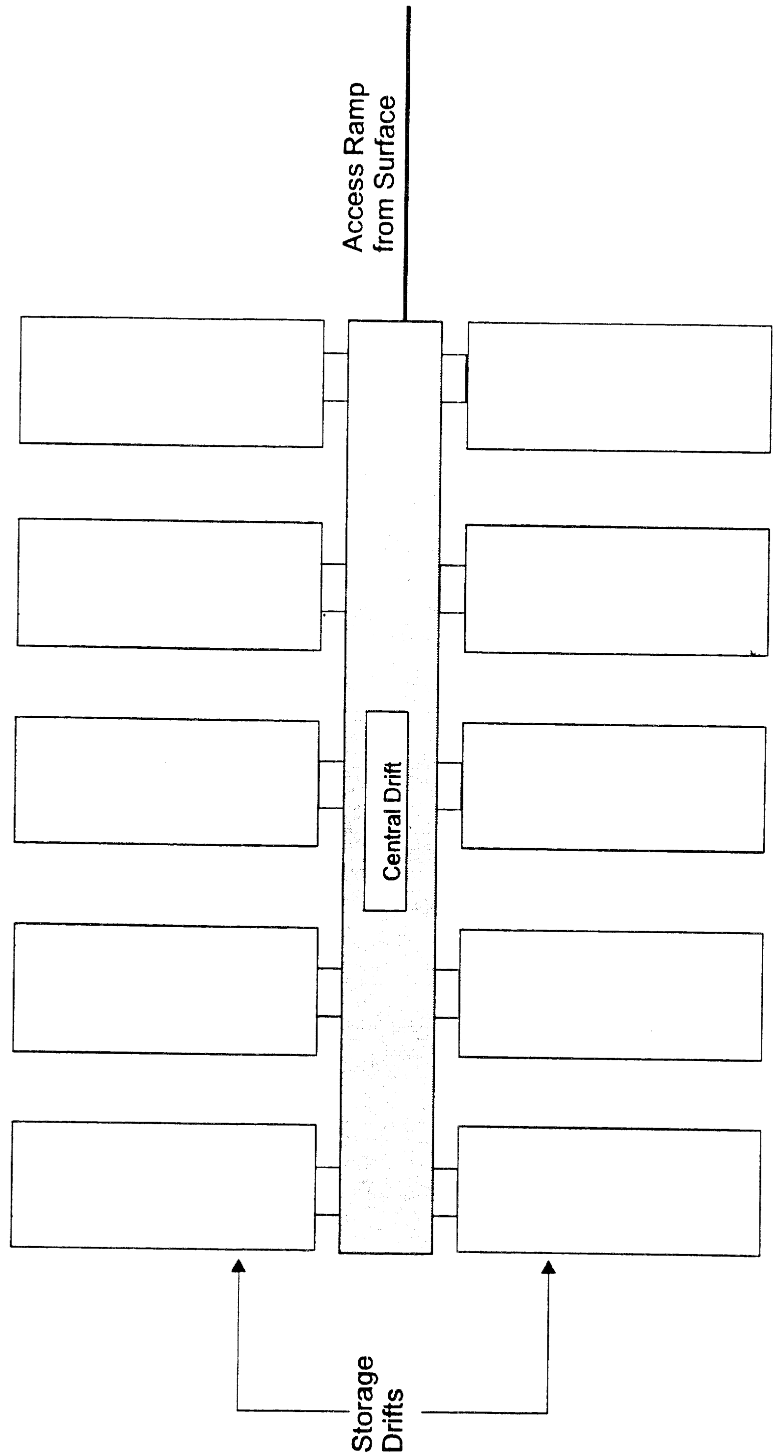


Figure 2.12: Conceptual Layout for Mined Cavity Disposal of Depleted Uranium Oxide



3.0 SITE MAPS AND USAGE REQUIREMENTS

The design assumes a reasonable industrial site is selected. Access to an all-weather road suitable for use by a maximum legal weight semitractor and trailer is essential. Access to a railroad spur is an option, the necessity of which will be determined by the ongoing evaluation of the Depleted Uranium Disposal Project. Utilities assumed to be available at the site are electricity, natural gas, potable water, and sanitary sewer. Telephone service is required. If any of the utilities or services noted above are not available, consideration must be given in the site design to providing for them. The approach assumes that clearing and grading will be relatively minor and limited to those areas immediately surrounding the planned locations of the buildings and disposal facilities. Site area does not change as the facility is completed and operations are initiated. The site approach uses the typical DOE/NRC approach, with initial property fence lines and markers surrounding a fenced-in controlled area.

A security system typical of a low-hazard commercial industrial system will be employed primarily to limit liability. Any radiation control area required will be designed in accordance with DOE or NRC regulations.

3.1 Wasteform Facility

3.1.1 Site Map and Land Area Requirements During Construction

Figure 3.1 depicts the proposed arrangement at the Wasteform Facility site during construction. Initially, roadway access would be prepared and a gravel road to the site established for construction vehicles. Trailers for the construction site would be located on the area adjacent to the proposed parking lot. When the necessary clearing has been done, the boundary markers and a substantial portion of the fencing would be installed. Gravel roads would be laid following the routes of all of the final roads.

3.1.2 Site Map and Land Area Requirements During Operations

Figure 3.2 depicts the proposed site layout (map) for operations. The site perimeter fence and the controlled area fence are the same. One wall of the Administration Building serves as a section of fence. The entrance to the site is controlled by a security station housed in the Administration Building. Both pedestrian and vehicle access and egress are controlled by guards located at this station. Table 3.1 provides footprint areas for the buildings. Table 3.2 summarizes site land parameters.

3.2 Vault Disposal Facility

3.2.1 Site Map and Land Area Requirements During Construction

The construction layout organizes the disposal area into 10-vault (2 by 5) blocks. A paved, 10-m-wide (~30 ft) road encircles each block. The lateral distance between vaults is 25 m (75 ft), while the longitudinal distance is 20 m (60 ft). This provides adequate room for the excavated material and working equipment. The overall dimensions of each 10-vault block become 250 m (750 ft) long by 140 m (462 ft) wide. The total site area for 169 vaults is 56 ha (140 acres).

3.2.2 Site Map and Land Area Requirements During Operations

Figure 3.3 displays the site map during operation of the vaults. Although this analysis separates operations from vault construction, in reality a 10-vault block would be constructed and filled annually. The paved roads provide easier passage for the trucks carrying the depleted uranium, and the gravel roads provide the surface for tracked cranes and other loading equipment. After closure, the roads provide access to the vaults for surveillance and monitoring. Table 3.3 summarizes site parameters.

3.3 Engineered Trench Disposal Facility

The current DOE inventory of UF_6 is 560,000 te (1.2 billion lb). The base case scenario for this report is the U_3O_8 cement-encapsulated form, which translates to approximately 147,300 m^3 (5.2 million ft^3) total. In considering disposal over a period of 20 years, 74,700 drums with a capacity of 55 gallons each would be needed each year. Based on practices elsewhere in the DOE system, the 4-drum pallets would be stacked three high in the 8 m (26 ft) trench. Based on this data, the U_3O_8 option would require approximately 0.94 ha (2.3 acres) of land per year for each trench.

The trench option is very flexible in terms of land utilization. Although the depth for a three-pallet-high trench is standard, the length and width are flexible parameters for this option. Shallow land disposal at the NTS uses trenches ranging in size from 4.5 to 6 m (15 to 20 ft) deep and 12 to 60 m (40 to 200 ft) wide, while the trenches at the Idaho National Engineering Laboratory (INEL) are generally 1.2 to 7.6 m (4 to 25 ft) wide, 6 to 7.6 m (20 to 25 ft) deep, and spaced about 5 m (16 ft) apart. Similar practices are used at Hanford.

For the purposes of modeling the depleted uranium trench disposal facility for grouted U_3O_8, a width of 60 m (200 ft) and a length of 157 m (515 ft) will be used with trenches spaced 20 m (66 ft) apart. Thus, for the trenches and the land separating them from each other, a minimum site size of 30.6 ha (76 acres) is required.

3.3.1 Site Map and Land Area Requirements During Construction

An access-controlled road from the Wasteform Facility would be created and a gravel road to the site established for construction vehicles. After the required clearing, the boundary markers and perimeter road would be installed. Gravel roads would be laid following the routes of all of the final roads. No permanent buildings for administrative and management personnel will need to be built, as such facilities will be shared with Wasteform Facility personnel.

3.3.2 Site Map and Land Area Requirements During Operations

In general, all trenches, road layouts, and support facilities would be designed to maximize land use and, therefore, increase waste capacity. Drainage ditches would be constructed between trenches and along access roads. Orienting the trenches so that the long axis is positioned more or less parallel to the ground-surface contours would reduce the time a given amount of surface runoff is in contact with a trench cover. Therefore, a smaller percentage of this runoff would be able to infiltrate into a trench's cover. Another advantage of this orientation is that any water infiltrating a trench would contact less waste as each trench's width is less than its end-to-end distance. Clay material and topsoil would be stockpiled adjacent to the trenches for sufficient intermediate covering material and final stabilization (U.S. NRC, 1982).

The exact location of each trench would be determined using the site's grid system. This grid system uses a baseline and reference points to determine both direction and distance. The boundaries and locations of each trench must be accurately located and mapped by means of a land survey. Near-surface disposal units must be marked in such a way that the boundaries of each unit can be easily defined. A buffer zone of land must be maintained between any buried waste and the disposal site boundary, and beneath the disposed waste. The buffer zone should be of adequate dimensions to carry out environmental monitoring activities and take mitigative measures, if needed (U.S. NRC, 1982).

The current plan is to use one trench per year for 20 years. In cases where a series of trenches have to be constructed on a slope, some advantage may be found in systematically placing the trenches so that the construction of a new trench takes place uphill from the completed trenches. Assuming that the covers over the trenches located downhill of the open trench are essentially complete and that their slope maximizes the runoff of precipitation falling on them, constructing the new trench uphill of the completed ones will be directing this "maximum runoff" away from an open trench rather than toward it. The amount of runoff generated uphill and around the open trench should be intercepted and transported away from the open trench by means of drainage ditches.

No Protective Action Distance (PAD) is expected to be required for the trench disposal option due to the properties of the materials involved, the lack of high energy (i.e., capability for dispersion), and the relatively macroscopic sizes involved (U.S. NRC, 1982). Figure 3.4 provides a site map of the trench facility during operations. Table 3.4 summarizes site land parameters.

3.4 Mined Cavity Disposal Facility

For grouted U_3O_8, the mined cavity disposal facility underground would be roughly a square-shaped area approximately 1,355 m x 1,380 m, approximately 187 ha (462 acres) of land.

3.4.1 Site Map and Land Area Requirements During Construction

Three main drifts bisect the underground area: (a) the waste main, connected to the surface by the waste ramp; (b) the tuff main, connected to the surface by the tuff ramp, which terminates at the finished tuff pile on the surface; and (c) the service main. Because of the dense waste loading permissible with unirradiated depleted uranium, 6.5-m-wide (21 ft) emplacement tunnels intersecting the three main drifts at right angles, spaced at 38.5 m (125 ft) on centers will be used. This results in an underground area requirement of about 173 ha (427 acres), and 150,000 linear ft of emplacement drifts for the base case.

3.4.2 Site Map and Land Area Requirements During Operations

For a reasonable grade for the movement of the waste, a waste ramp will be used. This ramp will allow access between the Central Surface Facilities area and the underground emplacement area. A ramp with a 5-degree grade could be used to reach the underground waste main drift approximately 180 m (590 ft) below the surface, in tuffs. The site map during operations (see figure 3.5) would be very similar to that of the construction phase. Security arrangements with regard to site access, surveillance, etc. would be in place. Utilities and transportation access to the site would also have been connected, as needed. Table 3.5 summarizes site impacts for the mined cavity disposal facility.

3.5 Effect of Variations Upon Site Requirements

Variations in the site map and land area requirements of the Wasteform Facility created by the selection of alternate wasteforms hinge on whether the variation selected requires the product to be in a cemented form or a bulk oxide form. If the cemented UO_2 variation is selected, the site map and land area requirements are reduced approximately 35 percent from those described for the base case. If either of the bulk depleted uranium oxide variations are chosen, the Cementing Building, Curing Building and the Supply and Shipping Warehouse will not be constructed. In this circumstance, the Wasteform Facility becomes a receiving pass through for the disposal site. It is assumed that the U_3O_8 or UO_2 in steel drums will merely be inspected on receipt and passed through in the same drums for disposal, with a conservative lag storage area to accommodate disposal scheduling.

Variations in the site and land area requirements of the vault disposal facility due to alternative wasteforms are directly proportional to the disposal volumes. Thus, the ungrouted U_3O_8 case requires 28.6 ha (71 acres). The grouted UO_2 case would require 12.9 ha (32 acres), while the ungrouted UO_2 case would require about 9.8 ha (24 acres).

Perturbations on the trench disposal facility include the options for the UF_6 to be converted to different forms of U_3O_8 or UO_2: bulk U_3O_8 in a container (ungrouted), UO_2 in cement, and bulk UO_2 in a container (ungrouted). Each wasteform results in a different disposal volume, thus affecting the amount of land required for the trenches. The bulk U_3O_8 form would be disposed of in 55-gallon drums and would require 0.45 ha (1.1 acres) of land for one trench per year [16.8 ha (41.5 acres) over 20 years]. The bulk UO_2 form, because it is so much heavier than U_3O_8, would be disposed of in 30-gallon drums and would require 0.19 ha (0.5 acre) per year [9.5 ha (23.5 acres) over 20 years]. Finally, grouted UO_2 would also be disposed of in 30-gallon drums and would require 0.28 ha (0.70 acres) of land for one trench per year [12.1 ha (29.9 acres) over 20 years]. These land requirements include spacing of 20 m (65.6 ft) between each trench.

The major changes to the mined cavity disposal facility resulting from the alternatives to the base case would be changes in the size and drilling requirements for the underground storage area. The effects of these changes have been noted in section 2.4. The greatest change from the base case would result in a 80 percent reduction in the underground storage area for the case of ungrouted UO_2 storage.

Table 3.1 Wasteform Facility Building Footprint Areas: Grouted U_3O_8 (Base Case)

Building	Area, m^2 (ft^2)
Administration Building	675 (7,270)
Product Receiving Warehouse	3,000 (32,300)
Cementing Building	864 (9,300)
Curing Building	3,600 (38,750)
Supply and Shipping Warehouse	4,225 (45,500)
TOTAL	12,364 (133,120)

Table 3.2 Site Land Parameters at the Wasteform Facility

Parameter / Impact	Value
Site Land Area	3.8 ha (9.3 acres)
Disturbed Land Area	3.8 ha (9.3 acres)
Total Fenced Area	3.3 ha (8.2 acres)
Total Paved Area	0.75 ha (1.8 acres)
Total Excavated Material	24,700 m^3 (872,000 ft^3)

Table 3.3 Site Land Parameters at the Vault Disposal Facility: Grouted U_3O_8 (Base Case)

Parameter	Value
Site Land Area	56.4 ha (140 acres)
Disturbed Land Area	56.4 ha (140 acres)
Total Fenced Area	56.4 ha (140 acres)
Total Paved Area	7.8 ha (19 acres)
Total Excavated Material	1,270,000 m^3 (45 million ft^3)

Table 3.4 Site Land Parameters at the Engineered Trench Disposal Facility

Parameter	Grouted U_3O_8	Bulk U_3O_8	Grouted UO_2	Bulk UO_2
Site Land Area	30.6 ha (76 acres)	16.8 ha (42 acres)	12.1 ha (30 acres)	9.5 ha (23 acres)
Disturbed Land Area	28.3 ha (70 acres)	15.2 ha (38 acres)	10.6 ha (26 acres)	8.1 ha (20 acres)
Total Fenced Area	30.6 ha (76 acres)	16.8 ha (42 acres)	12.1 ha (30 acres)	9.5 ha (23 acres)
Total Paved Area	1.1 ha (2.8 acres)	0.8 ha (2.0 acres)	0.7 ha (1.7 acres)	0.6 ha (1.5 acres)
Total Excavated Material	2,011,000 m^3 (7.1×10^7 ft^3)	1,081,000 m^3 3.8×10^7 ft^3)	755,000 m^3 (2.7×10^7 ft^3)	578,000 m^3 (2.0×10^7 ft^3)
Facility Length	728 m (222 ft)	401 m (122 m)	286 m (87 ft)	224 m (68 ft)
Facility Width	420 m (128 ft)	420 m (128 ft)	420 m (128 ft)	420 m (128 ft)

Table 3.5 Site Land Parameters at the Mined Cavity Disposal Facility Underground: Grouted U_3O_8 (Base Case)

Parameter / Impact	Value
Underground Site Land Area	187 ha (462 acres)
Disturbed Land Area	187 ha (462 acres)
Total Fenced Area	187 ha (462 acres)
Total Paved Area	38 ha (94 acres)
Total Excavated Material	1,518,000 m^3 (53,600,000 ft^3)

Figure 3.1: Site Map for Construction of the Wasteform Facility (Grouted U_3O_8 - Base Case)

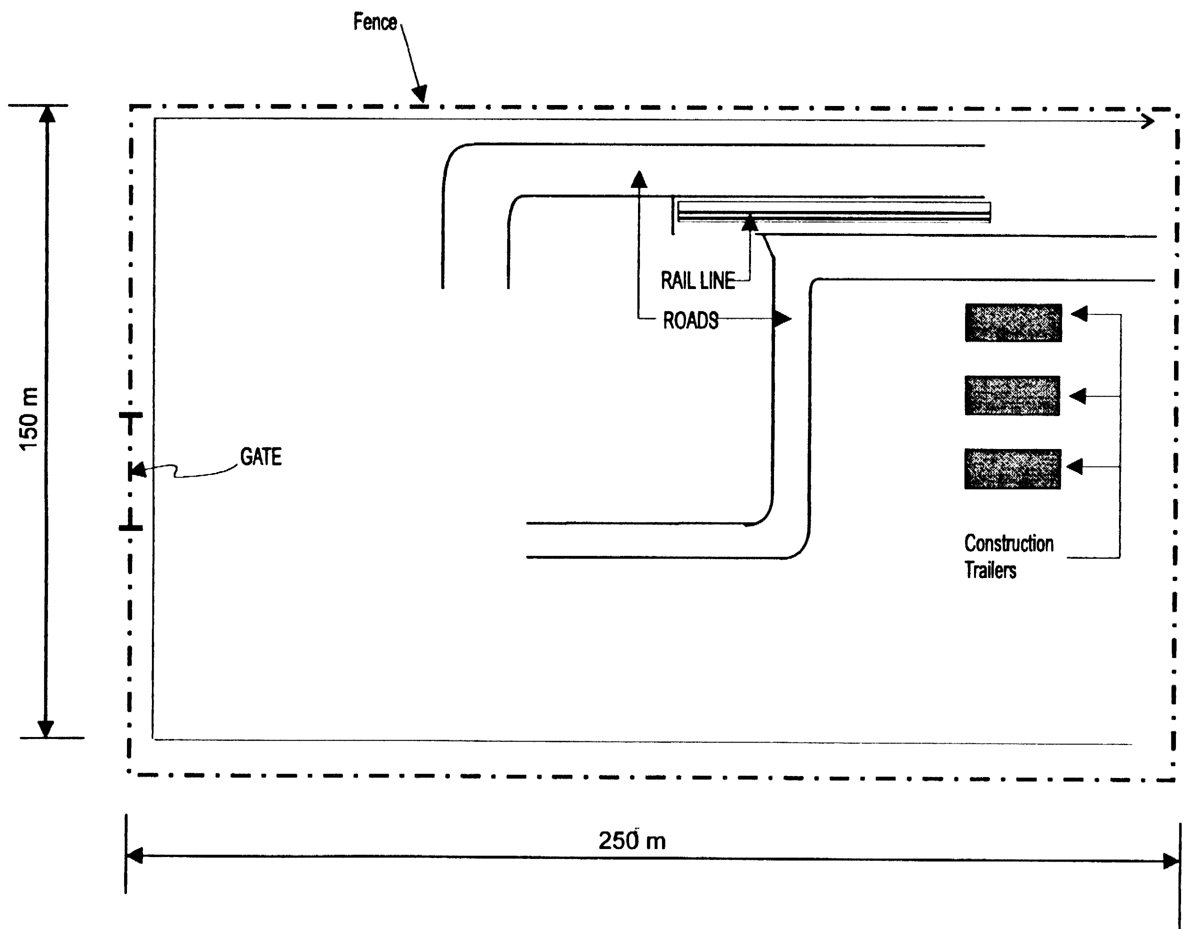


Figure 3.2: Site Map and Land Area During Operation of the Wasteform Facility (Grouted U_3O_8 - Base Case)

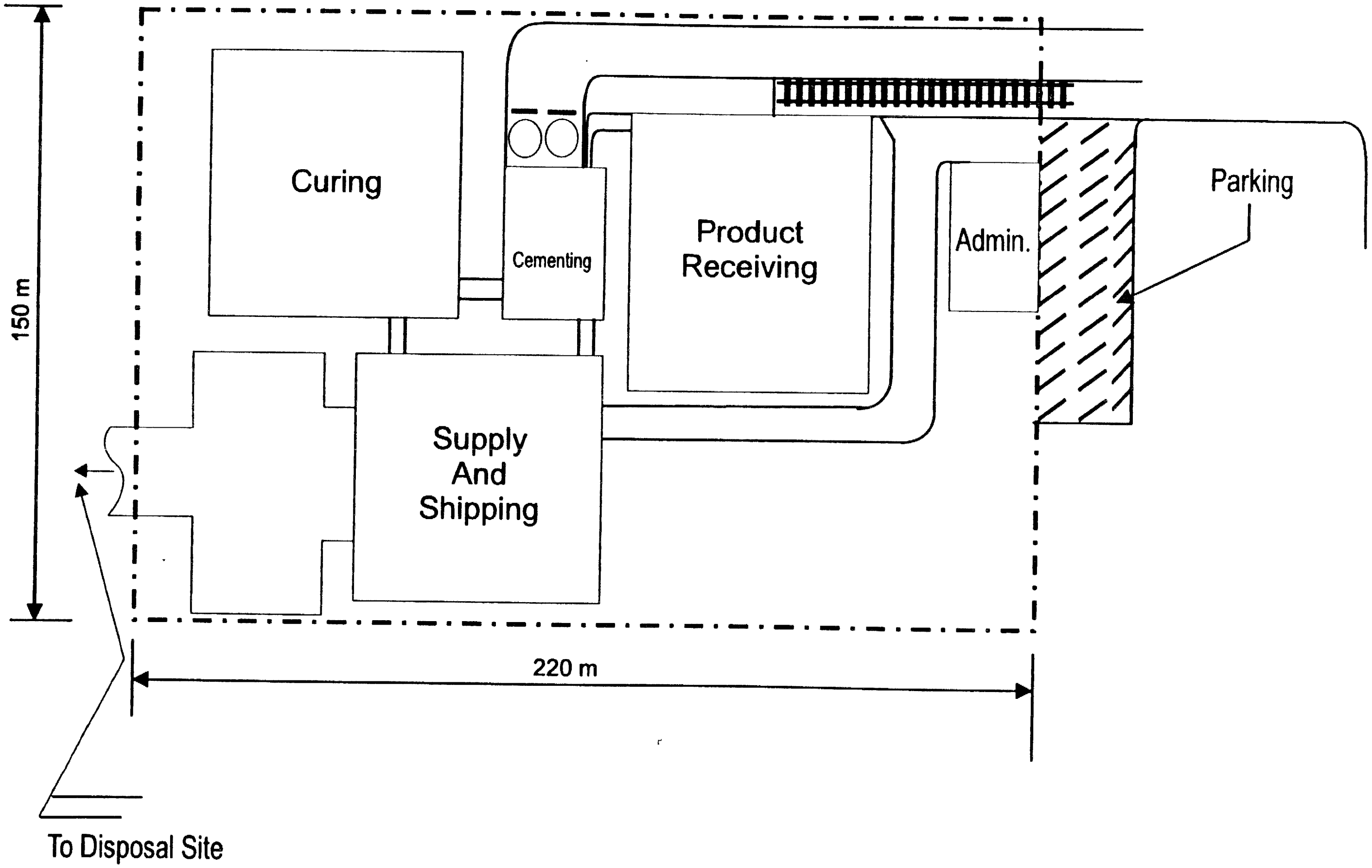


Figure 3.3: Site Map for Construction of the Vault Disposal Facility (Grouted U_3O_8 - Base Case)

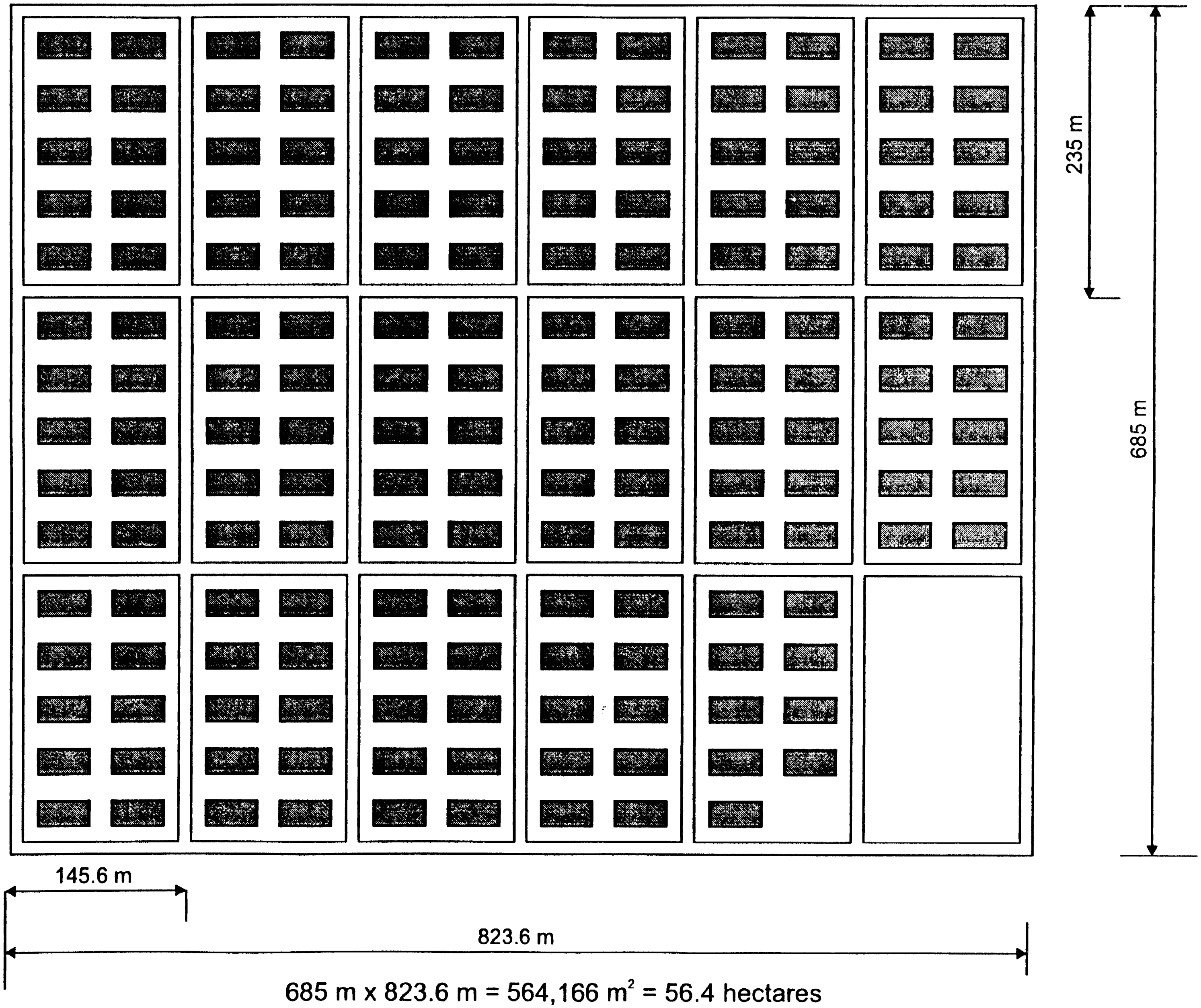


Figure 3.4: Site Map and Land Area During Operation of the Engineered Trench Disposal Facility (Grouted U_3O_8 - Base Case)

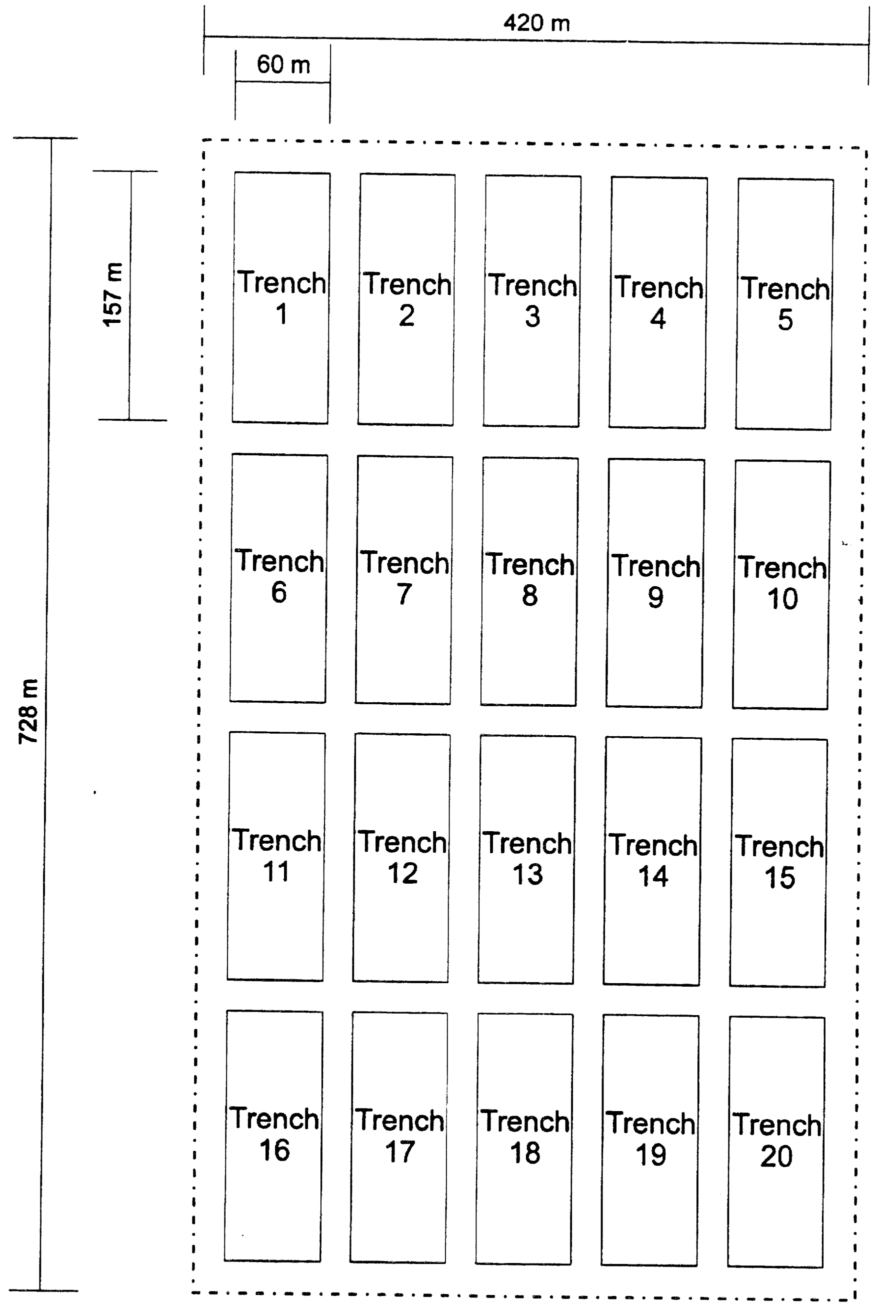
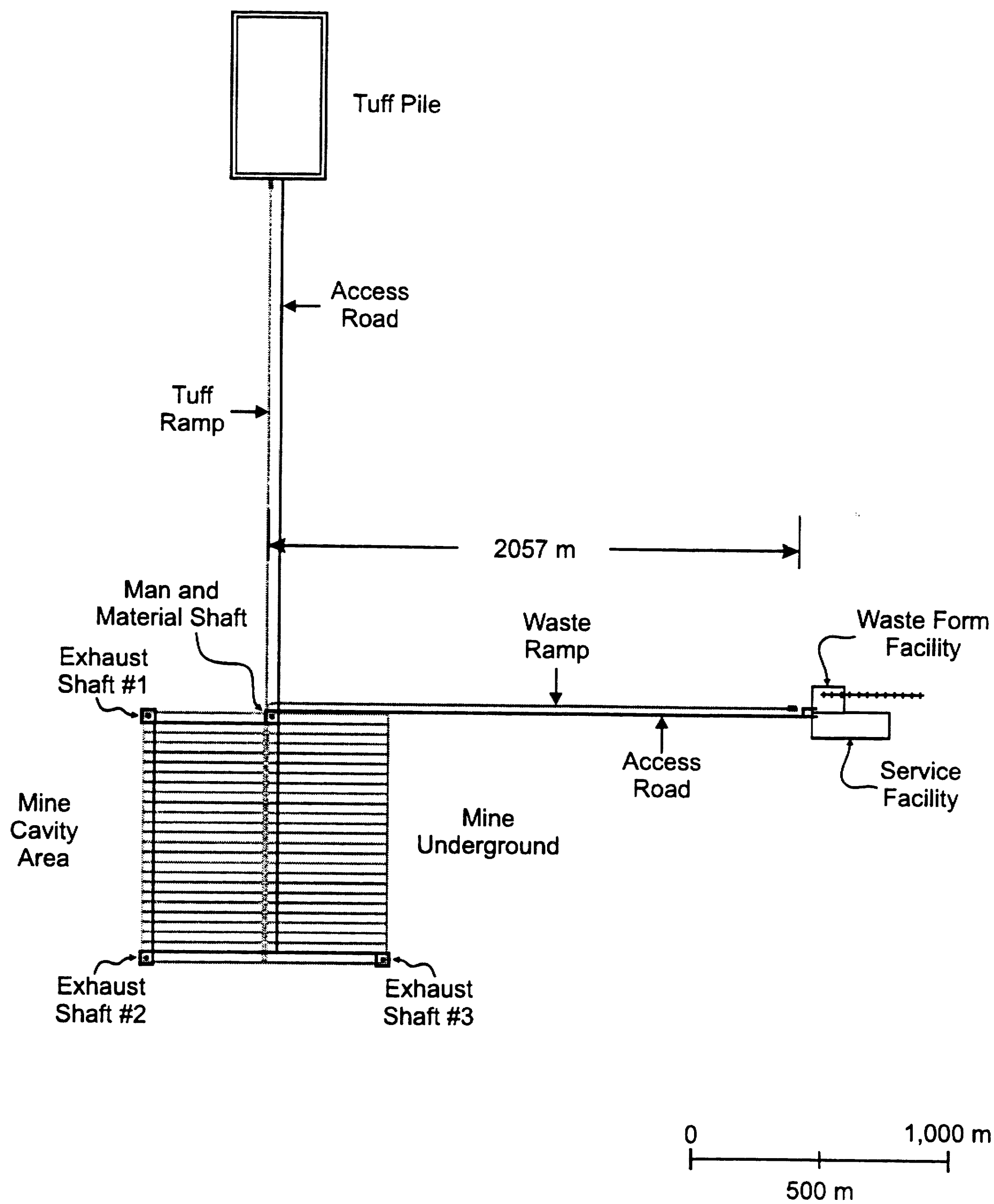


Figure 3.5: Site Map and Land Area During Operation of the Mined Cavity Disposal Facility



4.0 RESOURCE NEEDS

This section is devoted to discussing resources needed solely for each disposal option. It should be noted that there would be some overlap between resources required for any of the three disposal options and the Wasteform Facility (e.g., potable water, computer power).

During the preoperational phase, the potential applicant goes through a process of disposal site selection by choosing a region of interest, examining a number of possible disposal sites within the area of interest, and narrowing the choice to the proposed site. Through a detailed investigation of the disposal site characteristics, the potential applicant obtains data on which to base the analysis of the disposal site's suitability. Along with these data and analyses, the applicant submits other more general information to the NRC in the form of an application for a license for land disposal. The Commission's review of the application is in accordance with administrative procedures established by rules and may involve participation by affected State governments or Indian tribes (U.S. NRC, 1982).

In selecting the proper equipment, consideration must be given to the following points: (a) quantity and type of waste; (b) quantity of soil to be removed; (c) type of soil; (d) distance soil must be moved; (e) time required for covering soil compaction; (f) site clearing requirements; (g) site conditions and soil conditions, such as topography, soil moisture, and difficulty in excavation; (h) auxiliary tasks, such as maintaining road and drainage, assisting in vehicle unloading, and moving other materials and equipment around the site; (I) maintenance needs; (j) standby or backup equipment needs; (k) growth of waste quantities and related tasks over the life of the equipment; (l) lower reliability with age; (m) variation in waste quantities received; (n) variation in weather conditions; (o) availability of parts and maintenance; (p) purchase and operating costs; and (q) operator comfort. Each of these points relates to a time requirement or a certain capability. Equipment sizes, numbers, and types must be selected to handle all of these conditions, or arrangements must be made for other equipment to be brought in to temporarily assist. With the many factors involved, it is absolutely necessary that the equipment never be undersized.

4.1 Wasteform Facility

Table 4.1 summarizes the estimates of resource requirements during construction of the Wasteform Facility for the base case and variations. The estimates use the layouts from section 2 to provide rough, order of magnitude values. Table 4.2 presents the estimates of concrete used for construction for the base case only. The use of concrete is dominated by floor slab construction. Refinement of the resource estimates will be made during a more detailed design phase.

Table 4.3 presents the estimated resource requirements for utilities and fuel, energy, water use and wastewater generation, chemicals, and radioactive materials for the operation of the Wasteform Facility for the base case and variations.

Diesel fuel consumption is small, due almost totally to backup generator operation. The analyses assume 15 18-Kva UPS systems and 5 7-Kva UPS combinations on automated test schedules of 20 minutes every 2 weeks, and 24 hours of run time per year. The analyses also assume the use of two diesel electric systems, on schedules of 1 hour per month, and 24 hours of run time per year. Onsite vehicle usage is trucks to supply empty drums for the grouting process. The only on-site diesel-powered vehicle is a prime mover used for spotting rail cars. Natural gas usage is for space heating requirements.

Water is used for drinking, employee shower facilities, and sanitary facilities. Process water is used in formulating the grout mixture.

The feed material for the facility, U_3O_8 or UO_2, is the only radioactive material introduced into the facility.

4.2 Vault Disposal Facility

Tables 4.4 and 4.5 summarize materials and resources consumed during construction and routine operation of the vaults, respectively, for the base case and variations. Diesel fuel is required for trucks and emplacement cranes. Concrete is used for sealing the vaults. Apart from the emplacement of depleted uranium, no other radioactive materials are used.

4.3 Engineered Trench Disposal Facility

Most likely, the single most important factor affecting the containment capability of a burial ground is the degree to which groundwater and surface water can contact the waste and subsequently cause migration of the radionuclides. The most effective way to deter this is to place a permanent water-resistant cover over the trenches to restrict percolation of surface water through the waste. Many materials could be used to form this protective cover, such as clay (which will be used as the base case), soil additives, asphalt, plastic membranes, concrete, and stainless steel (Macbeth, 1979).

Table 4.6 summarizes the amount of water, diesel fuel, electricity, and trench materials needed for construction for the base case and variations. Personnel estimates from section 5 are used to provide these rough, order of magnitude values. Personnel usage constitutes the greatest percentage of water consumption. Fuel usage is estimated from an NRC EIS.

Remote hookup and release techniques are used routinely in the off-loading operations as a means of minimizing personnel exposure. Construction of new trenches adjacent to operational ones are assumed to proceed without any appreciable dose accumulation (U.S. NRC, 1982). Table 4.7 outlines the resources needed to operate the trench facility for the base case and variations.

Power sources and fuel for construction equipment, most likely diesel, would be needed. Energy required for heating and cooling the facilities are based upon 6-month intervals. Water required for this project will be mainly potable water for site personnel. Wastewater will be generated by site personnel as sanitary waste and needs to be considered. Apart from emplacement of the U_3O_8 or the UO_2 drums, no radioactive materials are needed for the trench option.

4.4 Mined Cavity Disposal Facility

The major material "consumed" during construction would consist largely of tuffs excavated from the underground area in order to provide for (a) the three main drifts (for services, tuff movement, and waste movement); (b) the perimeter drift, which encircles the underground area; and (c) the emplacement, or storage drifts. In addition, ramps must be excavated from the surface to main tuff and waste drifts, and shafts must be drilled from the surface to the underground area to provide access for men and materials, and for utilities and underground ventilation.

Considerable electrical power must also be expended in connection with such excavation. In addition, the walls of all drifts and ramps must be lined with steel-reinforced concrete, which is "shot" into place, and requires large amounts of water for in situ mixing with sand, cement, and aggregate. Table 4.8 summarizes materials and resources required during the construction of the mined cavity facilities for the base case and variations.

It is assumed that the mined cavity disposal facility is operated on a one shift/day basis, with a total work force of about 100 employees. Table 4.9 summarizes materials and resources consumed during routine operations the base case and variations.

The principal utility service required would be electrical power for the operation of ventilation systems, and industrial power equipment such as fork lifts for the transport of men and equipment, and for lighting and heating. This would require on the order of 5 to 10 million kWh per year. Fuel requirements would be for above ground uses only, such as transportation, and would be minimal.

Normal operating water requirements for Yucca Mountain are stated to be 9.5 million L (2.5 million gallons) per year, and could be scaled down for the depleted uranium depository to about 1.9 million to 3.8 million L (0.5 to 1.0 million gallons) per year. Apart from emplacement of the U_3O_8 or the UO_2, no radioactive materials are needed for the mined cavity option.

4.5 Effects of Variations Upon Resource Needs

4.5.1 Wasteform Facilities

Variations in the resource needs of the Wasteform Facility, created by the selection of alternate wasteforms, hinge on the need for cementing the depleted uranium oxide. If the cemented UO_2 variation is selected, the resource needs are moderately different than those described for the base case. If either of the bulk depleted uranium oxide variations are chosen, the Cementing, Curing, and Supply and Shipping Warehouse Buildings will not be constructed. In this circumstance, there is a significant change in the resource requirements. Tables 4.1 and 4.3 include the impacts on construction and operations for the proposed variations.

4.5.2 Vault Disposal Facilities

Table 4.4 displays the effect of variations upon construction. Table 4.5 shows the effect of variations upon operations. The effects are almost directly proportional to the disposal volume.

4.5.3 Engineered Trench Disposal Facility

Each of the variations has a significant impact on the size of one trench that is built yearly; there is no impact on the number of trenches, only on the amount of land needed for the site. Material quantities required for construction of the trench facility are included in table 4.6. Material and resource requirements for operation of the trench disposal facility are included in table 4.7.

4.5.4 Mined Cavity Disposal Facility

Table 4.8 includes the effect of the various forms on the materials and resources required during construction of the mined cavity disposal facility. Table 4.9 includes similar information for the various wasteforms when the mined cavity disposal facility is in operation.

Table 4.1 Materials and Resources Required During Construction of the Wasteform Facility: Grouted U_3O_8 (Base Case) and Variation Cases

ITEM	Grouted U_3O_8	Ungrouted U_3O_8	Grouted UO_2	Ungrouted UO_2
Concrete, redi-mix, m^3	15,200	4,133	7,770	2,440
Steel, te	944	260	504	155
Water, ML	8.0	2.6	5.2	1.8
Excavated Material, m^3	24,728	7,350	16,055	4,550
Wastewater, ML	1.25	0.55	1.25	0.50
Electricity, MW-hr	1,013	403	578	304
Masonry Brick, m^2	1,348	573	1,020	573
Diesel Fuel, L	242,000	67,200	123,000	40,200

Note: Gasoline used for onsite transportation activities is approximately two orders of magnitude less than diesel fuel usage.

Table 4.2 Concrete Estimated for the Wasteform Facility: Grouted U_3O_8 (Base Case)

Structure	Concrete Required, m^3			
	Floor	Walls	Roof	Total
Administration Building	88	94	101	283
Product Receiving Warehouse	1,800	550	1,500	3,850
Cementing Building	323	360	168	851
Curing Building	2,160	600	1,800	4,560
Supply and Shipping Warehouse	2,805	650	2,113	5,568

Table 4.3 Materials and Resources Required During Operation of the Wasteform Facility: Grouted U_3O_8 (Base Case) and Variations

ITEM	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Per Year	Total	Per Year	Total	Per Year	Total	Per Year	Total
Water, ML	73.5	1,470	0.52	10.4	30.9	618	0.52	10.4
Wastewater, ML	4.0	80	0.52	10.4	2.2	44	0.52	10.4
Natural Gas, Therms*	387	7,740	109	2,180	193	3,860	67	1,340
Electricity, MW-hr	2,152	43,040	572	11,440	1,188	23,760	414	8,280
Diesel Fuel, L	75,600	1,512,000	500	10,000	21,000	420,000	500	10,000

* 1 therm = 100,000 BTUs

Table 4.4 Materials and Resources Required During Construction of the Vault Disposal Facility: Grouted U_3O_8 (Base Case) and Variations

ITEM	Per Vault	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
		Per Year	Total	Per Year	Total	Per Year	Total	Per Year	Total
Number of Vaults	1	8.45	169	4.04	81	1.73	35	1.15	23
Concrete redi-mix, m^3	1,750	14,800	296,000	7,070	142,000	3,030	61,300	2,010	40,300
Gravel, te	910	7,690	154,000	3,680	73,700	1,570	31,900	1,050	20,900
Liner, m^2	2,220	18,800	375,000	8,970	180,000	3,840	77,700	2,550	51,100
Steel, te	58.5	494	9,890	236	4,740	101	2,050	67.3	1,350
Water, ML	0.78	6.59	132	3.15	63.2	1.35	27.3	0.90	17.9
Excavated Material, m^3	7,520	63,500	1,270,000	34,500	690,000	15,300	306,000	11,450	229,000
Wastewater, ML	0.02	0.17	3.38	0.08	1.62	0.03	0.70	0.02	0.46
Electricity, kW-hr	12,500	106,000	2,110,000	50,500	1,010,000	21,600	438,000	14,400	288,000
Diesel Fuel, L	17,800	150,000	3,010,000	71,900	1,440,000	30,800	623,000	20,500	409,000

Table 4.5: Materials and Resources Required During Routine Operation of the Vault Disposal Facility: Grouted U_3O_8 (Base Case) and Variations

ITEM	Grouted U_3O_8			Ungrouted U_3O_8		
	Per Vault	Per Year	20-Years	Per Vault	Per Year	20-Years
Number of Vaults	1	8.45	169	1	4.04	81
Water, ML	0.02	0.17	3.38	0.02	0.08	1.62
Wastewater, ML	0.02	0.17	3.38	0.02	0.08	1.62
Electricity, kW-hr	328,000	2,770,000	55,400,000	500,000	2,020,000	40,500,000
Diesel Fuel, L	51,100	432,000	8,640,000	51,000	206,000	4,140,000

ITEM	Grouted UO_2			Ungrouted UO_2		
	Per Vault	Per Year	20-Years	Per Vault	Per Year	20-Years
Number of Vaults	1	1.73	35	1	1.15	23
Water, ML	0.04	0.07	1.4	0.04	0.05	0.92
Wastewater, ML	0.04	0.07	1.4	0.04	0.05	0.92
Electricity, kW-hr	779,000	1,350,000	27,300,000	588,000	676,000	13,500,000
Diesel Fuel, L	98,500	170,000	3,450,000	97,900	113,000	2,250,000

Table 4.6: Materials and Resources Required During Construction of the Trench Disposal Facility: Grouted U_3O_8 (Base Case) and Variations

ITEM	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Per Year	Total	Per Year	Total	Per Year	Total	Per Year	Total
Water, ML	0.02	0.4	0.02	0.4	0.01	0.2	0.01	0.2
Excavated Material, m^3	101,000	2,010,000	51,800	1,040,000	35,200	703,000	26,200	525,000
Clay, m^3	577	11,500	374	7,490	305	6,110	268	5360
Sand, m^3	4,750	95,100	2,270	45,400	1,420	28,500	969	19,400
Gravel, te	202	4,030	98	1,950	62	1,240	43	863
Wastewater, ML	0.02	0.4	0.02	0.4	0.01	0.2	0.01	0.2
Electricity, kW-hr	334,000	6,680,000	179,000	3,580,000	126,000	2,530,000	98,100	1,960,000
Diesel Fuel, L	88,900	1,780,000	45,500	911,000	30,900	618,000	23,100	461,000

Table 4.7: Materials and Resources Required During Operation of the Trench Disposal Facility: Grouted U_3O_8 (Base Case) and Variations

ITEM	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Per Year	Total	Per Year	Total	Per Year	Total	Per Year	Total
Water, ML	0.093	1.86	0.053	1.06	0.042	0.84	0.036	0.72
Wastewater, ML	0.093	1.86	0.053	1.06	0.042	0.84	0.036	0.72
Electricity, MW-hr	1,080	21,600	773	15,500	655	13,100	585	11,700
Diesel Fuel, L	165,000	3,300,000	78,100	1,560,000	65,200	1,300,000	49,000	980,000

Table 4.8 : Materials and Resources Required During Construction of the Mined Cavity Facility - 7 ½ Year Construction Period: Grouted U_3O_8 (Base Case) and Variations

ITEM	Grouted U_3O_8	Ungrouted U_3O_8	Grouted UO_2	Ungrouted UO_2
Water, ML	19	13	10	9
Concrete Redi-Mix, m^3	123,000	74,100	55,400	44,600
Steel, te	4,827	2,908	2,174	1,750
Electricity, GW-hr	10,000	4,300	2,800	1,900
Diesel Fuel, L	892,000	519,000	379,000	299,000
Excavated Material, m^3	1,518,000	883,000	644,000	306,000

Table 4.9: Materials and Resources Required During Operation of the Mined Cavity Facility: Grouted U_3O_8 (Base Case) and Variations

ITEM	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Per Year	Total	Per Year	Total	Per Year	Total	Per Year	Total
Water, ML	3.3	66	2.3	46	1.8	36	1.5	30
Wastewater, ML	0.6	12	0.4	8	0.3	6	0.25	5
Electricity, GW-hr	8.5	170	6.0	120	4.75	95	3.9	78
Diesel Fuel, L	12,300	246,000	6,150	123,000	9,230	184,600	6,770	135,400

5.0 PERSONNEL STAFFING ESTIMATES

Personnel staffing estimates are preconceptual. They are derived by comparison to similar facilities described in the literature. The staffing estimates are divided into construction and operations personnel requirements. Table 5.1 summarizes construction manpower estimates. Table 5.2 provides operations manpower estimates.

5.1 Wasteform Facility

5.1.1 Construction Labor Force for the Wasteform Facility

The construction force is organized as follows:

- Management, engineering, design, and permitting (Home Office): this category includes management planning, engineering through Title III, and permitting personnel. Permitting includes licensing activities and National Environmental Policy Act (NEPA) documentation. This category is typically not located in the field, but rather, at the home (or regional) office of the respective contractors. Although the composition of this group will evolve, their level of effort is expected to be relatively constant over the entire construction period of 2 to 3 years at a level of 18 full-time equivalents (FTEs) per year.

- Management and supervision at the construction site (Field Office): this category represents overall field management and supervision during actual construction. Personnel, temporarily stationed in trailers, will transfer to finished buildings (e.g., Administration Building) upon their completion. This element of the construction staff will remain at a relatively constant level of approximately 18 FTEs per year for 2 years.

- Site preparation: this activity includes the surveyors, operating engineers, truck drivers, and laborers that provide the initial construction entrance, temporary (gravel) roads, storm water management, initial grubbing, installation of temporary utility service, and associated activities. These activities require resource expenditure at the rate of 90 FTEs per year for a limited duration (up to 1 year) at the initiation of the project.

- Construction of the site buildings: this activity is the building of the structures defined for the project. Construction of the Wasteform Facility buildings will require approximately 150 FTEs per year for 2 years.

- Checkout and startup: this activity includes readiness assessments and final licensing and permitting activities. Twenty FTEs for 120 days (7 FTE-years) are required. Roughly 500 FTE-years are required to complete the concept, design, construction, checkout, and startup of the facility.

5.1.2 Operation Labor Force for the Wasteform Facility

Operation of the Wasteform Facility is based on two shifts per day, 5 days per week. Security personnel are the only exception, working 24 hours per day (three shifts), 7 days per week. Table 5.3 delineates the staffing requirements for the Wasteform Facility. Consideration was also given to maintenance staff in table 5.3.

Appendix D provides a time and motion estimate of Wasteform Facility employees exposed to radiation, their average distances to radioactive materials, and approximate exposure times during each shift. Actual radiation exposures are anticipated to approach background levels and be well within DOE and NRC regulatory requirements.

Personnel will not be required to wear personal protective equipment (PPE) for protection from chemical or radiological hazards during normal operations. PPE will be available on site for certain maintenance or special operational activities (i.e., hooking up a line to an HF-carrying rail car or truck), or emergency situations. However, the accident analysis takes no credit for the use of PPE following an accident or process upset condition.

5.1.3 Variations

The impact of variations on construction and operation personnel staffing requirements is shown in table 5.4.

5.2 Vault Disposal Facility

5.2.1 Construction

The construction labor force is organized as follows:

- Management, engineering, design, and permitting (Home Office): this category includes management planning, engineering, and permitting personnel. Permitting includes licensing activities and NEPA documentation for the vault facility. This group would be located principally at a different site from the proposed vault facility. The composition of the team will evolve, but the level of effort is expected to be relatively constant over the entire construction period of the vaults (20 years) at a level around 5 FTEs per year.

- Management and supervision at the construction site (Field Office): this represents overall field management and supervision during construction. This personnel will be housed in buildings shared with Wasteform Facility personnel. The analyses anticipate a relatively constant level of approximately 5 FTEs per year for 20 years.

- Additional site preparation: this includes the initial construction entrance, gravel roads, storm water mitigation, initial grubbing, temporary utilities, etc. This requires about 5 FTEs per year for 2 years.

- Vault construction: 7 FTE-years per vault for 20 years.

- Readiness reviews, checkout, and startup: these terms are used synonymously, and will include training (and certification, as required) of the operating staff. This accrues to approximately 5 FTEs per year for 20 years.

5.2.2 Operation

Table 5.5 presents operational labor requirements. Vault operations consist of the following:

- Overall management and supervision
- Vault loading
- Vault fill-in and compaction
- Vault sealing
- Final closure, including backfill and grading
- Vault maintenance

Approximately 84 FTEs are required.

5.2.3 Variations

Table 5.6 summarizes the effects of variations. The variations result in significant reductions in the number of vaults and the direct operations associated with the vaults.

5.3 Engineered Trench Disposal Facility

5.3.1 Construction

The construction labor force is organized as follows:

- Management, engineering, design, and permitting (Home Office): this category includes management planning, engineering, and permitting personnel. Permitting includes licensing activities and NEPA documentation for the trench facility. This group would be located principally at a different site from the proposed trench facility. The composition of the team will evolve, but the level of effort is expected to be relatively constant over the entire construction period of the trenches (20 years) at a level around 5 FTEs per year.

- Management and supervision at the construction site (Field Office): this represents overall field management and supervision during construction. This personnel will be housed in buildings shared with Wasteform Facility personnel. The analyses anticipate a relatively constant level of approximately 5 FTEs per year for 20 years.

- Additional site preparation: this includes the initial construction entrance, gravel roads, storm water mitigation, initial grubbing, temporary utilities, etc. This requires about 5 FTEs per year for 2 years.

- Trench construction: 8 FTE-years per trench for 20 years.

- Readiness reviews, checkout, and startup: these terms are used synonymously, and will include training (and certification, as required) of the operating staff. This accrues to approximately 5 FTEs per year for 20 years.

5.3.2 Operation

Operation of the facility assumes 8-hour operation on a single-shift basis. The overview of trench facility staffing estimates approximately 47 FTEs. Table 5.7 presents operational labor requirements.

5.3.3 Variations

Variations on the trench facility include the use of different forms of depleted uranium. The base case of grouted U_3O_8 requires the maximum area of land and number of FTEs. If any of the other three options are selected, the quantity of land and the number of FTEs would be reduced considerably. This is illustrated in table 5.8.

5.4 Mined Cavity Disposal Facility

5.4.1 Construction

During construction, a large work force would be required to do site work, excavate drifts, pour concrete, and provide the craft labor necessary to construct the surface facilities. At peak employment, some 1,000 persons may be onsite.

5.4.2 Operation

Less than 50 persons would be required to operate the repository on a one shift/day basis.

5.4.3 Variations

The variations introduced by the three alternatives to the base case personnel staffing are displayed in table 5.9.

Table 5.1 Summary of Construction Labor Estimates (FTE-yr)

Grouted U_3O_8 (Base Case)

Disposal Approach	Wasteform Facility	Disposal Facility	Total
Vault	500	1,500	2,000
Trench	500	470	970
Mine	500	5,000	5,500

Ungrouted U_3O_8

Disposal Approach	Wasteform Facility	Disposal Facility	Total
Vault	195	880	1,075
Trench	195	400	595
Mine	195	3,000	3,195

Grouted UO_2

Disposal Approach	Wasteform Facility	Disposal Facility	Total
Vault	500	560	1,060
Trench	500	400	870
Mine	500	2,200	2,700

Ungrouted UO_2

Disposal Approach	Wasteform Facility	Disposal Facility	Total
Vault	200	480	680
Trench	200	360	560
Mine	200	1,700	1,900

Table 5.2 Summary of Operational Labor Estimates (FTEs): Grouted U_3O_8 (Base Case)

Disposal Approach	Wasteform Facility	Disposal Facility	Total
Vault	97	84	181
Trench	97	47	144
Mine	97	42	139

Table 5.3 Wasteform Facilities - Personnel Staffing for Operations by Shift: Grouted U_3O_8 (Base Case)

Administration and Technical Support

Plant Management

Shift	1	2	3	Total
Manager	1	1 - deputy		2
Secretary	1			1

Technical Services

Engineering

Shift	1	2	3	Total
Plant Engineer	1			1
Engineering Assistant	1			1

Cement Sampling and Testing

Shift	1	2	3	Total
Supervisor	1			1
Sampling Tech	2	1		3
Testing Tech	2	1		3

Table 5.3 Wasteform Facilities - Personnel Staffing for Operations by Shift: Grouted U_3O_8 (Base Case) (continued)

Administration Services

Plant Access and Security

Shift	1	2	3	4	Total
Captain	1				1
Guard-5 Days	2	2	2		6
Guard-7 Days	1	1	1	1	4

Procurement and Shipping/Receiving

Shift	1	2	3	Total
Supervisor	1			1
Secretary	1			1
Receiving Clerk	2	1		3
Inventory Clerk	2	1		3
Buyer	1			1

Health Physics

Shift	1	2	3	Total
Supervisor	1			1
Tech-Receiving	3	3		6
Tech-Cementing	1	1		2
Tech-Shipping	1	1		2

Table 5.3 Wasteform Facilities - Personnel Staffing for Operations by Shift: Grouted U_3O_8 (Base Case) (continued)

Totals for Administration and Technical Support

Shift	1	2	3	4	Total
Manager / Supervisor	5	1			6
Secretary	2				2
Engineering	2				2
Sample & Test	4	2			6
Guards	3	3	3	1	10
Procurement	5	2			7
Health Physics	5	5			10
					43 FTEs

Table 5.3 Wasteform Facilities - Personnel Staffing for Operations by Shift: Grouted U_3O_8 (Base Case) (continued)

Wasteform Facility

Product Receiving Warehouse

Shift	1	2	3	Total
Supervisor	1	1		2
Lift Operator	4	4		8

Cementing Building

Shift	1	2	3	Total
Supervisor	1	1		2
Batch Control Operator	1	1		2
Batch Technician	1	1		2
Batch Operator	2	2		4
Casting Control Operator	1	1		2
Casting Technician	1	1		2
Casting Operator	2	2		4

Curing Building

Shift	1	2	3	Total
Technician	3	3		6

Table 5.3 Wasteform Facilities - Personnel Staffing for Operations by Shift: Grouted U_3O_8 (Base Case) (continued)

Supply and Shipping Warehouse

Shift	1	2	3	Total
Lift Operator	2	2		4
Technician	2	2		4

Maintenance

Shift	1	2	3	Total
Supervisor	1			1
Clerk	2			2
Instrument Tech.	2	1		3
Electrical Tech.	2	1		3
Mechanical Tech.	2	1		3

Table 5.3 Wasteform Facilities - Personnel Staffing for Operations by Shift: Grouted U_3O_8 (Base Case) (continued)

Totals for Wasteform Facility

Shift	1	2	3	4	Total
Manager / Supervisor	3	2			5
Senior Operator	2	2			4
Lift Operator	6	6			12
Operator	4	4			8
Clerical	2				2
Maintenance	6	3			9
Technician	7	7			14
					54 FTEs

Table 5.4 Wasteform Facility Staffing Levels, Including Variation Effects

Variation	Construction Labor	Operations Labor, FTEs		
	FTEs-years	Administration and Technical Support	Wasteform Facility	Total FTE - years
Cemented U_3O_8 [base case]	500	43	54	97
Cemented UO_2	500	43	48	91
U_3O_8	195	24	11	35
UO_2	200	24	11	35

Table 5.5 Personnel Staffing for Operations by Shift at the Vault Disposal Facility

Activity 2.1: Management and Supervision

Shift	1	2	3	4	Total
Manager	1	1	0	0	2
Secretary/records	1	0	0	0	1
Quality Engineer	1	1	0	0	2
					5

Activity 2.2: Vault Drum Loading

Shift	1	2	3	4	Total
Manager/Supervisor	1	1	0	0	2
Operator	4	4	0	2	10
Technician*	4	4	0	2	10
Spotters/Loaders	4	4	0	2	10
					32

*Half are HP Technicians

Activity 2.3: Vault fill-in/Compaction

Shift	1	2	3	4	Total
Manager/Supervisor	1	1	0	0	2
Operator	2	2	0	1	5
Laborer	4	4	0	2	10
					17

Table 5.5 Personnel Staffing for Operations by Shift at the Vault Disposal Facility (continued)

Activity 2.4: Vault Sealing (1 month per vault)

Shift	1	2	3	4	Total
Manager/Supervisor	1	1	0	0	2
Operator	4	2	0	2	8
Concrete Finishers/Laborers	4	2	0	2	8
					18

Activity 2.5: Final Closure

Shift	1	2	3	4	Total
Manager/Supervisor	1	0	0	0	1
Operator	1	0	0	1	2
Spotters/Laborers	2	0	0	2	4
					7

Activity 2.6: Vault Maintenance

Shift	1	2	3	4	Total
Technician	2	2	0	1	5
					5

Table 5.5 Personnel Staffing for Operations by Shift at the Vault Disposal Facility (continued)

Total for Vault Facility

Shift	1	2	3	4	Total
Manager / Supervisor	5	4	0	0	9
Secretary	1	0	0	0	1
Quality Engineer	1	1	0	0	2
Operator	11	8	0	6	25
Technician	6	6	0	3	15
Laborer/Spotter/ Leader	14	10	0	8	32
					84 FTEs

Table 5.6 Effect of Variations Upon Vault Operational Labor Requirements

Case	Number of Vaults Annually	Labor FTEs
Grouted U_3O_8 (Base Case)	8 to 9 (8.45)	84
Ungrouted U_3O_8	4 to 5 (4.04)	42
Grouted UO_2	1 to 2 (1.73)	38
Ungrouted UO_2	1 to 2 (1.15)	30

Table 5.7 Personnel Staffing for Operations at the Trench Disposal Facility

Activity 2.1: Management and Supervision

	Per Year
Manager	1
Secretary/records	1
Quality Engineer	1
	3

Activity 2.2: Trench Loading

	Per Year
Manager/supervisor	1
Operator	4
Technician (1 Health Physicist)	2
Spotters/loaders	4
	11

Activity 2.3: Trench fill-in/Compaction

	Per Year
Manager/Supervisor	1
Operator	4
Laborer	8
	13

Table 5.7 Personnel Staffing for Operations at the Trench Disposal Facility (continued)

Activity 2.4: Final Closure (1 month/year)

	Per Year
Manager/supervisor	1
Operator	4
Spotters/laborers	4
	9

Activity 2.5: Trench Maintenance

	Per Year
Technician	1

Total for Trench Facility

	Total
Manager / Supervisor	4
Secretary	1
Quality Engineer	1
Operator	12
Technician	3
Laborer/Spotter	16
Supplemental Staff (reserve)	10
	47

Table 5.8 Effect of Variations on Trench Operational Labor Requirements

Case	Labor, FTEs
Grouted U_3O_8 (Base Case)	47
Ungrouted U_3O_8	21
Grouted UO_2	30
Ungrouted UO_2	18

Table 5.9 Effect of Variations on Mined Cavity Operational Labor Requirements

Case	Labor, FTEs
Grouted U_3O_8 (Base Case)	42
Ungrouted U_3O_8	26
Grouted UO_2	34
Ungrouted UO_2	24

6.0 FACILITY WASTES AND EMISSIONS

6.1 Wasteform Facility

6.1.1 Estimate of Wastes and Emissions Generated During Construction of the Wasteform Facility

6.1.1.1 Emission Estimates During Wasteform Facility Construction

Heavy construction is a source of pollutants that may have temporary adverse impact on local air quality. Emissions released during facility construction are associated mostly with land clearing, blasting, ground excavation, fill operations, and construction itself. Emissions vary substantially from day to day depending on the level of activity, the specific operation, and the prevailing weather conditions.

Air quality regulations have been established by Federal and State agencies to protect the public from the harmful effects of air pollution. The Clean Air Act (CAA) established primary National Ambient Air Quality Standards (NAAQS) for several pollutants, including carbon monoxide, hydrocarbons, nitrogen dioxide, sulphur dioxide, and particulate matter. These pollutants are called criteria air pollutants. The NAAQS define the ambient concentration below which no adverse impact to human health is expected. A listing of the NAAQS for these criteria air pollutants is provided in Table 6.1.

To estimate emissions from various sources of air pollution, the EPA has developed emission factors. During facility construction, air pollution can be expected to be caused primarily by vehicle exhaust and fugitive dust. The approximate emissions factor for heavy construction equipment exhaust is based on engine-type and annual operating time.

The size and scope of the construction activity for the Wasteform Facility is so small, involving only 10 acres for less than 2 years, that the impact of emissions from construction, with appropriate control measures in place, is considered to be acceptable. Table 6.2 provides estimates for construction emissions for the base case and variants.

6.1.1.2 Estimates of Effluents to the Surface Waters during Wasteform Facility Construction

There are no direct effluents generated from construction that are generic. Local hydrology and storm water management specific to a site may result in effluents. The potential impacts of site preparation and construction on local hydrology can be expected to include changes in the flow rate and direction of surface water, in the elevation and flow direction of groundwater beneath the site, and in the quality of surface water and groundwater. Site preparation and construction activities such as excavation and filling for a facility foundation, parking lots, and storage yards may alter the topography of the site. Changes in the amount of infiltration and runoff of surface water and effects on drainage patterns are expected. The usual clearing of site vegetation and the movement of construction equipment tends to compact site soils, decreasing infiltration and increasing both runoff and possible soil erosion. Surface waters could experience increased sedimentation during normal precipitation and storm events. Actual local conditions will contribute to variations in this potential effect. Techniques for minimizing soil erosion during construction, such as dikes, silt fences, quick revegetation of exposed soils, and sediment traps, should be considered.

During site preparation and construction, the potential also exists for impacts to surface waters as a result of fuel or oil spills from heavy construction equipment and any tank failures from onsite storage or transport of fuels. Quantities of these potentially hazardous liquids stored and transported during construction should be kept as small as possible, and a spill contingency plan meeting the National Pollution Discharge Elimination System (NPDES) permit for storm water discharges from construction sites would need to be developed. The implementation of best management practices to control surface runoff and sedimentation would ensure the protection of wetlands and aquatic ecosystems during construction.

6.1.1.3 Waste Generation Estimates for Wasteform Facility Construction

There will be no LLW generated during construction because no radioactive materials are used, and the generic site is not contaminated. Table 6.3 summarizes the wastes generated during construction and provides their treatability categories.

There will be no radioactive waste material (RWM) generated during construction.

6.1.2 Estimate of Wastes and Emissions Generated During Operation of the Wasteform Facility

6.1.2.1 Estimates of Emissions and Effluents to the Environment

Table 6.4 estimates emissions from routine operations at the Wasteform Facility. All of the HEPA exhausts are on the roofs of the buildings and would be considered general area sources. The Wasteform Facility processes 35,750 drums/yr of U_3O_8, 21,000 drums/yr UO_2, 74,700 drums/yr grouted U_3O_8, or 31,600 drums/yr grouted UO_2. There are several operations at the Wasteform Facility that contribute to uranium emissions: emptying the drums, filling the mixers, using vibrators to eliminate air pockets, packaging the grouted materials, and wet and dry decontamination.

It is possible to determine the annual airborne emission rate for this facility by assuming a release fraction of approximately 4 x 10^{-6} for U-238 (based on the Hanford Grout Treatment Facility). A single bank of high-efficiency particulate air (HEPA) filtration [decontamination factor (DF) = 1 x 10^{-3}] is assumed. Each U_3O_8 drum contains 1,170 lb U, a UO_2 drum contains 1,990 lb U, each grouted U_3O_8 drum contains 560 lb U, and a grouted UO_2 drum contains 1,320 lb U. Based on this information and the annual processing rates shown above, the annual emission rate is on the order of 0.10 to 0.18 lb U (45 to 82 g U). This information is included in Table 6.5.

The release fraction during grout curing is approximately 2 x 10^{-5} (based on the Hanford Grout Treatment Facility). Using the same information supplied above, the annual emission rate is on the order of 0.49 to 0.90 lb U (222 to 408 g U). This information is included in Table 6.5.

Emissions from diesel generators are not regulated by the EPA due to the fact that they are minimal. Therefore, emissions from the backup generators were assumed to be negligible for the purposes of this report.

Gasoline usage in transportation of workers to and from work is not estimated. Only gasoline/diesel fuel usage at the site is estimated.

In the Supply and Shipping Warehouse, the following contaminated materials are accumulated and prepared to be shipped offsite for treatment and disposal:

- Empty depleted uranium drums that are not recyclable
- Contaminated filters from the vacuum and ventilation systems
- Neutralized and solidified residue from the acid-spray cleaning system
- Solid LLW (decontamination wipes) from the Curing Building
- Miscellaneous radioactive waste

Other than this controlled offsite transfer and the foregoing airborne emissions, no routine uranium releases are anticipated.

There will be no effluents to surface waters caused by operations of the Wasteform Facility. The operations entailed by the Wasteform Facility to grout the depleted uranium are such that no extraneous waste is generated. All of the materials going into the facility are solely to grout the depleted uranium.

Table 6.6 summarizes air emissions from operations due to on-site diesel usage.

6.1.2.2 Waste Generation Estimates for Wasteform Facility Operations

Table 6.7 estimates LLW generation and provides treatability categories of secondary waste streams (WHC, 1992). Any drums that do not pass visual inspection for structural integrity would be cleaned by vacuuming, and if necessary, by a dilute acid and detergent wash. It is estimated that a maximum of 5 percent of the total number of drums would fall into this category. These drums would then be shipped offsite to scrap metal yards.

6.1.3 Variations

The selection of other variations for the final wasteform result in changes in the waste and emissions.

6.2 Vault Disposal Facility

6.2.1 Construction

Table 6.8 presents emission estimates for construction of the vault disposal facility. Apart from site-specific considerations, no effluents are anticipated. No LLW will be generated. No RMW will be generated. Table 6.9 presents estimates of hazardous waste generation and their treatability categories. Sanitary wastes are estimated at 60,000 m^3.

6.2.2 Operation

Table 6.10 lists emissions during vault disposal facility operations. Equipment engines are responsible for these emissions. No routine emissions of radionuclides are anticipated. No effluents are anticipated. No routine LLW is expected. No RWM will be generated. Hazardous wastes are anticipated to be four times the values in Table 6.8.

6.2.3 Variations

Tables 6.8 through 6.10 provide estimates of the effect of variations upon emissions.

6.3 Engineered Trench Disposal Facility

6.3.1 Construction

Table 6.11 presents emissions estimates for construction of the trench disposal facility. Wastes generated during construction of the trench disposal facility and their treatability categories are provided in table 6.12.

There are no direct effluents generated from construction that are generic. Local hydrology and storm water management specific to a site may result in effluents. The potential impacts of site preparation and construction on local hydrology can be expected to include changes in the flow rate and direction of surface water, in the elevation and flow direction of groundwater beneath the site, and in the quality of surface water and groundwater. Site preparation and construction activities such as excavation and filling for a facility foundation, parking lots, and storage trenches may alter the topography of the site. Changes in the amount of infiltration and runoff of surface water and effects on drainage patterns are expected. The usual clearing of site vegetation and the movement of construction equipment tends to compact site soils, decreasing infiltration and increasing both runoff precipitation and storm events. Actual local conditions will contribute to variations in this potential effect. Techniques for minimizing soil erosion during construction, such as dikes, beams, silt fences, quick revegetation of exposed soils, and sediment traps, should be considered:

During site preparation and construction, the potential also exists for impacts to surface waters as a result of fuel or oil spills from heavy construction equipment and any tank failures from onsite storage or transport of fuels. Quantities of these potentially hazardous liquids stored and transported during construction should be kept as small as possible and a spill contingency plan meeting the NPDES permit for storm water discharges from construction sites would need to be developed. The implementation of best management practices to control surface runoff and sedimentation would ensure the protection of wetlands and aquatic ecosystems during construction.

6.3.2 Operation

Table 6.13 lists emissions during trench disposal facility operations. Equipment engineers are responsible for these emissions. No routine emissions of radionuclides are anticipated.

6.3.3 Variations

As stated earlier, emissions vary substantially from day to day depending on the level of activity, the specific operation, and the prevailing weather conditions. The approximate emissions factor for heavy-construction equipment exhaust is based on engine type and annual operating time. The emissions estimates represent the maximum expected values during facility construction. The implementation of control methods can significantly reduce these quantities and thereby lessen their environmental impact. For example, watering is often selected as a control method to reduce fugitive dust emissions. According to the EPA, an effective watering program (that is, twice daily watering with complete coverage) is estimated to reduce dust emissions by up to 50 percent (EPA, 1986).

6.4 Mined Cavity Disposal Facility

6.4.1 Construction

Facility wastes during construction would largely consist of excavated material, construction wastes such as cuttings and excess materials, and wastes associated with the large work force, such as wastewater, food containers, etc. The major items would be excavated tuffs and soils, which would arise during a 7-year construction period, and thus be produced at a rate of approximately 230,000 cm^3 (8.1 million ft) per year. This waste would be transported up the tuff ramp and deposited at the surface of the repository on the tuff pile. Wastewater would amount to about 379 million L (100 million gallons) per year during the construction period. Tables 6.14 and 6.15 list estimated air emissions and waste generation with their treatability categories during construction.

6.4.2 Operation

Facility wastes during operation would arise principally from the chemical operations in the Wasteform Facility (section 6.2), and from the requirements of the 100-person work force, mainly water. Wastewater, as noted in section 4.4.2.2, would be in the order of 1.9 - 3.8 million L (0.5-1.0 million gallons) per year. Table 6.16 shows estimated air emissions during operation.

6.4.3 Variations

Variations from the base case would not be expected to produce any sizeable changes in the waste estimates stated above.

Table 6.1 National Ambient Air Quality Standards (NAAQS) for Criteria Air Pollutants

Criteria Air Pollutant	Averaging Time	Primary Standard ($\mu g/m^3$)
Carbon Monoxide (CO)	1-hour[b] 8-hour[b]	40 mg/m^3 10 mg/m^3
Hydrocarbons (HC)	3-hour	160
NOx (as NO_2)	Annual	100
SOx (as SO_2)	24-hour[b] Annual	365 80
Particulate matter[a]	24-hour[b] Annual	150 50

a. Refers to respirable particulate matter (measuring less than 10 microns in size.)
b. Not to be exceeded more than once a year.

Ref: 40 CFR § 50.0 et seq.

Table 6.2 Air Emission Estimates from Wasteform Facility Construction

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO2	
	Annual	Total	Annual	Total	Annual	Total	Annual	Total
SO_2	.644	1.29	.179	.357	.327	.654	.107	.214
NOx	9.79	19.6	2.71	5.43	4.97	9.95	1.62	3.25
NMHC's	.739	1.48	.205	.410	.376	.751	.123	.245
Carbon Monoxide (CO)	2.11	4.22	.585	1.17	1.07	2.14	.350	.700
Particulate Matter	.688	1.38	.191	.382	.350	.700	.114	.228
N_2O	.0100	.0200	.00250	.00500	.00500	.0100	.00150	.00300
CH_4	.06	.120	.0165	.0330	.0305	.0610	.0100	.0200
CO_2	366	732	102	204	186	372	60.7	122

Table 6.3 Wastes Generated During Construction of the Wasteform Facility

		Grouted U_3O_8		Ungrouted-U_3O_8		Grouted UO_2		Ungrouted UO_2	
Category	Material	(L)	(kg)	(L)	(kg)	(L)	(kg)	(L)	(kg)
Hazardous Liquids	Paints	6,400	6,400	2,560	2,560	2,240	2,240	900	900
	Phenol	1,600	1,000	640	400	560	350	225	150
	Sulfuric Acid	800	800	320	320	280	280	115	115
	TOTAL	8,800	8,200	3,520	3,280	3,080	2,870	1,240	1,165
Hazardous Solids	Mercury Lamps	765	10	306	4	300	4	120	1.5
	Lead Batteries	--	180	--	72	--	65	--	26
Non-Hazardous Solids	Conventional Waste	60×10^6	--	24×10^6	--	21×10^6	--	9×10^6	--

Table 6.4 Emissions Points and Flow Information for Wasteform Facility Operations

Building	Exhaust, m^3/min (ft^3/min)	Number of Exhaust Points	Height, m (ft)	Exhaust Velocity, m/sec (ft/sec)	Stack Diameter, m (ft)	Annual Uranium Release, lb U_3O_8	Annual Uranium Release, lb UO_2
Product Receiving Warehouse	1,200 (42,400)	3	18.3 (60)	3 (10)	1.76 (5.77)	~0	~0
Cementing Building	490 (17,300)	3	18.3 (60)	3 (10)	1.11 (3.64)	0.10	0.18
Curing Building	1,190 (42,000)	7	18.3 (60)	3 (10)	1.05 (3.44)	0.49	0.90
Supply & Shipping Warehouse	1,190 (42,000)	5	18.3 (60)	3 (10)	1.23 (4.04)	~0	~0

Table 6.5 Annual Airborne Emission Rates of Uranium

	U_3O_8	UO_2	Grouted U_3O_8	Grouted UO_2
Annual number of drums	35,750	21,000	74,700	31,600
Amount of U per drum	1,170 lb U	1,990 lb U	560 lb U	1,320 lb U
Airborne Emission Rate - Operations	N/A*	N/A*	0.10 lb U	0.18 lb U
Airborne Emission Rate - Grout Curing	N/A*	N/A*	0.49 lb U	0.90 lb U

*No wasteform processing is performed.

Table 6.6 Air Emissions Estimates from Wasteform Facility Operations

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Annual	20-Years	Annual	20-Years	Annual	20-Years	Annual	20-Years
SO_2	.402	8.03	.00250	.0500	.112	2.23	.00250	.0500
NOx	6.11	122	.0405	.810	1.70	33.9	.0405	.810
NMHC's	.461	9.22	.00300	.0600	.128	2.56	.00300	.0600
Carbon Monoxide (CO)	1.32	26.3	.00850	.170	.366	7.31	.00850	.170
Particulate Matter	.430	8.59	.00300	.0600	.120	2.39	.00300	.0600
N_2O	.00600	.120	neg.	.00100	.00150	.0300	neg.	.00100
CH_4	.0375	.750	neg.	.00500	.0105	.210	neg.	.00500
CO_2	229	4570	1.51	30.2	63.5	127	1.51	30.2

Table 6.7 Waste Estimates from Wasteform Facility Operations (Annual Basis)

Stream Description	Volume: U_3O_8, Bulk	Volume: UO_2, Bulk	Volume: U_3O_8 Grouted	Volume: UO_2 Grouted	Treatability Category
Facility Waste (Product)	7,440,000 L/yr	2,380,000 L/yr	15,550,000 L/yr	3,600,000 L/yr	N/A
HEPAs	23.8 m^3	23.8 m^3	23.8 m^3	23.8 m^3	Non-combustible Compactable Solid (LLW)
Other LLW	56.6 m^3	24.3 m^3	23.6 m^3	5.5 m^3	Combustible Solid (LLW)
Inorganic Solutions	0.31 m^3	0.2 m^3	0.18 m^3	0.1 m^3	Low-level Mixed Waste (LLMW)
Cleaning Wipes	N/A	N/A	5 kg (0.0078 m^3)*	5 kg (0.0078 m^3)*	Low-level Mixed Waste (LLMW)

* Based on bulk density of 40lb/ft^3

Table 6.8 Air Emission Estimates from Vault Construction

Criteria Air Pollutant (tons/year)	Per Vault (tons)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
		Annual	20-Years	Annual	20-Years	Annual	20-Years	Annual	20-Years
Number of Vaults	1	8.45	169	4.04	81	1.73	35	1.15	23
SO_2	.0945	.799	16.0	.383	7.66	.166	3.31	.109	2.18
NOx	1.44	12.2	243	5.82	116	2.52	50.3	1.65	33.1
NMHC's	.109	.918	18.4	.440	8.79	.190	3.80	.125	2.50
Carbon Monoxide (CO)	.310	2.62	52.4	1.25	2.51	.542	10.8	.257	7.13
Particulate Matter	.101	.854	17.1	.410	8.19	.177	3.54	.117	2.33
N_2O	.00150	.0120	.240	.00600	.120	.00250	.0500	.00150	.0300
CH_4	.00900	.0745	1.49	.0355	.710	.0155	.310	.0100	.200
CO_2	53.8	455	9090	218	4360	94.2	1880	61.9	1240

Table 6.9 Wastes Generated During Construction of the Vault Disposal Facility

		Grouted U308		Ungrouted-U3O8		Grouted UO2		Ungrouted UO2	
Category	Material	(L)	(kg)	(L)	(kg)	(L)	(kg)	(L)	(kg)
Hazardous Liquids	Paints	3,200	3,200	1,280	1,280	1,120	1,120	450	450
	Phenol	800	500	320	200	280	175	115	75
	Sulfuric Acid	400	400	160	160	140	140	60	60
	TOTAL	4,400	4,100	1,760	1,640	1,540	1,435	625	585
Hazardous Solids	Mercury Lamps	382	5	153	2	150	2	60	1
	Lead Batteries	--	90	--	36	--	33	--	13
Non-Hazardous Solids	Conventional Waste	30×10^6	--	12×10^6	--	11×10^6	--	5×10^6	--

Table 6.10 Air Emission Estimates from Vault Disposal Facility Operations

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Annual	20-Years	Annual	20-Years	Annual	20-Years	Annual	20-Years
SO_2	2.30	45.9	1.09	21.9	.903	18.1	.601	12.0
NOx	34.9	698	16.6	333	13.7	275	9.13	183
NMHC's	2.64	52.7	1.26	25.1	1.04	20.7	.690	13.8
Carbon Monoxide (CO)	7.52	150	3.59	71.7	2.96	59.2	1.97	39.3
Particulate Matter	2.45	49.1	1.17	23.4	.966	19.3	.642	12.8
N_2O	.0350	.700	.0165	.330	.0135	.270	.00900	.180
CH_4	.214	4.28	.102	2.04	.0845	1.69	.0560	1.12
CO_2	1310	26,100	625	12,500	515	10,300	340	6800

Table 6.11 Air Emissions Estimates from Trench Construction

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Annual	20-Years	Annual	20-Years	Annual	20-Years	Annual	20-Years
SO_2	.473	9.45	.242	4.83	.164	3.28	.123	2.45
NOx	7.18	144	3.68	73.5	2.50	49.9	1.87	37.3
NMHC's	.543	10.9	.278	5.55	.189	3.77	.141	2.82
Carbon Monoxide (CO)	1.55	30.9	.792	15.8	.538	10.8	.402	8.04
Particulate Matter	.505	10.1	.259	5.17	.176	3.51	.131	2.62
N_2O	.00700	.140	.00350	.0700	.00250	.0500	.00200	.0400
CH_4	.00440	.880	.0225	.450	.0155	.310	.0115	.230
CO_2	269	5,370	138	2,750	93.4	1,870	69.8	1,400

Table 6.12 Waste Generated During Construction of the Trench Disposal Facility

		Grouted U_30_8		Ungrouted-U_3O_8		Grouted UO_2		Ungrouted UO_2	
Category	Material	(L)	(kg)	(L)	(kg)	(L)	(kg)	(L)	(kg)
Hazardous Liquids	Paints	1600	1,600	640	640	560	560	225	225
	Phenol	400	250	160	100	140	90	60	40
	Sulfuric Acid	200	200	80	80	70	70	30	30
	TOTAL	2,200	2,050	880	820	770	720	315	295
Hazardous Solids	Mercury Lamps	190	3	80	1	75	1	30	0.5
	Lead Batteries	--	45	--	28	--	17	--	7
Non-Hazardous Solids	Conventional Waste	$15x10^6$	--	6×10^6	--	6×10^6	--	3×10^6	--

Table 6.13 Air Emission Estimates from Trench Operations

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Annual	20-Years	Annual	20-Years	Annual	20-Years	Annual	20-Years
SO2	.877	17.5	.415	8.30	.347	6.93	.261	5.21
NOx	13.3	267	6.31	126	5.27	105	3.96	79.2
NMHC's	1.01	20.1	.477	9.53	.398	7.95	.299	5.98
Carbon Monoxide (CO)	2.87	57.4	1.36	27.2	1.14	22.7	.853	17.1
Particulate Matter	.937	18.7	.444	8.87	.371	7.41	.279	5.57
N_2O	.0135	.270	.00650	.130	.00550	.110	.00400	.0800
CH_4	.0820	1.64	.0385	.770	.0325	.650	.0245	.490
CO_2	499	9,980	236	4,720	197	3,940	148	2,960

Table 6.14 Air Emission Estimates from Mined Cavity Construction

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Annual	Total	Annual	Total	Annual	Total	Annual	Total
SO2	.632	4.74	.368	2.76	.269	2.01	.212	1.59
NOx	9.61	72.1	5.59	41.9	4.08	30.6	3.22	24.2
NMHC's	.726	5.45	.422	3.17	.308	2.31	.243	1.82
Carbon Monoxide (CO)	2.07	15.5	1.20	9.03	.880	6.60	.694	5.21
Particulate Matter	.676	5.07	.393	2.95	.287	2.15	.227	1.70
N_2O	.00950	.0720	.00550	.0413	.00400	.0300	.00300	.0225
CH_4	.0590	.443	.0345	.259	.0250	.188	.0200	.150
CO_2	360	2,700	209	1,570	153	1,150	121	904

Table 6.15 Wastes Generated During Construction of the Mined Cavity Disposal Facility

		Grouted U_3O_8		Ungrouted-U_3O_8		Grouted UO_2		Ungrouted UO_2	
Category	Material	(L)	(kg)	(L)	(kg)	(L)	(kg)	(L)	(kg)
Hazardous Liquids	Paints	9,600	9600	3,840	3,840	3,360	3,360	1,350	1,350
	Phenol	2,400	1500	960	600	840	525	340	225
	Sulfuric Acid	1,200	1200	480	480	420	420	180	180
	TOTAL	13,200	12300	5,280	4,920	4,620	4,305	1,870	1,755
Hazardous Solids	Mercury Lamps	--	209	--	147	--	117	--	96
	Lead Batteries	--	384	--	270	--	215	--	176
Non-Hazardous Solids	Conventional Waste	90×10^4	--	64×10^4	--	50×10^4	--	42×10^4	--

Table 6.16 Air Emission Estimates from Mined Cavity Operations

Criteria Air Pollutant (tons/year)	Grouted U_3O_8		Ungrouted U_3O_8		Grouted UO_2		Ungrouted UO_2	
	Annual	20-Years	Annual	20-Years	Annual	20-Years	Annual	20-Years
SO_2	.0655	1.31	.0325	.650	.0490	.980	.036	.720
NOx	.994	19.9	.497	9.94	.746	14.9	.547	10.9
NMHC's	.0750	1.50	.0375	.750	.0565	1.13	.0415	.830
Carbon Monoxide (CO)	.214	4.28	.107	2.14	.161	3.21	.118	2.36
Particulate Matter	.0700	1.40	.0350	.700	.0525	1.05	.0385	.770
N_2O	.00100	.0200	.000500	.0100	.00075	.0150	.000550	.0110
CH_4	.00600	.120	.00300	.0600	.0045	.0900	.00350	.0700
CO_2	37.2	744	18.6	372	27.9	558	20.5	409

7.0 DESCRIPTION OF POTENTIAL ACCIDENTS

7.1 Radiological Accidents at Disposal Sites

The different disposal site approaches have a common radiological source that influences the nature and type of accident analyses. The only source of radiological accidents is the presence of depleted uranium in one of two chemical forms: uranium octaoxide powder and uranium dioxide sand/pellets. Detailed analyses of postulated release of uranium in NUREG-1140 for nuclear fuel fabrication plants have shown that the chemical toxicity of uranium is much greater than any dose rate associated with the radiation emitted by the uranium. Specifically, a chemically toxic lethal exposure from uranium would occur with a radiation dose of no more than 1 rem; such a radiation dose is not considered to have any significant health effects. Therefore, the accident analyses for a disposal site will deal principally with the calculation of uranium air concentration or intake resulting from postulated releases. However, it should also be noted that 10 CFR 20, 40 CFR 61, and 40 CFR 190 set specific public radiation dose standards that limit routine operational releases of radioactive material.

7.2 Analysis of Generic Nonradiological Accidents at a Disposal Site

Depleted uranium is assumed to be delivered to the disposal site either in 55-gallon drums containing 0.625 te (1,380 lb) uranium octaoxide powder or in 30-gallon drums containing up to 1.024 te (2,260 lb) of uranium dioxide sand or pellets. The U_3O_8 powder has a mean particle size around 50 microns with a small fraction below 10 microns. The UO_2 sand consists of particles between 300 and 1,200 microns in diameter. The UO_2 pellets would be approximately 7 mm (0.28 in.) in diameter and 13 mm (0.5 in.) long. When delivered to the plant site, the drums are immediately placed inside a storage building that is equipped with a HEPA filtration system. All processing of the material from the drums is performed inside buildings with HEPA filtration systems. The HEPA systems are assumed to be nuclear safety grade.

Both U_3O_8 and UO_2 are inert chemical forms of depleted uranium with melting points of 1,300 °C (2,372 °F) and 2,878 °C (5,212 °F), respectively (Table 1.1). U_3O_8 is the typical form of uranium after mining. UO_2 is a ceramic material that was selected for commercial light water reactor fuel designs because of its non-reactive chemical properties.

The ability of U_3O_8/UO_2 particles to become airborne in an accident is an important factor in calculating the health effects of postulated accidents that release depleted uranium to the environment. Particles can become airborne due to a force, such as an explosion, that propels them.

For particles greater than 1 micron in diameter to remain airborne, the air flow drag force must be equal to or greater than the gravitational force. Calculations of the required minimum air velocity as a function of particle diameter (U.S. AEC, 1968) show that an air velocity of 2 to 5 mph is sufficient to maintain the U_3O_8 powders airborne, while higher velocities of 10 to 50 mph are required to maintain the UO_2 300-1200 micrometer sand airborne. Although these velocities are possible, they would coincide with an atmospheric dispersion that would greatly dilute the concentration of uranium.

Another important parameter in evaluating accident consequences for the disposal site is the respiratory intake of particles. Established data and models used in the nuclear industry (ICRP, 1987) show that particles greater than 10 microns in diameter are retained in the nasal region, if they can even be inhaled, and subsequently released from the nasal region with little residence time. Therefore, the presence of particles with a diameter greater than 10 micrometers will not pose any inhalation health hazard. It is important to note that inhalation is the primary means by which uranium particles would be expected to pose a toxic hazard.

The U_3O_8 and UO_2 disposal material is available for direct release to the environment only during two phases of the plant operation: (a) arrival of the material in drums [55-gallon, 0.625 te for U_3O_8; 30-gallon, 1.024 te drums for UO_2], and (b) shipment of the material to the disposal areas on the site. As previously discussed, the chemical form and size of the UO_2 is inherently stable, nonreactive, and extremely difficult to be introduced into the respiratory or digestive system. Since there is no external toxic chemical hazard from this depleted uranium, the only means of posing a health effect is to transform the UO_2 into particles less than 10 micrometers in diameter.

Extremely high temperatures (i.e., > 4440 °F) and/or an explosion could result in converting the UO_2 into a respirable or ingestible form. Using data from gas/oil gases in a furnace, the American Society for Testing and Materials (ASTM) developed a standard temperature-time curve with a peak flame temperature of 2300 °F (Drysdale, 1985). This curve is used in the qualification of fire resistant components. Any fire temperature would be more than 2,000 degrees less than the melting points of the UO_2. Therefore, while a fire could distort or increase particle size by surface oxidation, it is unlikely to cause any size attrition resulting in fine particles and releases of uranium to the environment. This would have to be verified by specific analyses and testing as part of the licensing process.

A sufficiently powerful explosion could transform the UO_2 sand or pellets into respirable particles. However, there is no source of explosive material expected at this plant, including the outside receipt and shipping areas. Therefore, for direct environmental release, the chemical form of the UO_2 precludes any release due to fire, and the lack of explosive materials eliminates an explosion as a source of release.

For U_3O_8 powder, a small fraction exists in the 10 micron diameter or less size range. This fraction has been estimated as around 2×10^{-4}, based on NUREG-1320 and DOE-HDBK-0013-93. For UO_2, the respirable release fraction is estimated to be even smaller, 5×10^{-5}, in NUREG-

1140. As with UO_2, U_3O_8 is very stable, and at high temperatures, converts to UO_2. Again, size attrition appears unlikely, although experimental verification is necessary.

The other postulated accident outside the plant buildings involves the mishandling (i.e., drum drop or impact) of the U_3O_8 and UO_2. Any mishandling would, at the worst, cause the drum wall to rupture and release its contents of powder, sand, or pellets. As previously discussed, the chemical form and particle size of the UO_2 precludes it from being dispersed in the atmosphere and inhaled. Therefore, there would be no health effects from rupturing any drums of UO_2.

Inside the plant, the U_3O_8 or UO_2 would be combined with cement using a mixer. Other encapsulants could be used, such as polymers. In those cases, the uranium would be combined with resin materials and heated to a temperature between 200 and 300 °C. Neither of these two manufacturing operations provide the potential for any accidents involving the introduction of sufficient energy to release the uranium into the environment in the form of respirable particles.

The final form of the U_3O_8 or UO_2 materials would be within disposal drums. The steel outer container provides another layer of confinement beyond the chemically inert form of the depleted uranium.

7.3 Wasteform Facility

No accidents other than industrial dropping, tipping, or pinching have been identified with the operation of the Wasteform Facility. Drum-handling devices will be provided to minimize these potential accidents.

To initiate an environmental release, accidents outside the Wasteform Facility buildings must result in a failure of the 55- or 30-gallon drums. A prolonged high temperature fire, an explosion, or significant container mishandling could result in a breach of the container's structural integrity. A fire or explosion that breached the container housing could initiate an exothermal chemical reaction in the uranium, which would release respirable uranium particles to the atmosphere. No explosion source outside the facility buildings is expected to exist.

A conservative and bounding estimate of the effects of a chemical reaction or fire on an exposed drum that is outside the facility buildings is to assume that all of the uranium compound becomes airborne as respirable particles. Regulatory studies of ground level and heated buoyant plume release of uranium (NUREG-1140) were used to calculate the individual uranium intake for 95-percentile conservative atmospheric dispersion (F) and average 50-percentile dispersion (D). A significant health effect was determined by the NRC (NUREG-1140) to occur from the intake of 10 mg of uranium. Using the calculations in NUREG-1140 for both ground level and heated buoyant plume releases of uranium articles and accounting for the mass of the drum, the 10 mg intake would occur at approximately 4.5 km (2.7 miles) for the F metrology and approximately 1.0 km (0.6 miles) for the average D metrology.

The selection of other variations for the wasteform will only decrease the probability of accidents, due to reduced drum handling.

7.4 Vault Disposal Facility

The main safety objectives are protection of the general population from releases of radioactivity, protection of individuals from inadvertent intrusion, and protection of workers involved in operations. A fourth objective is to ensure stability of the site after closure.

Other long-term radiological accidents could result from inhalation of contaminated dust by a future reclaimer or exposures from consumption of food grown on the disposal site after it is contaminated by carrying wastes to the surface. Short-term effects include exposures to the public along transportation routes, consumption of contaminated water from an onsite or nearby well, and a person at the site boundary inhaling airborne contamination from single containers accidentally ruptured during handling.

7.5 Engineered Trench Disposal Facility

The main safety objectives are protection of the general population from releases of radioactivity, protection of individuals from inadvertent intrusion, and protection of workers involved in operations. A fourth objective is to ensure stability of the site after closure. The differences in crew sizes and types of activities directly affect projected risks.

Other long-term radiological accidents could result from inhalation of contaminated dust by a future reclaimer or exposures from consumption of food grown on the disposal site after it is contaminated by carrying wastes to the surface. Short-term effects include exposures to the public along transportation routes, consumption of contaminated water from an onsite or nearby well, and a person at the site boundary inhaling airborne contamination from single containers accidentally ruptured during handling.

7.6 Mined Cavity Disposal Facility

The greatest radiological hazards in the mined cavity disposal facility exists in the underground storage areas (emplacement drifts), in the event that ventilation is lost for a protracted period of time and seepage of radon leads to dangerous concentrations.

Serious industrial hazards exist, particularly in the construction phase. Fatalities in excavating and drilling operations (most recently, in the excavation of the tunnel beneath the English Channel) are commonplace. These can be the consequence of flying debris, unstable heavy machinery, and failure to use adequate shoring. In the operating phase, accidents can also occur in the handling of heavy drums by overloading fork lifts, dropping loads, etc. Finally, although the depleted uranium oxides do not represent a heat load and are not combustible, an accidental fire in an emplacement drift could conceivably lead to drum rupture and dissemination of waste materials.

Variations from the base case should neither diminish nor exacerbate the potential accidents described here.

7.7 Scoping Assessment of Accident Frequencies

To gain an understanding of the risks associated with the operation of a depleted uranium disposal facility, a scoping assessment of the occurrence frequencies of five potential accidents has been conducted. Details of the frequency estimation process are provided in the following sections.

Mishandling/Drop of Drum

Drums of U_3O_8 powder, or drums of UO_2 sand or pellets, are transferred into the facility using a series of cranes and hoists. There is a potential that they may rupture if mishandled during transfer. The probability of creating a leak from mishandling was calculated to be 1.1×10^{-5}/operation where an operation is defined as the handling of a drum, while moving it from the truck bay to the storage area, both of which have HEPA filtration.

The disposal facility receipt rate is 35,750 U_3O_8 drums/year or 21,000 UO_2 drums/year.

Assuming that each drum is handled twice, once to unload the truck or rail car and once to move it into the facility building, the probability of a mishandling accident is:

$$35{,}750\ U_3O_8\ \text{drums/year} \times 2\ \text{operations/drum} \times 1.1 \times 10^{-5}\text{/operation} = 7.9 \times 10^{-1}\text{/year}$$

$$21{,}000\ UO_2\ \text{drums/year} \times 2\ \text{operations/drum} \times 1.1 \times 10^{-5}\text{/operation} = 4.6 \times 10^{-1}\text{/year}$$

The estimated frequency for U_3O_8 drum mishandling is 7.9×10^{-1}/year, and the estimated frequency for UO_2 drum mishandling is 4.6×10^{-1}/year.

For the UO_2, the material at risk contains approximately 1,024 kg. The release fraction is estimated as 5×10^{-5}. HEPA filtration is expected to remove 99.9 percent of the particles. Thus, the environmental release source term is 0.05 g as UO_2.

For the U_3O_8, the material at risk contains approximately 625 kg. The release fraction is estimated as 2 x 10^{-4}. HEPA filtration removes 99.9 percent of the oxide particles. Consequently, the environmental release source term becomes 0.125 g as U_3O_8.

Fire, Explosion, or Chemical Reagent Contact Inside the Facility

A detailed design would be needed to accurately calculate the frequency of a fire, explosion, or release of chemical reagent that could cause a release of uranium particles inside the facility. It is likely that the initiator of such an accident would be the leak or rupture of a furnace, tank, or pipe. Some furnace, tank, and pipe rupture frequencies have been previously calculated for UF_6 processing to be from 5.8 x 10^{-6}/year to 9.6 x 10^{-6}/year. As a conservative estimate, since a pipe, tank, or furnace rupture or failure may not necessarily lead to a fire, explosion, or chemically induced uranium release, the largest of these frequencies, 9.6 x 10^{-6}/year, is assumed for this accident with both U_3O_8 and UO_2.

For UO_2, the maximum material at risk would be 6,144 kg (13,545 lb) (essentially two containers are charged to each mixer at any one time, and there are three mixers per unit). Again, the respirable release fraction is 5 x 10^{-5}. The HEPA filters would remove 99.9 percent. The environmental source term would become 0.31 g as UO_2.

For U_3O_8, a similar argument yields a maximum material at risk of 3,750 kg (8,267 lb). The respirable release fraction is 2 x 10^{-4}. The HEPA filters remove 99.9 percent. The environmental source term becomes 0.75 g as U_3O_8.

Mishandling or Drop of Encapsulated Wasteform

Although the final form and weight of encapsulated material produced at the disposal site may be refined for leach resistance purposes, it is reasonable, for accident purposes to assume a comparable number of drums as the incoming material. Thus, the estimated frequency for drum mishandling/drop is 7.9 x 10^{-1}/year for U_3O_8 and 5.9 x 10^{-1}/year for UO_2.

For UO_2, the material at risk is approximately 2,720 kg (5,997 lb) of uranium dioxide (i.e., four drums on a pallet). The analysis assumes a damage fraction of 25 percent. As an approximation, the analysis uses a respirable release fraction of 10^{-7} in an area without HEPA filtration. The environmental source term becomes 68 mg as UO_2.

For encapsulated U_3O_8, the material at risk is approximately 1,196 kg (2,637 lb) of uranium oxide. Again, as an approximation, the analysis assumes 25 percent damage fraction and uses a respirable release fraction of 10^{-7} in an area without HEPA filtration (i.e., the fines are encapsulated). The resulting environmental source term becomes 30 mg as U_3O_8.

Externally Initiated Events

Externally initiated events tend to be site specific. As a first approximation, the DOE performance category frequencies are used in the estimates. The release fractions used for internal events are based on falling powders. For external events, most of the drums are at or near ground level. Although much of the powder may be released to the atmosphere, much lower release fractions are assumed. These are delineated in section 2.

The disposal facilities have a low hazard rating. This constitutes a performance category of 2. This represents an annual frequency of 5×10^{-4} for events causing damage and loss of function. For major earthquakes, failure of the structure and confinement systems occurs. The product receiving area, the cementing area, and the curing/shipping and storage areas constitute the areas of the plant with material at risk (5,376, 247.5 and 3,755 te, respectively). The earthquake results in damage fractions of 50 percent for UO_2 product receiving containers, 100 percent in the cement mixing area, and 10 percent in the curing/storage area. The respirable fractions are 10^{-7}. The resulting source terms are 269 g, 24.8 g, and 37.6 g for the product receiving, cement mixing, and curing/shipping and storage areas, respectively, all as UO_2.

Similarly, a major tornado would also result in failure of the structures and the confinement systems. Tornado missiles would increase damage fraction to 100 percent. Using the respirable fraction of 10^{-7}, the resulting respirable source terms become 538 g, 24.8 g, and 376 g for the product receiving, cement mixing, and curing/shipping and storage areas, respectively.

Plane crashes are analyzed in the Supplemental Accident Analysis (see section 7). Floods are not assumed to occur since the facility would be located at a site that precludes severe flooding.

Similar earthquake analyses have been performed for U_3O_8. As before, the product receiving storage, cement mixing, and curing/shipping and storage areas constitute the areas of the plant with material at risk (5,588, 258.5, and 4,923 te, respectively). The damage fractions are the same as the UO_2 case, but the airborne respirable fractions are 6×10^{-5}, 6×10^{-5}, and 10^{-8}, respectively. The resulting source terms become 167.6 kg, 15.5 kg, and 4.9 g, respectively. Similarly, a tornado would also result in the failure of the structures and confinement systems. Tornado missiles would increase damage fraction to 100 percent. The resulting source terms become 335.3 kg, 15.5 kg, and 49 g, respectively.

Summary of Estimated Frequencies

Tables 7.1 and 7.2 present summaries of the estimated frequencies for accidents identified and evaluated in this section. The tables also delineate the maximum source of respirable uranium particles released to the environment for each accident type.

Table 7.1 Scoping Assessment of Accidents for Internal Events

Accident	Frequency (per year)	Frequency Range			Effective MAR	RAF	RF	Leak Path	Source Term	Release Duration
		$>10^{-2}$/yr	10^{-2} to 10^{-4}/yr	$<10^{-4}$/yr						
Mishandling or Drop of Drum or Cylinder										
U_3O_8	7.9 x 10^{-1}	x			625 kg	2 x 10^{-4}		$1x10^{-3}$	0.125 g	puff
UO_2	$4.6x10^{-1}$	x			1,024 kg	5 x 10^{-5}		$1x10^{-3}$	0.05 g	puff
Fire or Explosion Reagent Inside										
U_3O_8	$9.6x10^{-6}$			x	3,750 kg	$2x10^{-4}$		$1x10^{-3}$	0.75 g	5 min
UO_2	$9.6x10^{-6}$			x	6,144 kg	$5x10^{-5}$		$1x10^{-3}$	0.31 g	5 min
Mishandling or Drop of Encapsulated Waste form										
U_3O_8	7.9 x 10^{-1}	x			299 kg	$1x10^{-7}$		1	30 mg	puff
UO_2	$5.9x10^{-1}$	x			680 kg	$1x10^{-7}$		1	68 mg	puff

Table 7.2 Scoping Assessment of Accidents for External Events

Accident	Frequency (per year)	Frequency Range			Effective MAR	RAF	RF	Leak Path	Source Term	Release Duration
		$>10^{-2}$/yr	10^{-2} to 10^{-4}/yr	$<10^{-4}$/yr						
Major Earthquake - Product Receiving Area										
U_3O_8	$5x10^{-4}$		x		2,794,000 kg	$6x10^{-5}$		1	167.6 kg	puff
UO_2	$5x10^{-4}$		x		2,688,000 kg	$1x10^{-7}$		1	269 g	puff
Major Earthquake - Cement Mixing Area										
U_3O_8	$5x10^{-4}$		x		258,500 kg	$6x10^{-5}$		1	15.5 kg	puff
UO_2	$5x10^{-4}$		x		247,500 kg	$1x10^{-7}$		1	24.8 g	puff
Major Earthquake - Curing/Shipping and Storage Area										
U_3O_8	$5x10^{-4}$		x		492,300 kg	$1x10^{-7}$		1	4.9 g	puff
UO_2	$5x10^{-4}$		x		375,500 kg	$1x10^{-7}$		1	37.6 g	puff
Tornado - Product Receiving Area										
U_3O_8	$5x10^{-4}$		x		5,588,000 kg	$6x10^{-5}$		1	335.3 kg	puff
UO_2	$5x10^{-4}$		x		5,376,000 kg	$1x10^{-7}$		1	538 g	puff

Table 7.2 Scoping Assessment of Accidents for External Events (continued)

Accident	Frequency (per year)	Frequency Range			Effective MAR	RAF	RF	Leak Path	Source Term	Release Duration
		$>10^{-2}$/yr	10^{-2} to 10^{-4}/yr	$<10^{-4}$/yr						
Tornado - Cement Mixing Area										
U_3O_8	$5x10^{-4}$		x		258,500 kg	$6x10^{-5}$		1	15.5 kg	puff
UO_2	$5x10^{-4}$		x		247,500 kg	$1x10^{-7}$		1	24.8 g	puff
Tornado - Curing/Shipping and Storage Area										
U_3O_8	$5x10^{-4}$		x		4,923,000 kg	$1x10^{-7}$		1	49 kg	puff
UO_2	$5x10^{-4}$		x		3,755,000 kg	$1x10^{-7}$		1	376 g	puff

8.0 TRANSPORTATION

8.1 Intrasite Transportation

Intrasite transportation of radioactive materials is limited to:

- transport of impounded, noncompliant conversion product material from the Product Receiving Warehouse impound area to the Supply and Shipping Warehouse via fork lift,

- transport of drums of conversion product material (Wasteform Facility feed material) from the Product Receiving Warehouse to the Cementing Building via power roller conveyor lines,

- transport of drums of wasteform product from the Cementing Building to the Curing Building via power roller conveyor lines,

- transport of cured drums of wasteform product from the Curing Building to the Supply and Shipping Warehouse via power roller conveyor lines, and

- transport of drums of wasteform product from the Supply and Shipping Warehouse to the disposal site via intrasite conveyance, most practically a fork lift moving four drums at a time.

Other intrasite transportation involves:

- transport of new wasteform product drums from the Supply and Shipping Warehouse to the Cementing Building via power roller conveyor lines.

LLRW is not expected to be a routine by-product of the Wasteform Facility. Any LLRW that is generated as the result of an off normal process condition will be packaged in accordance with DOE requirements and transported via fork lift to the Supply and Shipping Warehouse for storage until appropriate disposal is arranged.

Hazardous waste materials (waste cleaning solutions, spent lubricants, laboratory wastes) requiring special treatment before disposal will be packaged and transported via fork lift to the Supply and Shipping Warehouse to be shipped for treatment and disposal offsite.

8.2 Offsite Transportation

Offsite transportation of radioactive materials is limited to the receipt of conversion process product in steel drums. Drums of U_3O_8 are received by truck or rail car at a rate averaging 137 drums per day. Four truck shipments or two rail car shipments or any equivalent mixture of the two, is required to accommodate the wasteform process.

Other receipts of process and plant operation materials are:

- empty drums for casting and packaging the wasteform product at an average rate of 150 drums per day,
- bulk deliveries of sand and cement for pneumatic transfer to storage hoppers,
- fuel and lubricants for plant vehicles, emergency power generator, and maintenance uses, and
- personnel protective equipment.

No products or by-products are shipped offsite, the disposal site being collocated with the Wasteform Facility. The only potential out-shipments are returned, noncompliant U_3O_8 drums, and hazardous waste for disposal.

8.3 Differences Between Options and Variations

The selection of other wasteforms will only decrease the amount of handling (transportation) necessary. Tables 8.1 through 8.4 summarize the transportation requirements for the proposed wasteform variations.

Table 8.1 Offsite Transportation - Supplies and Input Materials for the Wasteform Facility - Base Case

	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5	Input Material No. 6	Output Material No. 1
Chemical content/ composition	U_3O_8 100%	U_3O_8 100%	Cement 100%	Sand 100%	New Drums 55 gallon	Various	Cemented U_3O_8
Type/chemical	U_3O_8	U_3O_8	cement	sand	drums	general supplies	cement/sand/U_3O_8
Physical Form	solid, granular	solid, granular	solid, dry	solid, dry	solid, fabricated	various	solid, monolith
Type	55 gal drum	55 gal drum	bulk	bulk	banded, palletized	various	55 gal drum
Container weight	34 kg (75 lb)	34 kg (75 lb)	NA	NA	10 kg (25 lb) (pallet and banding)	various	34 kg (75 lb)
Material weight	625 kg (1,380 lb)	625 kg (1,380 lb)	25 te/truck trailer 45 te/rail car	25 te/truck trailer 45 te/rail car	34 kg (75 lb) each 136 kg per pallet	various	598 kg (1,320 lb
Annual quantity	23,350 te	23,350 te	11,175 te	11,175 te	38,950 te	low volume low weight	44,700 te
Packaging Containers, No./yr.	35,750 drums	35,750 drums	NA	NA	9,738 pallets	various	74,700
Transportation mode	truck	rail	truck/rail	truck/rail	truck	truck	intra-site conveyor
Number of packages per shipment	28 drums	320 80 drums/car 4 cars/train	NA [7.6 m^3 (10 yd^3) per truck trailer]	NA [7.6 m^3 (10 yd^3) per truck trailer]	24 pallets	various	NA
Number of shipments per year	1,277	112	540 truck 50 rail	540 truck 50 rail	406	52	NA

Table 8.2 Offsite Transportation — Supplies and Input Materials for the Wasteform Facility - Bulk U_3O_8 Variation

	Input Material No. 1	Input Material No. 2	Input Material No. 3	Output Material No. 1
Chemical content/ composition	U_3O_8 100%	U_3O_8 100%	Various	U_3O_8
Material				
Type/chemical	U_3O_8	U_3O_8	general supplies	U_3O_8
Physical form	solid, granular	solid, granular	various	solid, granular
Packaging				
Type	55 gal drum	55 gal drum	various	55 gal drum
Container weight	34 kg (75 lb)	34 kg (75 lb)	various	34 kg (75 lb)
Material weight	625 kg (1,380 lb)	625 kg (1,380 lb)	various	625 kg (1,380 lb)
Shipping				
Annual quantity	22,350 te	22,350 te	low volume low weight	22,350 te
Packaging containers, No./yr	35,750	35,750	various	35,750
Transportation mode	truck	rail	truck	intrasite conveyor
Number of packages per shipment	28	320	various	NA
Number of shipments per year	1,277	112	52	NA

Table 8.3 Offsite Transportation — Supplies and Input Materials for the Wasteform Facility - Cemented UO_2 Variation

	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5	Output Material No. 1
Chemical content/ composition	UO_2 100%	UO_2 100%	Cement 100%	New Drums 30 gallon	Various	Cemented UO_2
Type/chemical	UO_2	UO_2	cement	drums	general supplies	cement/UO_2
Physical Form	solid, granular	solid, granular	solid, dry	solid, fabricated	various	solid
Type	30 gal drum	30 gal drum	bulk	banded, palletized	various	30 gal drum
Container weight	45.4 kg (100 lb)	45.4 kg (100 lb)	NA	10 kg (25 lb) pallet and banding	various	45.4 kg (100 lb)
Material weight	1,020 kg (2,260 lb)	1,020 kg (2,260 lb)	25 te/truck trailer 45 te/rail car	45 kg (100 lb) each 180 kg per pallet	various	907 kg (2,000 lb)
Annual quantity	21,500 te	21,500 te	7,170 te	10,600 te	low volume low weight	28,670 te
Packaging Containers, No./yr.	21,000 drums	21,000 drums	NA	2,650 pallets	various	31,600 drums
Transportation mode	truck	rails	truck/rail	truck	truck	intra-site conveyor
Number of packages per shipment	16 drums	192 48 drums/car 4 cars/train	NA (bulk)	24 pallets	various	NA
Number of shipments per year	1,313	110	347 truck 32 rail	111	52	NA

Table 8.4: Offsite Transportation — Supplies and Input Materials for the Wasteform Facility - Bulk UO_2 Variation

	Input Material No. 1	Input Material No. 2	Input Material No. 3	Output Material No. 1
Chemical content/ composition	UO_2 100%	UO_2 100%	Various	UO_2
Material				
Type/chemical	UO_2	UO_2	general supplies	UO_2
Physical form	solid, granular	solid, granular	various	solid
Packaging				
Type	30 gal drum	30 gal drum	various	30 gal drum
Container weight	45.4 kg (100 lb)	45.4 kg (100 lb)	various	45.4 kg (100 lb)
Material weight	1,020 kg (2,260 lb)	1,020 kg (2,260 lb)	various	907 kg (2,000 lb)
Shipping				
Annual quantity	21,500 te	21,500 te	low volume low weight	21,500 te
Packaging containers, No./yr	21,000 drums	21,000 drums	various	21,000
Transportation mode	truck	rail	truck	intrasite conveyor
Number of packages per shipment	16	192	various	NA
Number of shipments per year	1,313	110	52	NA

9.0 LICENSING AND REGULATORY COMPLIANCE

To maintain flexibility regarding future decisions on the operation of a depleted uranium disposal facility, this section addresses both NRC and DOE requirements for disposal of LLW. If the disposal operation were privatized, it would be regulated by the NRC. If it were contracted for by DOE, performance would be in accordance with DOE orders.

9.1 Commercial Disposal Facilities

9.1.1 Overview

Commercial facilities for radioactive waste disposal are subject to NRC regulations, published in 10 CFR Parts 0 to 199 or similar Agreement State regulations. Regulations in 10 CFR 61 establish the performance objectives, technical requirements, and licensing procedures and criteria for disposal of radioactive wastes received from other persons. This section applies to land disposal, particularly near-surface disposal, i.e., disposed of within the upper 30 m (98 ft) of the earth's surface. While the NRC recognizes deeper burial may be satisfactory, and for the CEC found it preferable, requirements for such facilities are not currently included in 10 CFR 61.

Disposal of the Department's depleted uranium inventory at an existing commercial facility would require a modification to that facility's radioactive materials license to allow acceptance of this waste. A new commercial facility would need to apply for and receive a radioactive materials license. A potential applicant must identify a potential site and perform extensive technical analyses prior to submitting an application to the licensing authority. While a license applicant need not be a government agency, the licensing authority will only issue a license if the proposed disposal site is owned by the Federal or a State government. Upon approval, the licensee is responsible for the site through the construction, operation, closure, and stabilization phases. Additionally, the licensee must maintain an onsite presence for a 5-year period of post-closure observation and maintenance to ensure that the site is stable and ready for institutional control. Thereafter, the license is transferred to the site owner, or to the Federal or a State government. The only exception to this is if the site is owned by DOE, over which the NRC does not have regulatory authority. In this instance, the license would be terminated and the site would fall under DOE regulation.

9.1.2 Specific Regulations

9.1.2.1 Performance Objectives

Overall siting, design, operation, closure, and post-closure control must ensure that the following performance objectives are met:

- Exposure to radioactivity released to the general environment in groundwater, surface water, air, soil, plants, or animals must not exceed an annual dose of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ for any member of the public (10 CFR 61.41).

- During operations, exposure to radioactivity must not exceed the limits established in 10 CFR 20, the NRC's standards for radiation control, except for releases of radioactivity in effluents, which must meet the above criteria (10 CFR 61.43).

- Inadvertent intruders to the site, who could occupy the site or contact the waste once institutional control is lifted, must be protected (10 CFR 61.42).

- Long-term stability of the site must be attained such that ongoing active maintenance (exclusive of surveillance, monitoring, and custodial care) will not be required after closure (10 CFR 61.44).

9.1.2.2 Technical Requirements

Disposal Facility Site Selection Criteria. While institutional control is only assumed to last 100 years, "site characteristics should be considered in terms of the indefinite future, and evaluated for at least a 500-year timeframe (10 CFR 61.7)." The site must be capable of being characterized, modeled, analyzed and monitored. Sites should be located in areas where population growths and future development will not affect meeting the performance objectives. Furthermore, sites should be free of natural resources to the maximum extent practical (to reduce the likelihood of future inadvertent intrusion); well drained and free of flooding with a sufficient depth to the water table (to prevent surface and ground water intrusion as well as erosion); and tectonically and geologically stable (e.g., not subject to faulting, seismic activity, vulcanism, erosion, or landslides).

Disposal Facility Design. Site and facility features must be directed toward long-term stability, which will allow isolation without requiring continuing active maintenance to ensure integrity. The design should complement and improve on the site's natural characteristics and be compatible with the disposal site closure and stabilization plan. The site and disposal unit covers must be designed to minimize contact of waste with water during storage and subsequent disposal, and should direct percolating or surface water away from the disposed waste without causing erosion that could degrade site stability. Covers must also be designed to resist degradation by surface geologic processes and biotic activity.

Disposal Facility Operation and Closure. Only radioactive wastes may be disposed of at the site, and each disposal unit shall be closed and stabilized as it is filled. Within the disposal unit, void spaces should be filled with earth or other material, and wastes must be placed and covered such that releases do not exceed the radiation dose limits for individual members of the public set forth in 10 CFR 20.1301 and 20.1302 after site closure. A sufficient buffer zone of land must be maintained to carry out environmental monitoring activities capable of providing an early warning of releases of radionuclides (i.e., before they leave the site boundary).

Wasteform Criteria. The NRC classifies depleted uranium as a Class A waste as defined in 10 CFR 61. Due to a lack of structural stability, Class A wastes must be segregated unless they meet the more rigorous disposal form requirements for other waste classes. As a minimum, Class A wastes must not [10 CFR 61.56(a)]:

- be readily capable of detonation, explosive decomposition, or explosive reaction with water,
- be pyrophoric, unless they are treated, prepared, and packaged to be nonflammable, or
- contain or be capable of generating toxic gases, vapors, or fumes.

Liquid wastes must be solidified or packaged in enough absorbent material to absorb twice the volume of liquid. Solid wastes shall contain as little free standing, noncorrosive liquid as possible, not to exceed 1 percent volume.

9.1.3 Other NRC Guidance

To date, there has been no disposal of depleted uranium in the quantities possessed by DOE. However, the NRC has looked at a large quantity disposal in the EIS for the CEC, a proposed commercial facility for uranium enrichment in Homer, Louisiana. Claiborne was projected to produce 3,800 te (8.4 million lb) of depleted UF_6 per year for approximately 30 years of operation. The EIS determined the depleted UF_6 should be converted to a more chemically stable form, such as U_3O_8, prior to disposal. The EIS considered two methods of disposal, near-surface and deep geological, such as an abandoned mine or engineered facility. Environmental impact analyses indicated that near-surface disposal would result in releases in excess of those allowed under 10 CFR 61, while a deep geological facility showed impacts below these limits. However, the EIS made several assumptions about the near-surface disposal facility, such as it would be situated in the humid southeast, which led to these results. Changes to these assumptions could yield different conclusions.

The NRC has also submitted a letter to DOE in response to the Department's request for recommendations on uses and technologies to facilitate the long-term management of depleted UF_6. The NRC recommended that, should DOE pursue disposal of this material, it should be converted to "a more stable physicochemical form, such as U_3O_8, which is thermodynamically stable and relatively insoluble." The NRC went on to say limited quantities could be disposed of in near-surface disposal facilities, but for a large quantity like DOE's inventory, a mined cavity would likely provide better containment (U.S. NRC, 1995).

9.2 DOE Disposal Facilities

9.2.1 Overview

DOE and its prime contractors are exempt from the NRC facility licensing requirements. Therefore, disposal of depleted uranium as LLW at a DOE facility would not be subject to NRC or Agreement State licensing but would have to meet DOE requirements. In fact, DOE requires that LLW be disposed of at the generator's site, if available, or at another DOE disposal facility. Exemptions to this requirement are currently approved within DOE on a case-by-case basis (U.S. DOE Order 5820.2A).

A new facility for disposal of depleted uranium would be required to prepare and maintain a radiological performance assessment. The performance assessment considers the waste type, inventory, facility design, geologic setting, hydrology, and meteorology in evaluating potential long-term radiological impacts of the disposal system. This performance assessment is reviewed by a peer review panel, which evaluates the technical adequacy of the document. DOE must conclude that the performance assessment provides reasonable assurance that the performance objectives listed in section 9.2.2.1 are met before the facility is authorized to operate.

DOE sites that treat, store, or dispose of LLW must develop "waste acceptance criteria" that address requirements for:

- allowable quantities/concentrations of specific radioisotopes,
- criticality safety requirements (wasteforms and geometries),
- restrictions on classified LLW (for security reasons),
- external radiation and internal heat generation,
- restrictions on the generation of harmful gases, vapors, or liquids in the waste,
- chemical and structural stability of waste packages, radiation effects, microbial activity, chemical reactions, and moisture,

- restrictions on chelating and complexing agents having potential to mobilize radionuclides, and

- quantity of free liquids.

Waste generators must treat and package LLW to meet these waste acceptance criteria.

9.2.2 Specific Requirements

9.2.2.1 Performance Objectives

DOE performance objectives for a LLW disposal facility are as follows:

- public health and safety and groundwater resources must be protected.

- the effective dose equivalent to any member of the public shall not exceed 25 mrem/year.

- inadvertent intruders to the site after active institutional control (100 years) shall not receive in excess of 100 mrem/year for continuous exposure, or 500 mrem for a single acute exposure.

9.2.2.2 Technical Requirements

Disposal Facility Site Selection Criteria. Disposal site selection criteria shall be developed based on an evaluation of the prospective site in conjunction with the planned waste confinement technology. The site should have hydrogeologic characteristics, which when augmented by the planned waste confinement technology, will protect groundwater resources. As with the NRC, the potential for natural hazards (e.g., floods, erosion, tornadoes, earthquakes, and volcanoes) shall be considered in site selection. Also, site development plans should address the impact on current and projected populations, land use resource development plans and nearby public facilities, accessibility to transportation routes and utilities, and the location of waste generation.

Disposal Facility Design Criteria. Confinement to control releases is the primary design consideration for an LLW disposal facility. Barriers shall be established on a site-specific basis, and should include Wasteform, packaging, and geologic setting. Sites with permeability characteristics that do not provide confinement shall be augmented by low-permeability walls around the LLW, lining the excavation with low permeability material, and other suitable methods. Additionally, the facility should be designed to minimize contact between the LLW and water. Typical requirements include (U.S. DOE Order 6430.1A):

- placing a layer of highly permeable material, such as sand or gravel, beneath the LLW to channel any percolating water to a sump.

- mounding the soil surface to facilitate runoff.

- covering the disposal area with low-permeability material, such as clay, to prevent infiltration of rainwater. This cover material should be protected by a layer of overburden (e.g., sand, gravel, top soil).

- a diversion system for surface water runoff (not required after site closure).

- temporary protective covers (e.g., tarpaulin) over the LLW before completion of the natural in-place soil barrier.

- revegetation of the overburden layer.

Design criteria shall be established prior to selection of disposal facilities or new disposal sites. These criteria shall be based on assessments of projected waste volumes, waste characteristics, facility and site performance requirements, and analyses of physiographic, environmental, and hydrogeological data. Disposal units shall be designed consistent with site characteristics and in accordance with the NEPA process.

Disposal Facility Operation and Closure. Operating facilities shall have procedures to ensure that operations protect the environment, public, and worker health and safety, provide security, and minimize the need for long-term control. Permanent identification markers shall be provided for disposal excavations and monitoring wells. Voids between containers placed in disposal units should be minimized. Emergency management systems should be in place in accordance with DOE 5500-series Orders. An environmental monitoring program must be in place to measure operational effluent releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters that may affect long-term site performance.

Comprehensive site closure plans are to be developed for disposal facilities and approved by the DOE field organization. Monitoring and maintenance of the closed facility is to continue through the period of institutional control.

Wasteform Criteria. DOE requirements for wasteforms coincide with the NRC requirements.

10.0 PRELIMINARY SCHEDULE ESTIMATES

A preliminary schedule for the overall Depleted Uranium Hexafluoride Management Program is illustrated in Figure 10.1. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

After a DOE Record of Decision (ROD), there would be a period of approximately 1 year or so for management plans, approvals, and initial budgeting. Next, there would be a period of approximately 3 years for depleted uranium wasteform development and testing, and generation of baseline design parameters. This includes computer modeling of disposal sites. Design and engineering activities would overlap this time, and would probably add another year. Information to support license and permit applications will be developed beginning with the onset of design and engineering.

For DOE projects, this period provides sufficient time for initiating the Federal budget cycle planning. NEPA activities, if necessary, will also parallel design and engineering.

Licensing and permitting could possibly add from 5 years to 10 years to the schedule. A licensing and permitting strategy will be employed to anticipate and avoid needless delay. DOE procurement is an element to be factored into the schedule. An effort will be made to avoid excessive delays. Construction would follow. The overall schedule is 31 years. The use of existing wasteform and disposal facilities might shorten these time periods. However, licensing and permitting remain as the most unknown areas that can significantly increase schedules.

After the initial closure is completed, there are three more phases to consider: post closure (1-10 years), active institutional care (1-100 years), and passive institutional care (101-300 years). Activities included in post closure include site development, environmental monitoring, performance objective monitoring, site remediation, security, building maintenance, and labor. The next phase, active institutional care, involves activities such as demolition of buildings, removal of site services, site development, environmental monitoring, performance objective monitoring, site remediation, and security. Finally, for passive institutional care, activities include aisle closure, installation of passive drains and connection of primary and secondary collection systems, removal of retention/sedimentationpond and stormwater detention pond, completion of vault cover and removal of retaining walls, environmental monitoring, performance objective monitoring, site remediation, and security (Feizollahi, 1993).

10.1 Wasteform Facility

Construction of the Wasteform Facility will begin in year 8. As roads and rail lines (if used) are put in place, the large but uncomplicated steel-shell buildings of the Wasteform Facility will be

Draft Engineering Analysis Report for the Long-Term Management erected followed by installation and testing of equipment. Construction of disposal facilities will not interfere with the Wasteform Facility.

10.2 Vault Disposal Facility

Construction of the Vault Disposal Facility would begin in year 10 and continue through year 30 with sufficient numbers of vaults constructed for the next year's waste. With only nominal interaction, construction of the Vault Disposal Facility will not impact the Wasteform Facility and vice versa.

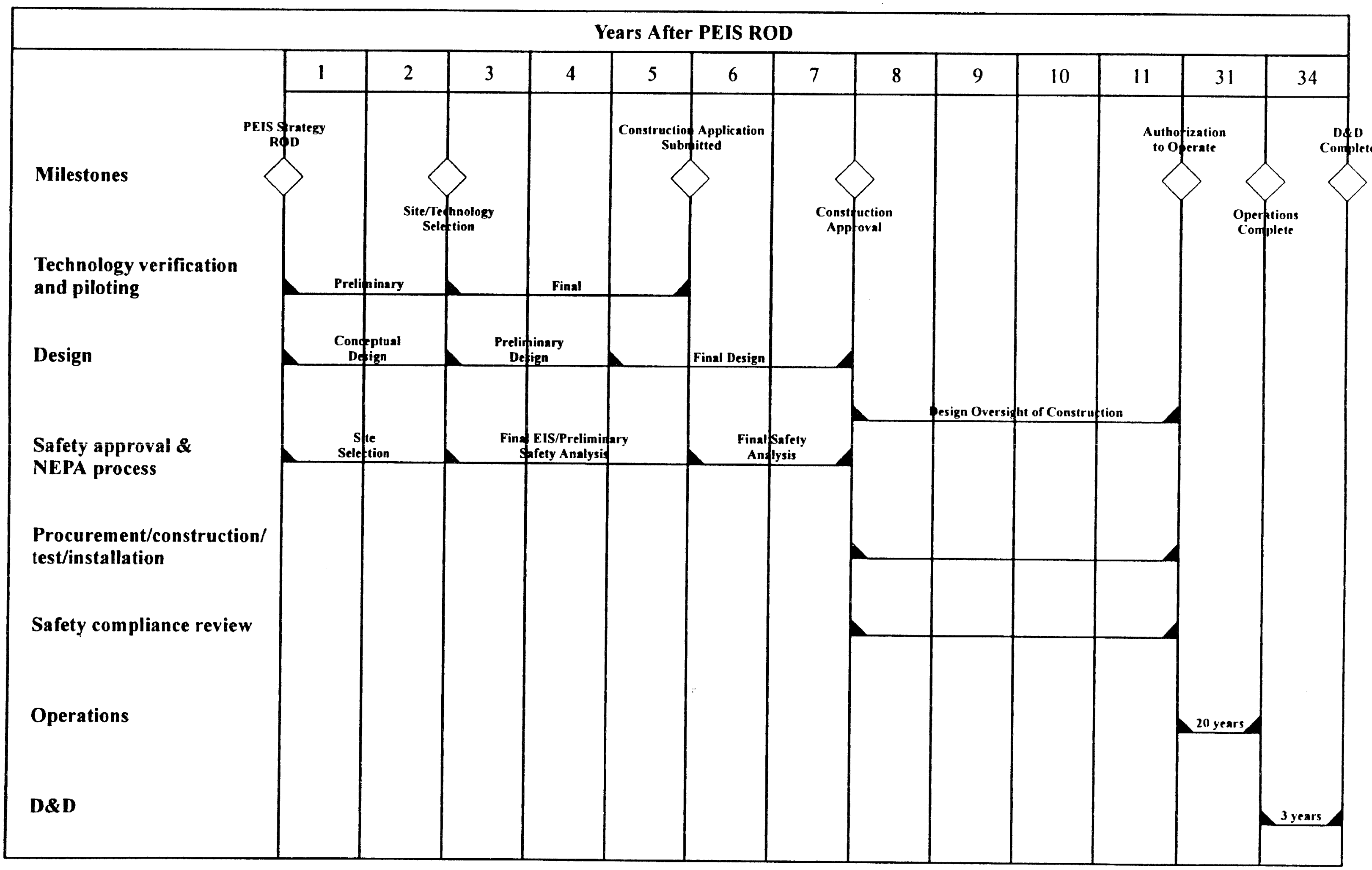
10.3 Engineered Trench Disposal Facility

Construction of the trench disposal facility would begin in year 10. It is most likely that after 1 month of preliminary excavation, waste disposal could begin without waiting for the entire trench facility to be excavated. This would begin the continual process of simultaneously excavating and disposing, completing disposal in the first trench within a 12-month period. The excavation schedule would have to take into account this 1 year disposal schedule and keep ahead at an appropriate rate.

10.4 Mined Cavity Disposal Facility

The mined cavity disposal facility construction would begin in year 3 with site preparation. The mined cavity would then be available to accept waste beginning in year 11.

Figure 10.1: Estimate of Overall Schedule for the Disposal Program



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12.0 GLOSSARY

Bulk Disposal - disposal of U_3O_8 (or UO_2) in its crystalline form, packaged in appropriately sized steel drums.

Cost Analysis Report - This report will analyze the total costs for each management option to provide a sound basis that can be used to estimate the life cycle costs associated with these alternatives.

Depleted uranium hexafluoride - uranium hexafluoride that has been fed through the "enrichment" process and is depleted in the U-235 isotope.

Grouted triuranium octaoxide - U_3O_8 consolidated in a mixture of cement, sand, and water (grout) and cast into a solid monolith.

Public Participation Plan - this plan lays out DOE's strategy for ensuring effective, two-way communication with the public throughout its decision-making process. The Public Participation Project consists of a variety of activities and methods for the public and stakeholders to participate in the projects from which DOE will gather information to make its decision.

Record of Decision (ROD) - this document will select the optimum strategy for a long-term management plan for the Depleted Uranium Hexafluoride Management Program.

Triuranium octaoxide -U_3O_8 - an oxide form of uranium that is very stable. This is the form of "yellowcake," or mined uranium that has been refined.

Uranium dioxide - UO_2 - a black, crystalline powder that is widely used in the manufacture of fuel pellets for nuclear reactors. Pressed and sintered, it is stable when exposed to water or air below 300°C.

Uranium hexafluoride-UF_6 - a white crystalline solid at atmospheric conditions. This form is used as feed for almost all enrichment plants.

APPENDIX A

Low-Level Waste Disposal at DOE Sites

Appendix A: Low-Level Waste Disposal at DOE Sites*

LLW has been generated and disposed of by government laboratories and facilities since the beginning of the Manhattan Engineer District program to develop the atomic bomb during World War II. Until the early 1960's, LLW generated by activities or licensees of the Atomic Energy Commission (AEC) was disposed of at facilities owned and operated by the AEC. Most LLW generated at AEC facilities was disposed of at the site where it was generated. The majority of LLW generated during this time was disposed of using near-surface burial. Ocean disposal was also used for a portion of the LLW between 1946 and 1970, but was stopped by the United States in 1971.

In the late 1950's and early 1960's, the AEC started a program to encourage the development of commercial nuclear industries. Part of this program was to develop commercial disposal facilities for LLW. The first commercial disposal facility was opened in 1962 near Beatty, Nevada. Subsequently, five additional disposal sites were opened: Maxey Flats, near Morehead, Kentucky; West Valley, New York; Barnwell, South Carolina; Sheffield, Illinois; and Hanford, Washington. In May 1963, the AEC decided that all AEC licensees and all AEC facilities without onsite disposal should make use of commercial facilities for the disposal of LLW. By 1978, three of the six commercial sites were closed: West Valley in 1975, Maxey Flats in 1977, and Sheffield in 1978. In 1979, the Beatty and Hanford sites were temporarily closed by the governors of the host states. With only one commercial site remaining, DOE began to consider alternatives to commercial disposal.

In November 1979, DOE issued guidance for the disposal of LLW and directed all DOE field offices and nuclear reactor programs to terminate disposal of LLW at commercial sites. DOE facilities without onsite disposal capacity were directed to ship their LLW to DOE facilities at either the NTS, INEL, SRS, the Hanford Site, or facilities operated by the Albuquerque and Oak Ridge field offices. Currently, DOE disposes of LLW at six sites: Hanford, Washington; INEL, Idaho; NTS, Nevada; Los Alamos National Laboratory (LANL), New Mexico; Oak Ridge Reservation (ORR), Tennessee; and SRS, South Carolina (figure A.1). Table A.1 summarizes the status of LLW disposal facilities at the six sites. ORR uses above-grade tumulus disposal. The other five sites use below-grade disposal. All six sites have additional LLW disposal facilities planned. Site-specific descriptions of LLW disposal at the six sites follows.

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* Framework for DOE Low-Level and Mixed Low-Level Waste Disposal: Current Overview, DOE/ID-10484, U.S. Department of Energy, Office of Waste Management, June 1994.

Hanford Site

The Hanford Site is located northwest of the city of Richland, Washington. The climate is semiarid with an average annual rainfall of about 16 cm (6.3 in.), which supports the site vegetation of sagebrush and cheatgrass. Groundwater depth is from 59 to 107 m (195 to 350 ft). The waste management facilities are in the 200 Areas, which are located on a plateau approximately 3.7 km (7 mi) from the Columbia River.

The active low-level burial grounds (LLBGs) are classified as shallow landfill disposal facilities and cover a total area of about 660 ha (1,500 acres). The landfill is divided into eight burial grounds, comprising a number of trenches or caissons. Two burial grounds are located in the 200 East Area, and six are located in the 200 West Area.

Two basic types of trenches have been used for disposal in the LLBG: V-trenches and industrial trenches. The V-trenches normally were dug to a depth of 5 m (16 ft) with the bottom ranging from 0 to 5 m (0 to 16 ft) wide. Industrial, or wide bottom trenches may be up to 15.25 m (50 ft) deep with the bottom ranging from 5 m (16 ft) to over 30.5 m (100 ft) wide.

Before receipt of waste at the LLBG, the solid waste management organization characterizes the waste and designates the waste according to DOE Order 5820.2A, the Washington Administrative Codes 173-303-070, and the Hanford Site Solid Waste Acceptance Criteria. The generator is responsible for packaging the waste according to Department of Transportation (DOT) regulations for hazardous materials. The waste received by the LLBG is typically packaged in wooden boxes, steel drums, concrete burial vaults, or some other type of approved package in compliance. Generators are assessed annually to ensure their waste program will ensure the Hanford Waste Acceptance Criteria (WAC).

In addition to specific restrictions in the Hanford WAC, the following materials are prohibited in radioactive solid waste proposed for disposal at the Hanford Site facilities:

- Liquids (except properly packaged)
- Etiologic agents or infectious wastes
- Radioactive animal carcasses (except properly packaged)
- Reactive metals
- Chemically incompatible materials in any waste container
- Explosives

- Pyrophorics
- Gas cylinders that are not permanently vented
- Chelating compounds
- Unidentified, uncharacterized, or poorly characterized waste
- Greater-Than-Class-C (GTCC) radioactive waste, except upon specific written approval by DOE
- Long half-life radionuclides (as identified in the Hanford WAC) except case-by-case
- The hazardous component of mixed low-level waste (MLLW) exceeding limits set forth for land disposal
- Waste packages that do not meet criticality limits

An engineering study is planned to optimize the total capacity of LLW disposal facilities within the 200 Areas. Engineering estimates for disposal indicate that 84,000 m^3 (3 million ft^3) of space is available for LLW in burial ground 218-W-5. Preliminary calculations show that it is possible to dispose of more than 23 million m^3 (80 million ft^3) of combined daily cover and waste in the area designated 218-W-5 South. A generic site like Hanford could be used for the disposal of depleted uranium (encapsulation of the U_3O_8 or UO_2 would be required).

Idaho National Engineering Laboratory

INEL is located approximately 39 km (21 mi) west of Idaho Falls, Idaho. The climate is semiarid, with sagebrush-steppe characteristics. Average annual precipitation is 21.6 cm (8.5 in.). The depth to the aquifer varies from 61 to 274.5 m (200 to 900 ft). The Radioactive Waste Management Complex (RWMC) is located in the southwest portion of the site. The RWMC encompasses 58 ha (144 acres) and consists of two main disposal and storage areas: the Transuranic (TRU) Storage Area and the Subsurface Disposal Area (SDA). The facility currently receives solid LLW for disposal at the SDA.

LLW is currently being disposed of in the SDA, a 36-ha (88-acre) area at the RWMC. Contact-handled LLW (< 500 mrem/hr at 1 m) is usually disposed of by high density stacking in segregated pits. Remote-handled LLW (> 500 mrem/hr at 1 m) is usually disposed of from bottom discharge shielded casks into "soil vaults." A soil vault is a hole augured into the ground in predefined areas between existing closed pits and trenches. There are no plans to expand the existing RWMC SDA. Currently, new disposal concepts are being evaluated to establish environmental compliance plans and functional and operational requirements for new disposal facilities.

The requirements pertaining to the disposal of LLW are specified in the INEL Low-Level Radioactive Waste Acceptance Criteria (WAC). The INEL WAC prescribe detailed requirements for waste characterization and periodic audits of waste generators. As part of this audit program, waste receiving facilities perform representative sampling of received waste packages, including waste package radiography, gamma spectroscopy analysis, head-gas sampling, radiological measurements, gross weight assessment, physical inspection, and intrusive inspection.

Applicable disposal limitations are described in the INEL WAC. The following materials are specifically prohibited from disposal:

- Unpackaged or improperly packaged waste materials
- Nonradioactive materials
- Pressurized containers
- Gaseous radioactive materials
- Radioactive mixed waste as defined in 40 CFR 261
- Readily accessible classified materials
- Chelating or complexing agents that have the potential for mobilizing radionuclides
- Free liquids
- GTCC radioactive waste
- Pyrophoric radionuclides greater than 1 percent
- Phenolic compounds
- Polychlorinated biphenyls (PCBs) greater than 50 ppm
- TRU waste
- Spent nuclear fuel (SNF)

- High-level waste (HLW)
- Pathogenic wastes
- Explosives
- Toxic gases, vapors, or fumes
- Wastes with pH less than 2.0 or greater than 12.5

The disposal capacity remaining available for LLW in the RWMC SDA is 39,000 m^3 (1.4 million ft^3) as of January 1993. This capacity is available in the current active pits and does not consider any specific actions to extend the life of the existing disposal facility. Although the characteristics of the site appear acceptable for disposal of depleted uranium, the available site capacity may not be adequate.

Nevada Test Site

The NTS Site is a DOE nuclear testing facility located about 104 km (65 mi) northwest of Las Vegas. The climate is arid with extreme diurnal temperatures. Vegetation is predominately desert shrubs. Groundwater (uppermost alluvial aquifer) varies from 200 to 500 m (656 to 1650 feet) deep.

NTS contains two sites for the disposal of LLW. The Area 5 RWMS was established in 1978 for the disposal of LLW and classified LLW generated by NTS operations and other DOE facilities. The developed portion of the Area 5 RWMS occupies 37 ha (92 acres) in the southeast corner of the 296-ha (732-acre) designated area. This developed area of the RWMS currently consists of 17 landfill cells (pits and trenches) and 13 greater confinement disposal boreholes.

The Area 3 RWMS covers an area of approximately 20 ha (50 acres). Contaminated debris from the NTS Atmospheric Testing Debris Disposal Program and packaged bulk LLW from other DOE facilities is disposed of in subsidence craters that have resulted from underground nuclear tests. The waste materials are disposed of by using conventional landfill techniques, where each layer of waste is covered with 1 meter of fill before the disposal of additional waste materials.

The DOE Nevada Field Office has defined in its WAC the requirements for all waste generators and requires generators to have a waste characterization and certification program, supported by a DOE Order 5700.6C-based quality assurance program. Criteria in the NTS WAC include:

- Restrictions on:
  -Free liquids
  -Hazardous waste components
  -Particulates
  -Gases
  -Stabilization
  -Etiological agents
  -Chelation agents
  -PCBs
  -Explosives and pyrophorics
- Package design
- Nuclear heating
- Radiation levels
- Activity limits
- Multiple hazards
- Size
- Weight
- Loading
- Marking and labeling
- Barcoding
- Treatment
- Reactive wastes
- Potentially incompatible waste

It is estimated that a total capacity of 67,000 m^3 (2.3 million ft^3) remain in the Area 5 RWMS and 382,000 m^3 (13.3 million ft^3) remain in the Area 3 RWMS for LLW disposal. Thus, there appears to be ample capacity at NTS for the disposal of depleted uranium in trenches or boreholes.

Analysis of the WAC indicates that U_3O_8 would require grouting, but UO_2 would not require grouting.

Los Alamos National Laboratory (LANL)

LANL is located in north-central New Mexico, in a semiarid, temperate climate with mixed forests and grasslands. The region is seismically, volcanically, and geomorphically active. Groundwater in the main aquifer is 180 to 370 m (594 to 1221 ft) below the mesa tops, with water present in some canyon bottoms as perched or shallow-alluvium aquifers and as intermittent or perennial streams. The site is bounded on the southeast by the Rio Grande River.

LLW is disposed of in Technical Area (TA) 54, Area G. The facility occupies 25.9 ha (64 acres) with an additional 9.7 ha (24 acres) dedicated for future expansion. The facility consists of 39 landfill cells (pits and trenches) and 237 land disposal shafts.

As these disposal facilities currently handle LANL-generated wastes only, the LANL WAC are designed to address internal generators. The generators are responsible for properly identifying, characterizing, segregating, packaging, and documenting waste prior to shipment to TA-54, Area G; ensuring that the waste sent to TA-54, Area G complies with the WAC; and implementing a LLW certification program.

All waste disposed at TA-54, Area G must be solid with no free liquids. In the case of powders or particulate wastes, if more than 1 wt-% of the particles are smaller than 10 microns, or more than 15 wt-% consists of particles less than 200 microns in size, then the particulate portion of the waste must be immobilized to reduce inhalation and dispersion risks during handling. Pressurized and evacuated containers cannot be disposed unless they are vented to atmospheric pressure. RCRA-regulated components are currently not acceptable for disposal at Area G. Restrictions on radionuclide content only relate to the exclusion of TRU and GTCC waste, criticality safety, and safe handling during disposal.

Current remaining disposal capacity at Area G is expected to satisfy LANL needs through the end of 1995. The future expansion area will provide for the disposal of an additional 127,000 m^3 (4.4 million ft^3) of waste. At this time, it appears that space limitations would be an inhibiting factor in the disposal of depleted uranium at the LANL Site.

Oak Ridge Reservation

The ORR is located west and south of the population center of Oak Ridge, Tennessee. The Oak Ridge climate is typical of the humid southern Appalachian region. The average annual precipitation measured in the Oak Ridge vicinity is 138 cm (54 in.), ranging from 95 cm (37 in.) to 187 cm (76 in.). Depth to the water table varies both spatially and temporally, from 0.3 to 20 m

(1 to 67 ft). The major portion of the industrial and drinking water supplies in the Oak Ridge area is taken from surface-water sources.

The ORR is currently operating Solid Waste Storage Area (SWSA) 6 as a disposal site for LLW. This 28-ha (68-acre) site has been employed since 1969 using a variety of Greater Confinement Disposal (GCD) techniques including below-grade concrete silos and wells and two above-grade tumulus demonstration projects.

Concrete silos are being phased out of operation based on agreements between DOE and the State of Tennessee. A concrete silo is constructed of two 16-gauge, corrugated steel pipes -- one 2.4 m (8 ft) in diameter and the other 2.7 m (9 ft) in diameter. The smaller pipe is concentrically placed inside the larger pipe, and both placed vertically in a trench. The annular space between the two pipes is filled with concrete. The pipes range from 4.3 to 6 m (14 to 20 ft) in length, depending on the depth of the water table at the location. A wire reinforced, 30.48-cm-thick (12 in.) concrete pad is poured in the bottom of the silo. The silos are aligned in clusters within the trench. The depth of the trench is always located and dug with its lowest point a minimum of 0.6 m (2 ft) above the maximum water table elevation. The silo is capped with a 30.48-cm-thick (12 in.) steel-reinforced concrete cap.

Aboveground tumulus disposal is the preferred method for disposal of LLW in SWSA 6. Tumulus disposal involves the placement of containerized LLW into x by y by z concrete vaults that are subsequently stacked on a curbed concrete pad and capped with natural materials. The Tumulus II pad is located on an approximately 0.4-ha (1-acre) site. The pad is approximately 18.2 by 27.4 m (60 by 90 ft) and contains a total of 220 vaults.

SWSA 6 only accepts wastes generated by facilities on the ORR, thus the WAC are designed only for internal generators. The generators are responsible for:

- Waste minimization
- Proper package classification, identification, and containerization
- Ensuring WAC are met (Waste Acceptance Criteria for Radioactive Solid Waste Disposal at SWSA-6)
- Implementing a generator waste certification program

All waste disposed of in SWSA 6 must be certified not to contain:

- Free liquids

- PCB-contaminated materials
- Compressed gases
- Hazardous wastes (listed or characteristic as defined in 40 CFR 261 Subparts C
- Chelating agents
- Transuranic elements in concentrations greater than 100 nCi/g

SWSA 6 will meet the contact-handled solid LLW disposal needs for Oak Ridge National Laboratory (ORNL) through 1998. If depleted uranium was disposed of at the ORR Site, it would probably be in aboveground tumuli. However, limited space for disposal of LLW may be a factor.

Savannah River Site

SRS is located in south-central South Carolina, 40 km (25 mi) southeast of Augusta, Georgia; 35 km (22 mi) south of Aiken, South Carolina; and 160 km (100 mi) from the Atlantic Coast. The major geophysical feature is the Savannah River, which forms the southwestern boundary of the site.

Previously, SRS operated a solid waste burial ground, Low-Level Radioactive Waste Disposal Facility (LLRWDF), for the disposal of LLW. In 1987, however, DOE issued guidance directing that new disposal facilities constructed in humid climates be "decoupled from the groundwater table." To comply with this directive, a project to build disposal vaults (called the E-Area Vaults) for the disposal of LLW was developed.

The E-Area Vaults were designed for a 20-year operational life for disposal of LLW. Three different types of vaults are used for proper waste segregation. The low-activity waste (LAW) vaults will accept LAW, i.e., waste radiating $<$ 200 mrem/hr. The intermediate-level waste (ILW) vaults are designed to accept two waste types: ILW, i.e., waste radiating $>$ 200 mrem/hr, and tritium waste, defined as waste containing $>$ 10 Ci/package of tritium.

Detailed procedures for accepting non-hazardous LLW in the E-Area Vaults are provided in the SRS Waste Acceptance Criteria Manual, WSRC-1A, as required by DOE Order 5820.2A. Waste generators are responsible for:

- Ensuring prohibited materials are not shipped as LLW to SRS
- Adhering to the principles of waste minimization
- Establishing auditable programs to minimize the amount of LLW generated
- Implementing and documenting a LLW certification program
- Providing annual and 10-year forecasts of LLW streams to be shipped to the facility
- Complying with the requirements for waste containers
- Characterizing all waste streams using approved methods
- Financing corrective actions required as a result of nonconformance
- Providing waste data via the Waste Information Tracking System

The following materials are prohibited from disposal at the E-Area Vaults:

- Hazardous wastes as designated by South Carolina Hazardous Waste Management Regulations and EPA regulations
- Rags or wipes that have come in contact with any F-listed solvent as defined by RCRA
- Free liquids in greater than incidental quantities (1 percent of the waste volume when the waste is in a disposal container)
- Gaseous waste (e.g., unpunctured aerosol cans and gas cylinders)
- Explosive materials
- Pyrophoric materials
- Chelating agents in amounts greater than 1 percent of the weight of the waste
- Unneutralized acids or bases not in the pH range of 5 to 9
- Unreacted alkali metals
- Biological, pathogenic, or infectious materials
- TRU waste > 100 nCi/g
- Waste containing 50 ppm or greater PCBs
- Petroleum-contaminated soil with greater than 100 ppm total petroleum hydrocarbons
- Petroleum-contaminated soil with greater than 10 ppm benzene, toluene, ethyl benzene, or xylene
- Waste containing radionuclides in concentrations greater than allowed by the process requirements as specified in attachments B through F of the SRS WAC
- Waste containing or capable of generating quantities of toxic gases, vapors, or fumes harmful to personnel transporting, handling, or disposing of the waste
- Chemically incompatible materials in any waste container or package

- Waste generating a radiation rate greater than 50 R/hr at 0.3 m (1 ft) from outer surface of disposal container without prior Solid Waste Management approval
- Nitrated organic resins
- Waste classified as GTCC
- Waste that has not been certified as described in the SRS WAC
- Packages containing greater than 15 percent void volume
- Waste containing no more than 1 wt-% of particles less than 10 microns in diameter or more than 15 wt-% of particles less than 200 microns in diameter
- Waste packages generating more than 1 watt per ft^3

Each LAW Vault is 196 m (643 ft) long by 44 m (145 ft) wide by 8 m (27 ft) tall having approximately 51,000 m^3 (1.7 million ft^3) of disposal capacity. Each non-tritium ILW Vault is 57.6 m (189 ft) long by 14.6 m (48 ft) wide by 8.8m (29 ft) tall having approximately 6,000 m^3 (200,000 ft^3) of disposal capacity. The tritium vaults are structurally identical to the non-tritium ILW vaults except for the length, which is only 17.4 m (57 ft). The tritium vaults have a disposal capacity of approximately 1,710 m^3 (57,000 ft^3). SRS appears suitable for the disposal of depleted uranium, most likely in vaults. The U_3O_8 will require grouting, but the UO_2 will not require grouting.

Commercial LLW Disposal in the United States*

As early as 1959, under an amendment to the Atomic Energy Act of 1954, states began assuming responsibilities for some regulatory and licensing aspects associated with the management of commercially generated radioactive waste. The management of these wastes, including disposal, was provided by private sector companies. The level of effort associated with these services was dictated by the demand for such services by waste generators. Seven LLW disposal sites have been established for the commercial nuclear industry. Of these, four have been closed and three are currently operating with restrictions.

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* *Report to Congress*, "1993 Annual Report on Low-Level Radioactive Waste Management Progress," DOE/EM-0236, U.S. Department of Energy, Office of Environmental Management, Washington, DC, November 1994.

Beatty, Nevada

The Beatty LLRW disposal facility was the first commercially operated radioactive waste disposal facility to be licensed by the AEC, now the NRC. The Beatty site is located on the Amargosa Desert in Nye County, on land owned by the State of Nevada. The disposal site is on an 32.4-ha (80-acre) tract approximately 17.6 km (11 miles) south of the town of Beatty, and 168 km (105 mi) northwest of Las Vegas.

Underlain by folded metamorphic and sedimentary bedrock, the site surface is approximately 840 m (2,800 ft) above sea level. A regional groundwater table lies at a depth between 78 to 99 m (260 and 330 ft) below the surface in the alluvial soils.

An intermittent river, the Amargosa River, lies 8 km (5 mi) from the site and serves as the principal drainage channel in the area. There is no source of perennial surface water within 10 mi of the site.

The climate at the site is arid, with an average annual rainfall varying from 6 to 12.5 cm (2.5 to 5.0 in.), and a potential evaporation rate of approximately 250 cm (100 in.) per year.

The LLW disposal facility is adjacent to a chemical waste disposal facility, which is separated from the LLW facility by a buffer zone, which is a minimum of 61 m (200 ft) wide. A security fence also separates the two facilities.

The LLW disposal site consists of 22 trenches of varying dimensions, ranging from 90 to 240 m (300 to 800 ft) in length, 1.2 to 105 m (4 to 350 ft) in width, and 15 to 125 cm (6 to 50 in.) in depth. The trenches constructed in more recent years have tended toward the larger dimensions. Although the characteristics of the site make it suitable for the disposal of depleted uranium in trenches, the site is currently closed.

Maxey Flats, Kentucky

The Maxey Flats LLRW disposal site is located about 14 km (9 mi) northwest of Morehead, Kentucky, 104 km (65 mi) northeast of Lexington, Kentucky, and 320 km (200 mi) southeast of Cincinnati, Ohio. The site occupies 113.3 ha (280 acres) and is owned by the Commonwealth of Kentucky. The site was opened under a lease arrangement between the State of Kentucky and Nuclear Engineering Company, Inc. (NECO) (now US Ecology, Inc.) of Louisville, Kentucky, in January 1963. US Ecology, Inc., operated Maxey Flats until December 1977, at which time commercial operations were terminated. The disposal site has remained closed since that date. It was closed because of infiltration into trenches, resulting in leaching out of radionuclides.

The ridge area where the site is located slopes off sharply on three sides. The area is drained on three sides: to the east by a perennial stream, No-Name Creek, which collects about 75 percent of the surface runoff; to the west by Drip Springs Hollow Creek; and to the south by Rock Lick Creek. The drainage from these tributaries flows into Fox Creek and then into the Licking River. The site is in a humid region, with rainfall varying by season, but most abundant in spring and early summer. The average annual rainfall in the region is 115 cm (46 in.). The groundwater depth is 9 to 15.2 m (30 to 50 ft).

The disposal site currently consists of 52 trenches, a number of hot wells, and several special pits. The trenches vary considerably in size, ranging from 45 to 204 m (150 to 680 ft) in length, 3 to 23 m (10 to 75 ft) in width, and 3 to 9 m (9 to 30 ft) in depth. The floor of each trench slopes at 1 degree toward a sump constructed at the low end to permit water collection and removal. The hot wells are lined, variable in size [generally 4.5 m (15 ft) deep and several feet in diameter], and capped with concrete. The hot wells were used to dispose of high-activity gamma sources. The special pits, which vary from 4.5 to 22.5 m (15 to 75 ft) in length, 3 to 7.5 m (9 to 25 ft) in width, and 1.5 to 4.5 m (5 to 15 ft) in depth, were used to dispose of large volumes of higher activity waste, such as spent resins from power reactors. Trenches of the type used at the Maxey Flats Site probably would not be suitable for the disposal of depleted uranium, and the site is currently closed.

West Valley, New York

The Nuclear Service Center is a 1353.7-ha (3345-acre) site located about 48 km (30 mi) southeast of Buffalo, New York, in a rural area near the small community of West Valley. In February 1982, DOE took possession of most facilities at the Center for the purpose of carrying out the West Valley Demonstration Project (WVDP), which includes decontamination and decommissioning of facilities and the site. The State-owned commercial LLRW disposal site is currently under the custody of the New York State Energy Research and Development Authority (Energy Authority). The West Valley disposal site, opened as a commercial venture in 1963, was operated by Nuclear Fuel Services under a lease arrangement with the State of New York until March 1975. At that time, operations were suspended after an overflow of contaminated water was detected from two of the disposal trenches. The disposal site has remained closed since that date.

The surface water in the vicinity of the disposal area consists of Frank's Creek on the east side, Erdman Brook on the north side, and an unnamed tributary on the northwest side, all which join to the northeast of this area.

The site consists of two distinct sets of parallel trenches, identified as the north and south disposal areas. The northern area, used from 1963 to 1969, consists of five long trenches numbered 1 to 5 and two "special" trenches numbered 6 and 7. Trenches 1 through 5 are nominally 9 m (30 ft) wide, 6 m (20 ft) deep, and 183 m (600 ft) long. The distance between trenches is 1.2 to 1.8 m (4 to 6 ft); however, due to the method of construction (bulldozer excavation) and instances of wall collapse, some trenches are believed to be connected. The trenches were originally covered with a 1.2-m (4-ft) cap; in 1978, an additional 1.2 m (4 ft) of cover was added. Trench 7 is a narrow, shallow concrete vault in which wastes were disposed, and Trench 6 is actually a series of holes for the disposal of high-activity waste requiring immediate shielding.

The southern area was developed between 1969 and 1975. This area also consists of seven trenches (numbered 8 to 14) that are typically 9 m (30 ft) wide, 6 m (20 ft) deep, and 183 m (600 ft) long. During development of this area, a number of changes in construction and disposal practices were incorporated as a result of the experience gained from the northern area. Among other things, the separation distance between trenches was increased to 3 m (10 ft), trench floors were sloped, and cap thickness was increased to 2.4 m (8 ft). Waste was emplaced beginning at the shallow end of the trench and proceeding to the deeper end. This allowed precipitation that entered the trenches during construction and filling to drain away from the waste and collect at the lower end of the trench. From there, the infiltrate was pumped to two lagoons located adjacent to the northern trenches. These lagoons are now filled with earth. A third lagoon for pumped-out trench water was constructed adjacent to the southern trenches in 1975. The West Valley Site is currently closed and is not available for the disposal of depleted uranium.

Richland, Washington

The Richland commercial LLW disposal site is located on the central plateau of the Hanford Site, about 37 km (23 mi) northwest of Richland, Washington, in the southeastern part of the state. The site consists of 40.5 ha (100 acres) of land leased by the State of Washington from DOE.

The Hanford Site is located in the Pasco Basin on the semiarid alluvial plain of the Columbia River. The depth of the water table in the region of the disposal site ranges from 65 to 117 km (195 to 350 ft).

The Columbia River flows through the site about 11.3 km (7 mi) from the commercial waste disposal site. There are no surface-water bodies on or near the disposal site. Two ephemeral streams and a small natural pond are located on the surrounding site.

The Pasco Basin is characterized by a semiarid climate, with an average annual precipitation of about 15 cm (6.3 in.) and an annual potential evaporation rate of 140 cm (55 in.).

The Richland commercial LLRW disposal site is unique among comparable sites in that it is the only one located on Federal land. The Hanford Site includes a number of DOE nuclear research facilities, including reactors, chemical processing plants, laboratories, and supporting facilities. The commercial LLW disposal site is essentially bounded on the east and west sides by two DOE radioactive waste disposal areas that have been used for the disposal of waste since 1944 and are still in active use.

The site currently consists of 14 parallel land disposal trenches that vary dimensionally from 91.4 to 280 m (300 to 840 ft) in length, 7.5 to 43 m (25 to 140 ft) in width, and 6.1 to 9 m (20 to 45 ft) in depth. The site also has four 9-m-deep (30 ft) caissons and three underground storage tanks ranging in size from 3,800 to 76,000 L (1,000 to 20,000 gallons) (originally there were five tanks; two were removed in the mid-1980's and the remaining three tanks are no longer in use). The site is currently operating but is accepting waste from the northwest compact generators only.

Sheffield, Illinois

The Sheffield LLRW disposal site is located about 8 km (5 mi) southwest of Sheffield, Illinois. Sheffield is about 225 km (140 mi) west-southwest of Chicago, and about 72.4 km (45 mi) east-southeast of Moline. The disposal site is on a 76.9-ha (190-acre) tract of land adjacent to two hazardous waste disposal areas. The hazardous waste disposal areas are located to the north and northwest of the site. The Sheffield disposal site, opened in 1968, was first operated by California Nuclear, Inc., and later by NECO, now US Ecology, Inc. Disposal operations ceased in 1978 when the site operator experienced lengthy delays during the license renewal process.

The Sheffield LLRW disposal site is located on rolling glaciated terrain. The site is underlain by both shallow and deep aquifers. The bedrock underneath the site is approximately 450 ft thick and provides a relatively impermeable barrier between the two aquifers.

The site is in the headwater tributaries of Lawson Creek, which is 1.6 km (1 mi) east of the site at its nearest point. Three small intermittent streams drain the Sheffield site. Two streams drain the southern portion of the site, and the third drains the northern portion of the site. A small lake is located directly north of the site. The climate is humid with a mean annual precipitation of about 9 cm (35 in.). This exceeds evapotranspiration by about 10 percent.

The waste is buried in 21 separate trenches. A typical trench is 152.5 m (500 ft) long, 16.7 to 20 m (50 to 60 ft) wide, and 7 to 8 m (20 to 25 ft) deep. A minimum of 3.5 m (10 ft) separates the trenches at the surface. The Sheffield Site is currently closed and is not available for the disposal of depleted uranium.

Barnwell, South Carolina

The Barnwell LLRW disposal facility was originally licensed for aboveground storage of radioactive waste in November 1969. The license was amended in April 1971 to permit Chem-Nuclear Systems, Inc. (CNSI), the site operator, to bury LLRW, and waste disposal was subsequently initiated. The Barnwell Site is located near the eastern boundary of DOE's Savannah

River Plant in the southwestern part of South Carolina. The disposal site consists of 121.4 ha (300 acres) of land located about 8 km (5 mi) west of the town of Barnwell, South Carolina, on the edge of the small community of Snelling.

The site is located on part of the Coastal Plain geologic province, which is characterized by flat, largely unconsolidated sediment layers. A regional groundwater table lies within the Hawthorne Formation at depths that range from 10 to 20 m (30 to 60 ft) below grade. The principal source of potable water in the area is from the underlying Tuscaloosa Formation at depths in excess of 117 m (350 ft).

The nearest surface water to the site is Lower Three Runs Creek, which is about 5 km (3 mi) away. This creek, a tributary of the Savannah River, drains the major portion of the site and flows into the river about 110 km (70 mi) downstream. However, because of the gentle slope of the topography and the absorptive nature of the sand cover, surface water runoff occurs only after unusually heavy rainfall.

The climate at the site is mild and humid, with a mean annual precipitation of 119 cm (47 in.) [ranging from 74 to 185 cm (29 to 73 in.)]. Regionally, about 38 cm (15 in.) of the annual average rainfall reaches the water table as recharge. The water table aquifer flows at a rate of approximately 7 ft per year.

The site consists of 73 standard trenches and 7 slit trenches. The standard trenches vary dimensionally from the initial four trenches, each of which is 67 m (200 ft) long by 15 m (50 ft) wide by 4.5 m (15 ft) deep, to the later unit, which is 333 m (1,000 ft) long by 33 m (100 ft) wide by 7 m (21 ft) deep. The slit trenches, which get their name from their dimensions, are 1.2 m (4 ft) wide by 167 m (500 ft) long and approximately 7 m (22 ft) deep. The Barnwell Site is currently operating with restrictions on waste generators that only allow LLW from members of the southeast compact. It is unlikely that this site would be available for the disposal of depleted uranium.

Envirocare of Utah, Inc.

Envirocare's disposal facility is located approximately 75 miles west of Salt Lake City in Utah's West Desert. Appropriate hydrogeological and geotechnical conditions combined with a remote location away from residential and agricultural activities provide a suitable disposal facility. Average annual precipitation is 4.8 in.

Envirocare has disposed of waste from many commercial and government projects since 1988. They are licensed by the NRC and the Utah Divisions of Radiation Control and Solid and Hazardous Waste to provide permanent disposal services for mixed waste, naturally occurring and accelerator-produced radioactive materials, and low-activity radioactive (source, special nuclear, and by-product) materials. Envirocare is also licensed to treat mixed waste and dispose of by-product 11e.(2) mill tailings. Radioactive waste disposal is protected through a three-step process of evaluation, segregation, and disclosure. Pre-approved incoming waste is further inspected and analyzed upon arrival. It is then segregated and its location in the disposal cell is recorded.

In a continuous "cut-and cover" process, radioactive waste material is deposited in 12-in. layers and then compacted. This process minimizes void spaces in the embankment. Once design capacity is reached, waste in the completed cell is entombed in a 7-ft clay radon barrier, a rock filter zone, and a coarse rock erosion barrier.

Supporting its disposal services, Envirocare developed the MICRO-LOC Treatment System and processing facility. The operation is designed to economically treat large-volume mixed waste streams, and can accommodate up to 150 tons of material per day. The MICRO-LOC System is capable of treating both characteristic and listed mixed wastes to meet the applicable RCRA treatment standards.

The Envirocare facility is permitted to treat and dispose of over 300 characteristic and listed mixed wastes in a variety of physical forms including soil, concrete, sludge, and building debris. To facilitate efficient treatment, Envirocare will develop an individual MICRO-LOC formula for each candidate waste stream. Following management approval, mixed waste may be shipped to the site in containers or in bulk form. Wastes requiring treatment are sent to the waste receiving area where they are assessed and prepared for processing.

Status of Commercial LLW Disposal

With the passage of Public Law 96-573, the Low-Level Radioactive Waste Policy Act of 1980, states were assigned responsibility for the disposal of LLRW generated within their borders, with the exception of certain LLRW owned or generated by the Federal government, or which is otherwise the responsibility of the Federal government. The States' responsibilities were to be discharged for the most part by establishing new disposal facilities. The 1980 act was amended by the Low-Level Radioactive Waste Policy Amendments Act of 1985, Public Law 99-240, which provided milestones, incentives, and penalties to promote the States' continuous progress toward new LLRW facility development.

As of December 1993, 42 states have formed 9 interstate compact regions. Three states are awaiting ratification of a new compact by Congress. Three states, unaffiliated with a compact, plan to construct disposal facilities. Two unaffiliated states, the District of Columbia, and Puerto Rico, which generate minimal amounts of LLRW, do not plan to construct disposal facilities. Figure A.2 illustrates the current configuration of compact regions and unaffiliated states, and includes the potential disposal site locations announced as of December 1993.

Compacts and states that met each of the milestones in the Act retained access to disposal facilities that were operating in Beatty, Nevada; Barnwell, South Carolina; and Richland, Washington, through 1992. During 1993, only two LLRW disposal facilities were in operation, serving a total of 46 states and the District of Columbia; one in Richland, Washington, operated by US Ecology, Inc., and one in Barnwell County, South Carolina, operated by CNSI.

Based on the provisions of the Act, the Richland facility closed to all generators outside of the Northwest compact region on December 31, 1992. However, through a long-term contract signed in 1992 with the Northwest Interstate Compact Committee, Rocky Mountain compact generators now dispose of their waste at the Richland facility.

Except for the Northwest, Rocky Mountain, and Southeast compacts, none of the states and compacts met the Act's January 1, 1993, deadline to provide long-term disposal capacity for their generators. The State of South Carolina provided a temporary solution to States' disposal problems in 1993. Legislation enacted in South Carolina in the spring of 1992 allowed the regional facility at Barnwell to remain open to states within the Southeast compact region through December 31, 1995; and until June 30, 1994, to others who met eligibility requirements and entered into contracts with the Southeast Compact Commission for Low-Level Radioactive Waste Management. Michigan, New Hampshire, Puerto Rico, and Rhode Island were not eligible to contract for access to Barnwell because of previous findings of noncompliance with the Act's milestones. Maine was eligible but did not sign a contract. Maine generators continue to store their waste until Congress approves the compact with Texas and Vermont and the disposal facility opens in Texas.

Based upon data reported from disposal site operators in 1993 and a 5-year average (1986-1990) of waste disposed by those states without access to disposal in 1993, approximately 95 percent or 22,184 m^3 (792,275 ft^3) of the Nation's estimated 237,732 m^3 (838,119 ft^3) of LLRW was disposed in 1993.

Since June 30, 1994, when contracts for access to the Barnwell facility expired, 30 states, the District of Columbia, and Puerto Rico, are without access to a disposal facility. The 1993 data reported from disposal site operators was prorated to calculate the estimated total volume of LLRW to be disposed in 1994. The total volume of waste in 1994 is estimated to be approximately the same as 1993, or 23,732 m^3 (838,119 ft^3). Approximately 17,606 m^3 (628,755 ft^3) or 75 percent of that waste is expected to be disposed in 1994. In 1995, only the Northwest, Rocky Mountain, and Southeast compact states were projected to have access to disposal. It is possible that in 1995, more than 50 percent of the Nation's LLRW would have to remain in storage.

In 1993, legislation was enacted in Texas and Maine to form a compact with Texas, Maine, and Vermont for the disposal of their LLRW. Following legislation enacted in Vermont in April 1994, a bill granting congressional approval was introduced in the Senate on June 21, 1994. The agreement will aid the process of consolidating disposal facilities and will eliminate the costs for development of facilities in Maine and Vermont.

Two states noted progress in licensing efforts. On December 8, 1993, a license application for a site in Wake County, North Carolina, was filed for a disposal facility to serve the Southeast compact region following the scheduled closure of the Barnwell, South Carolina, facility. The facility is expected to be operational in 1996. If approved in a timely manner, the Southeast compact facility will be able to continue providing disposal capacity to the region's generators when regional access to the Barnwell facility ends on December 31, 1995. In September 1993, a license was issued to US Ecology, Inc., to develop and operate a LLW facility in Ward Valley, California. This is the first license issued since enactment of the Low-Level Radioactive Waste Policy Act of 1980.

During 1993, State siting processes in California, Nebraska, and Texas continued to be challenged. Although progress was noted in California with the issuance of a license, further progress has been delayed because of issues concerning the transfer of the Federally owned Ward Valley Site by the Department of the Interior to California. In July 1992, US Ecology, Inc., filed a lawsuit asking that the court require the California Department of Health Services (DHS) to issue a decision on the Ward Valley license application without holding adjudicatory hearings as requested by the California Senate. In May 1993, the court ruled that adjudicatory hearings were not required and that the DHS could proceed with its licensing decision. In September 1993, the DHS issued the license but agreed to conduct a public hearing to assist the Secretary of the Interior in making a decision to transfer the Federally owned land to the state.

In September 1994, a member of Congress requested the Secretary of the Interior reexamine the scientific basis for the selection of the site in Ward Valley, California. The Secretary then requested the National Academy of Sciences to assess the site's environmental issues by December 1, 1994.

In Nebraska, the Governor announced that community consent did not exist for a planned facility in Boyd County, and on January 12, 1993, filed a lawsuit to prevent licensing or constructing a facility anywhere in the state until community consent was demonstrated. After the court dismissed the case, the State appealed the decision, and on June 13, 1994, the Eighth Circuit Court of Appeals affirmed the lower court's determination in favor of the Commission and US Ecology, Inc. On July 26, 1994, the Nebraska attorney general informed the Governor that he would challenge the decision to the U.S. Supreme Court.

In Texas, Alert Citizens for Environmental Safety and individual landowners filed suit and argued that the Texas legislature's mandate to select a site in Hudspeth County was unlawful and denied the plaintiffs equal protection and due process of the law in violation of the Constitution. The court dismissed the case and the decision was appealed.

In 1993, the nationwide need for temporary storage capacity became more immediate than in past years as evidenced by studies conducted in Illinois and New York. Since the closure of Barnwell, many states will now need to implement their "Governor Certification" plans for temporary storage to manage LLRW.

The January 1, 1990, milestone in the Act required that the governor of each state that had not filed a complete license application for a new facility by January 1, 1990, or would not have access after 1992 to an operating disposal facility must "provide a written certification to the Nuclear Regulatory Commission (NRC), that such State will be capable of providing, for the storage, disposal, or management of low-level radioactive waste generated within the State." Most of these "Governor Certification" plans depended on generators providing storage capacity through license amendments or construction of new facilities. In addition, the plans depended on generators to reduce accumulation of waste through volume reduction or waste minimization.

Despite the 1990 "Governors' Certification" plans, some generators have indicated that inadequate storage space may force a possible curtailment in the use of radiopharmaceuticals for diagnostic and therapeutic treatments. In other cases, rather than attempting to build storage capacity, key research laboratories that use radioisotopes may consider moving their operations to areas where disposal capacity exists, and this movement may have an economic impact on affected communities.

Some observers have noted that temporary storage will also cause long-term problems for generators, regulators, and disposal facility operators alike. When new disposal capacity does finally become available, new disposal facilities will have to be able to receive waste at a significantly higher rate than the rate of waste generation to expeditiously reduce the inventory of waste in temporary storage. This could overburden transportation and handling systems until the temporary storage inventory is disposed. It may also result in an increased regulatory burden for inspections and perhaps higher costs for disposal.

To the extent that states and compact regions focus resources and attention on resolving temporary storage issues, progress toward establishing a disposal facility may be adversely affected. However, development of temporary storage may prove to be as difficult as the development of permanent disposal facilities.

In anticipation of a lack of storage capacity sometime after the Barnwell closure and the prospect of significant disposal cost increase once new facilities begin operation, generators in most states and compact regions have adopted waste minimization and volume reduction practices. In many cases, volume reduction requires that the waste generated within a state or compact region be sent outside the region for treatment and processing.

In late 1992, staff members of the Rocky Mountain Low-Level Radioactive Waste Board drafted the Interregional Access Agreement for Waste Management. The agreement is intended to prevent compact regions and unaffiliated states from impeding the return of residue from waste treated outside their region that originated in their state or region.

The Act clearly defines the authority for states and compacts to regulate LLRW for disposal, but does not specifically address waste treatment. Although each of the compacts consented to by Congress includes various authorities related to management of LLRW for purposes other than disposal, Section 4 of the Act reserves certain authorities to the Federal Government, such as authority over interstate commerce. Therefore, compacts may not exercise authority over the interstate movement of waste through contracts such as the Interregional Access Agreement for Waste Management.

The disposal of commercially generated MLLW continued to be a topic of concern for states throughout 1993. The two operating LLRW disposal facilities do not have permits under RCRA to accept MLLW. However, Envirocare of Utah, Inc., is licensed to accept some low activity mixed waste at its facility.

With volumes of commercial mixed waste for disposal anticipated to be small, and estimated costs prohibitively high for construction of appropriate disposal facilities, many states support the idea of DOE accepting a role in the disposal of commercial MLLW. Additionally, those states and compact regions developing new LLRW disposal facilities are not including disposal capabilities for commercial MLLW. The reasons cited for not developing new commercial MLLW disposal facilities include legislative prohibitions, unacceptable economies of scale, and technical concerns in addressing the joint regulations.

Overseas Experience

Canada*

The situation with respect to solid wastes is that these are stored in concrete silos after volume reduction while permanent disposal options are being studied. A LLRW management site has been in operation at the Chalk River Nuclear Laboratory (CRNL) site in Ontario since 1948. ILW has been stored in a variety of concrete and steel containers, and in the past, LLW has been disposed of in unlined trenches or infiltration pits. These trenches and pits are all located in unsaturated sand dunes lying above a sand aquifer. Some of the LLW has been disposed of in liquid form in the infiltration pits.

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* Low-Level Radioactive Waste Treatment Systems in Northern Europe, DOE/ID/12637-TI, by Studsvik Energiteknik AB, U.S. Department of Energy, Idaho Operations Office, August 1987.

A second waste storage facility is operated at Ontario Hydro's Radioactive Waste Operations Site 2, located 250 km (155 mi) northwest of Toronto. The facilities here include trenches, tile holes (concrete lined pits), and an aboveground storage building for LLW.

Both of these sites have been used to gain experience in site characterization. This has involved a number of field and laboratory studies, including examination of the pollution plumes at CRNL in order to obtain data on groundwater velocity distributions and the dispersive and sorptive characteristics of the geological materials. These data were used as input to mathematical models of groundwater and radionuclide migration for comparison with tracer tests and the CRNL plume data. It was concluded that at best the models could only be used to estimate general rates and direction of contaminant movement and that the predicted concentration were not sufficiently accurate to predict radiological doses to man.

Great Britain*

British Nuclear Fuels (BNFL) operates a solid LLW disposal site at Drigg, Cumbria. This is a near-surface disposal facility excavated into a sequence of glacial deposits overlying a sandstone aquifer. Historically, waste has been loose tipped into the trenches. Recent disposals are containerized and consigned to a concrete-lined vault. Cut-off and secant pile walls operate in conjunction with a clay cap to reduce infiltration and hence minimize release rates.

The depositional history of the geology at Drigg has resulted from a series of glacial advances and retreats, giving a complex structure of boulder clays and sands and gravels overlying the St. Bees sandstone. Post-tectonic deformation has resulted in faulting and discontinuities in the glacial deposits. The base of the waste disposal trenches are keyed into one of these naturally occurring horizontal layers of clay.

This layer reduces vertical migration of activity into underlying aquifers in the disposal area.

The Drigg Site used a variety of features designed to minimize the release of activity from the LLW. These can be divided into four types:

- Natural barriers, such as clay horizons, which form the base of the trenches and prevent release into underlying aquifers;

- Caps and horizontal barriers, which reduce infiltration and reduce the rates of activity mobilization;

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* RECOD '94, Proceedings, The Fourth International Conference on Nuclear Fuel Reprocessing and Waste Management, London, UK, 24-28 April 1994.

- Vertical barriers, such as secant pile and bentonite walls, designed to reduce lateral migration of contaminant; and

- Manmade drainage systems, which reduce waste saturation and hence release.

When installed, the artificial barriers all have measurable properties that can be used as input data to the safety assessments. However, the materials that make up these barriers are not in equilibrium with each other, the waste, or the surrounding host material. The barriers, therefore, not only degrade but can also alter the performance of the surrounding natural materials. The majority of the barriers installed at Drigg are monitored to assess this evolution.

Table A.1 DOE Low-Level Waste Disposal Facilities

DOE Site	Currently Operational	Current Disposal Method	Planned Facility
Hanford LLBG Grout	 Yes No	 Trenches Vaults	 Yes; additional capacity available Yes; vitrification facility
INEL	Yes	Pits, trenches, soil vaults	Yes; additional pits planned
NTS Area 3 Area 5	 Yes Yes	 Craters Pits, trenches	 Yes; three reserve craters Yes; two reserve trenches
LANL TA-54 G	 Yes	 Pits, disposal shafts	 Yes; expansion of existing disposal area
ORR SWSA 6	 Yes	 Above-grade tumulus	 Yes; six above-grade tumulus pads planned
SRS LLRWDF Saltstone E-Area Vaults	 Yes Yes Yes	 Trenches Vaults Vaults	 Yes; additional capacity available

Figure A.1 DOE Low-Level Disposal Sites

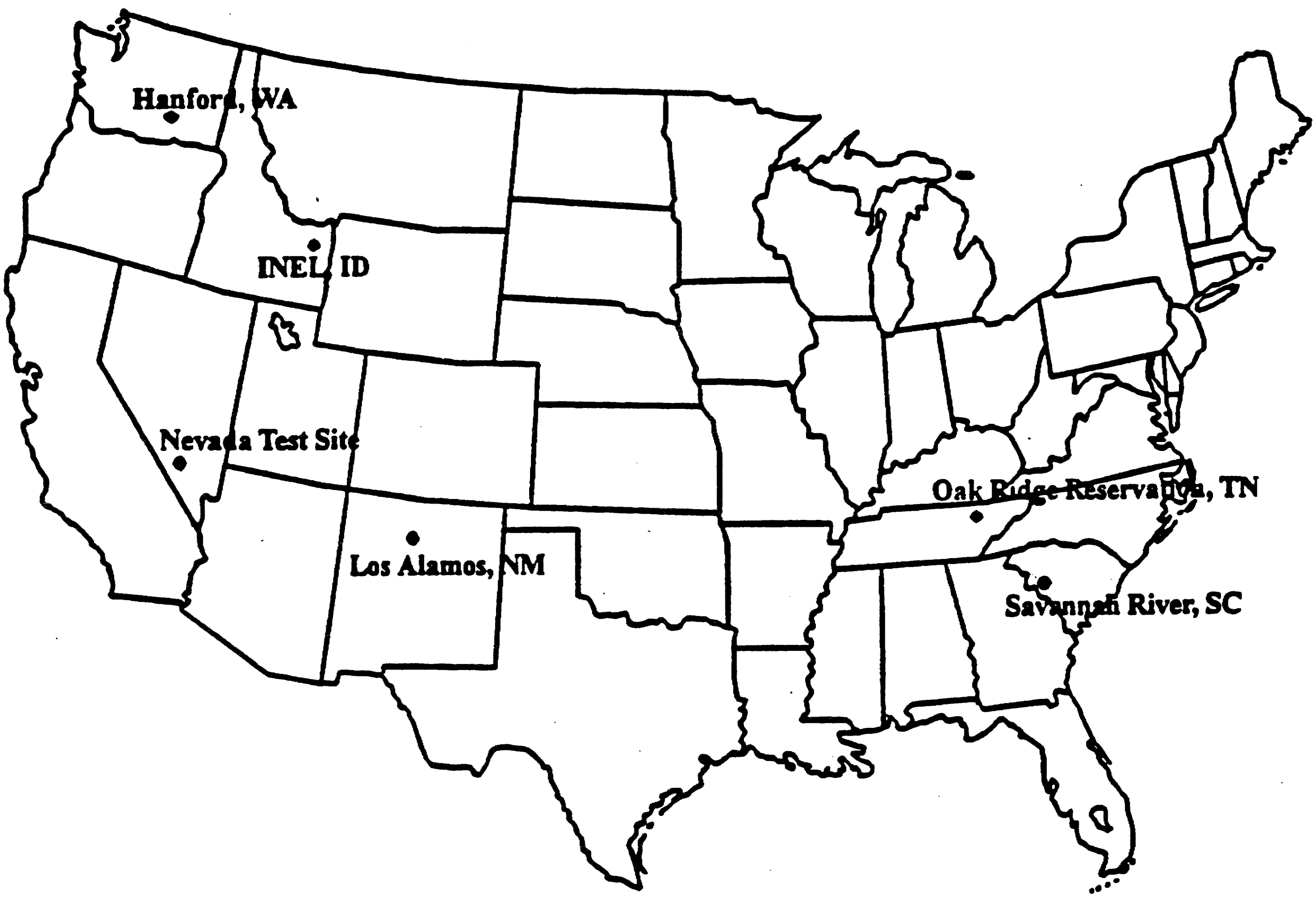
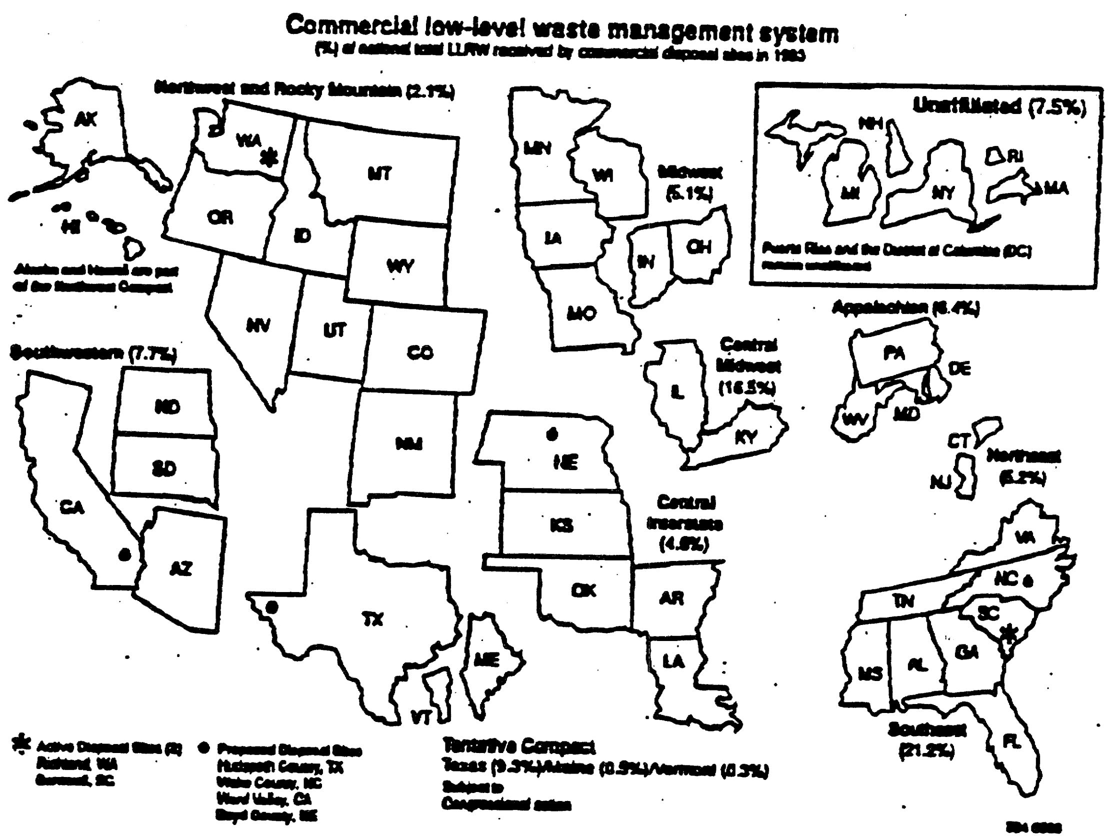


Figure A.2 Current Configuration of Unaffiliated States and Compact Regions



APPENDIX B

NRC's Position Letter

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 3, 1995

Mr. Charles E. Bradley, Jr.
Office of Uranium Programs
Office of Nuclear Energy
U.S. Department of Energy
NE-33, Germantown Bldg
Washington, DC 20585

Dear Mr. Bradley:

This is in response to the U.S. Department of Energy's (DOE's) recent request for recommendations on the potential uses for, and technologies that could facilitate the long-term management of, depleted uranium hexafluoride (DUF_6) stored at the Paducah, Kentucky, and Portsmouth, Ohio, gaseous diffusion plants and at the Oak Ridge Reservation in Tennessee (59 FR 56324, November 10, 1994). The U.S. Nuclear Regulatory Commission's interest in the disposition of DUF_6 at these facilities stems from our responsibilities under the Energy Policy Act of 1992 and the effect that the long-term management strategy(s) chosen by DOE for DUF_6 at DOE's facilities may have on the management of DUF_6 at facilities under the Commission's jurisdiction, that is, the U.S. Enrichment Corporation plants and the proposed Louisiana Energy Services, Claiborne Enrichment Center.

NRC staff has not developed recommendations on the potential uses for DOE's DUF_6. Although beneficial uses of the DUF_6 may be forthcoming in the future, NRC staff believes that, because of the current, excess world-wide inventory of DUF_6, DOE should assume that a significant portion of both DOE and commercial DUF_6 will require disposal as waste. Disposal of the DUF_6 will likely require conversion of the material to a more stable physiochemical form, such as U_3O_8. NRC staff has recommended in the past that U_3O_8, which is thermodynamically stable and relatively insoluble, is a likely form for disposal. Although DU_3O_8 could be disposed of in limited quantities in conventional near-surface disposal facilities, the very large quantities derived from a significant fraction of the nation's enrichment tailings indicate a need for a unique disposal facility. We have assumed that such a large quantity, in proper form, might well be disposed of in a mined cavity, perhaps an exhausted uranium mine, providing better containment for such a large quantity of depleted uranium.

The current storage methods employed at the Paducah, Portsmouth, and Oak Ridge facilities have demonstrated insignificant impacts from a health and safety standpoint for about fifty years. However, conversion of the DUF_6 to U_3O_8 could provide even safer intermediate storage for possible future use or eventual disposal.

Although we recognize that, currently, there is limited capacity for converting the DUF_6 to U_3O_8, and that a mined cavity for its disposal has yet to be developed, we believe that conversion of DUF_6 to U_3O_8, and placement of the material in a mined cavity, is one long-term management option that should be included in any evaluation of options by DOE for its DUF_6.

If you have any questions concerning the staff's recommendation, please contact Michael F. Weber, of my staff, at (301) 415-7298.

Sincerely,

Robert M. Bernero, Director
Office of Nuclear Material Safety
and Safeguards

APPENDIX C

Equipment Lists for the Disposal Facility

Appendix C: Equipment Lists for the Disposal Facility

Table C.1 Equipment List for the Administration Building

Item/Description	Number
HVAC system	1
Office PC/LAN system	16/1
Office furnishing	16
Conference furnishing	1
Lunchroom furnishing	1
Storage shelving system	1
Site telephone system	1
Portal monitor	1
Transformer	1
Emergency lighting system	1
Security door, remote operation	1
Security gate, remote operation	1
Area monitoring system, video	1
Total equipment cost	
Total installed equipment cost	
Building charge, standard construction	680 m^2 (7320 ft^2)

Table C.2 Equipment List for the Product Receiving Warehouse

Item/Description	Number
HVAC system	1
PC	2
Office furnishing	1
Deck plate, size to forklift and load	6
Forklift truck, electric	6
Forklift truck recharging station	1
Bridge crane, 15 te	1
Receiving inspection station, complete	1
Transformer	1
Emergency lighting system	1
Prime mover for rail car & semi trailer use	1
Total equipment cost	
Total installed equipment cost	
Building charge, standard construction	4240 m^2 (45,600 ft^2)

Table C.3 Equipment List for the Cementing Building

Item/Description	Number
HVAC system	1
PC	1
Office furnishing	1
Drum elevator	2
Bulk hopper	2
Drum tipper	4
Metering hopper	12
Metering control system	1
High shear mixer (3.82 cubic meter cap.)	4
Transformer	1
Emergency lighting system	1
Pour station, vibrating	4
Quality inspection station	1
Roller conveyor (powered) system	1
HEPA filtration system	2
Total equipment cost	
Total installed equipment cost	
Building charge, standard construction	1640 m^2 (17,600 ft^2)

Table C.4 Equipment List for the Curing Building

Item/Description	Number
HVAC system	1
Humidity control system	1
PC	1
Office furnishing	1
Roller conveyor system	1
Roller conveyor (powered) system	1
Product quality monitoring station	1
Transformer	1
Emergency lighting system	1
Total equipment cost	
Total installed equipment cost	
Building charge, standard construction	4240 m^2 ($45,600\ ft^2$)

Table C.5 Equipment List for the Supply and Shipping Warehouse

Item/Description	Number
HVAC system	1
PC	1
Office furnishing	1
Storage shelving system	1
Roller conveyor system	1
Forklift truck, electric	2
Forklift truck recharging station	1
Maintenance shop, complete	1
Packaging and certification station	1
Transformer	1
Emergency lighting system	1
Mobile hoist	1
Total equipment cost	
Total installed equipment cost	
Building charge, standard construction	4240 m^2 (46,300 ft^2)

Table C.6 Equipment List for the Vault Disposal Facility

Item/Description	Number
Main Drain	1
Sump Pump	1
Monitoring pipes*	
Trucks, drum transport	5
Emplacement Cranes, 10,000-lb capacity**	4
Front-End Loaders, 3½ cu yd capacity	5
Total Equipment Cost	
Total Installed Equipment Cost	
Building Charge	570,000 m^2 (6.1 million ft^2)

* Adequate for monitoring all 5 bays of each of 169 vaults.
** Cranes must be mobile, mounted on track-vehicles for access to the vaults over graded terrain.

Table C.7 Equipment List for the Engineered Trench Disposal Facility

Item/Description	Number
0.6-m French drain	1
Sump Pump	2
Monitoring pipes	
4536-kg Vibratory Compactor	1
Wheeled Container Handlers	20
Trucks, drum transport	5
Emplacement Cranes, 10,000-lb capacity	4
Fork-Lift Trucks, 5-te capacity	25
Pallets, 4' x 4', wood	400,000
Total Equipment Cost	
Total Installed Equipment Cost	
Building Charge	208,000 m^2 (2.2 million ft^2)

Table C.8 Equipment List for the Mined Cavity Disposal Facility

Item/Description	Number
Emplacement (Sub-Surface) Area:	
Sump Pump, 2,000 gpm @ 1,000 ft hd	1
Positive (Force) Fan, 200,000 cfm	1
Negative (Exhaust) Fan, 200,000 cfm	1
Support Shop with equipment	1
Men & Materials Elevator/shaft	1
Surface Support Area:	
Recovery/Service Vehicles	5
Fork Lift Trucks, 5-te lift capacity*	50
Pallets, 4' x4', wood	400,000
Total Equipment Cost	
Total Installed Equipment Cost	
Building Charge	2.2×10^8 m^2 (2.3×10^9 ft^2)

* Equipped with drum-handling attachments to stack drums on pallets.

APPENDIX D

Radiation Exposure and Manpower Distribution Estimating Data

Appendix D: Radiation Exposure and Manpower Distribution Estimating Data

WASTEFORM DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 13)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 14)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	8,938	1	3	Steel	0.053"	4,469
Transfer pallet to warehouse storage	2	0.2	8,938	1	6	Steel	0.053"	3,575
Transfer pallet to conveyor bay	2	0.2	8,938	1	6	Steel	0.053"	3,575
Load drum on conveyor to cementing building	2	0.05	35,750	2	3	Steel	0.053"	3,575
Warehouse storage surveillance	2	8	520	3	3	Steel	0.053"	8,320
Building Management	1	8	260	3	10	Steel	0.053"	2,080
Security	1	2	1,095	3	15	Steel	0.053"	2,190
CEMENTING BUILDING (2 shifts/ 5 days a week)								
DUO metering hopper operations	2	8	520	4	6	Steel	1/4"	8,320
Drum recycle transfer station operations	1	8	520	4,5	16	Steel	1/4", 1/2"	4,160
Sand/cement hopper operations	1	8	520	6	40	Steel	1/4"	4,160
Pour stand operations	3	8	520	7	6	Steel	0.053"	12,480
Laboratory/Sampling Operations	3	8	520	5	6	Steel	1/2"	12,480
Decontaminate full drum exterior	1	0.5	75	7	3	Steel	0.053"	38
Load full drum on conveyor to curing building	1	0.25	75	7	3	Steel	0.053"	19
Drum/conveyance surveillance	2	8	520	8	3	Steel	0.053"	8,320
Building Management	3	8	260	6	20	Steel	1/4"	6,240
Security	1	2	1,095	6	30	Steel	1/4"	2,190
CURING BUILDING								
Drum/conveyance surveillance	3	8	520	9	3	Steel	0.053"	12,480
Security	1	2	1,095	9	15	Steel	0.053"	2,190

SUPPLY AND SHIPPING BUILDING								
Unload drum from conveyor onto pallet	1	0.05	74,700	7	3	Steel	0.053"	3,735
Transfer pallet to temporary storage position (12)	1	0.2	9,338	10	6	Steel	0.053"	1,868
Transfer pallet to shipping bay (12)	1	0.2	18,675	10	6	Steel	0.053"	3,735
Load pallet onto disposal transport	2	0.1	18,675	10	3	Steel	0.053"	3,735
New drum handling	1	8	520	11	60	Steel	0.053"	4,160
Decontaminate empty drum	1	0.5	286	11	60	Steel	0.053"	143
Predisposal storage surveillance	1	8	520	11	3	Steel	0.053"	4,160
Building Management	1	8	260	11	10	Steel	0.053"	2,080
Security	1	2	1,095	11	15	Steel	0.053"	2,190
ADMINISTRATION BUILDING								
Building Operations	16	8	260	3	160	Steel	0.053"	33,280
Security	2	8	1,095	3	160	Steel	0.053"	17,520

1) Single pallet with four U3O8 drums.
2) Single U3O8 drum.
3) Up to 2,235 U3O8 drum pallets in receiving warehouse.
4) Content of single hopper.
5) Content of single high shear mixer.
6) Four hoppers.
7) Single grouted-U3O8 drum.
8) Cumulative inventory of a single conveyor line.
9) Cumulative inventory of curing building (grouted-U3O8 drums).
10) Single pallet of four grouted-U3O8 drums.
11) Cumulative inventory of supply/shipping building (grouted-U3O8 drums).
12) Grouted-U3O8 drums: 1/2 loaded directly onto transports, 1/2 temporarily stored then transfered to transport.
13) 35,750 U3O8 drums received per year.
    8,938 U3O8 drum pallets received per year (35,750 U3O8 drums / 4 drums per pallet).
    286 rejected empty drums in recycle process are sent to decontamination station (0.8% rejection rate - assumption).
    74,700 grouted-U3O8 drums produced per year.
    75 contaminated drums are decontaminated per year (0.1% contamination rate - assumption).
    260 workdays per year X 2 shifts per day = 520 shifts per year.
    365 days per year X 3 shifts per day = 1,095 shifts per year.
14) Materials do not include walls between operating areas.

WASTEFORM DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 11)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 12)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead Crane	2	52	1	1	10	Steel	0.053"	104
HVAC	2	520	1	1	10	Steel	0.053"	1,040
Powdered Conveyor Belt to Cementing Building	2	104	1	1	10	Steel	0.053"	208
CEMENTING BUILDING								
Drum Elevator	2	104	2	2	10	Steel	0.053"	416
Metering system conveyor (auger/screw conveyor)	2	104	12	3	20	Steel	1/4"	2,496
DUO Metering hopper	2	52	4	4	1	Steel	1/4"	416
Drum Tipper	2	52	4	4	3	Steel	1/4"	416
Roller Conveyor	2	104	1	4	3	Steel	1/4"	208
Cement Metering hopper	2	52	4	5	20	Steel	0.053"	416
Sand Metering hopper	2	52	4	5	20	Steel	0.053"	416
Bulk Hopper	2	52	2	5	30	Steel	0.053"	208
High Shear Mixers	2	52	4	6	3	Steel	1/2"	416
Empty Drum Conveyer	2	104	1	6,7	6	Steel	1/2",0.053"	208
Vibrator Pour Stand	2	52	4	7	3	Steel	0.053"	416
Roller Conveyor	2	104	5	8	3	Steel	0.053"	1,040
Vacuum Station Equipment	1	52	1	4,6	16	Steel	1/4",1/2"	52
Monitoring Station Equipment	1	26	4	8	3	Steel	0.053"	104
Decontamination Equipment	1	26	1	8	20	Steel	0.053"	26
HVAC	2	520	1	5	20	Steel	0.053"	1,040
HEPA	2	26	2	5	20	Steel	0.053"	104
CURING BUILDING								
Roller conveyor (powered) system	2	104	2	9	3	Steel	0.053"	416
Humidity Control System	2	26	1	9	20	Steel	0.053"	52
HVAC	2	520	1	9	20	Steel	0.053"	1,040

SUPPLY AND SHIPPING BUILDING								
Conveyor system for new drum transfers	2	104	1	10	60	Steel	0.053"	208
HVAC	2	520	1	10	60	Steel	0.053"	1,040
Dilute Acid Spray/Rinse/Drying System	1	52	1	10	60	Steel	0.053"	52
Decontamination Equipment	1	26	1	10	60	Steel	0.053"	26
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.053"	1,040

1) Up to 2,235 U3O8 drum pallets in receiving warehouse.
2) Single U3O8 drum.
3) Four hoppers.
4) Single hopper.
5) Cumulative inventory of cement building setting conveyor lines.
6) Single high shear mixer.
7) Single grouted-U3O8 drum.
8) Cumulative inventory of a single conveyor line (grouted-U3O8 drums).
9) Cumulative inventory of curing building (grouted-U3O8 drums).
10) Cumulative inventory of supply/shipping building (grouted-U3O8 drums).
11) 2 hours per week (104) for complex systems with multiple active components (conveyors) - includes instrumentation.
1 hour per week (52) on active components (cranes, mixers, pumps) - includes instrumentation.
1/2 hour per week (26) on passive components (hoppers, monitoring equipment) - includes instrumentation.
10 hours per week (520) on HVAC.
12) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 6)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 7)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 169 Vaults								
Transport pallets to vault	1	1	2,668	1	6	Steel	0.053"	2,668
Unload pallet from transport at vault	2	0.2	18,675	2	3	Steel	0.053"	7,470
Transfer drum to disposal position	2	0.25	18,675	3	6	Steel	0.053"	9,338
Vault fill-in with gravel and compact	4	40	169	4	6	Steel	0.053"	27,040
Cement cover vault	12	160	8	4	10	Steel	0.053"	16,224
Earth fill on cement cover	8	80	8	4	20	Steel	0.053"	5,408
Disposal area surveillance	1	8	520	4	10	Steel	0.053"	4,160
Vault Manager/staff	2	8	260	5	160	Steel	0.053"	4,160
Disposal management	4	8	520	4	20	Steel	0.053"	16,640
Security	1	2	1,095	4	50	Steel	0.053"	2,190

1) Seven pallets of grouted-U3O8 drums.
2) Single pallet with four grouted-U3O8 drums.
3) Single U308 drum.
4) Cumulative inventory of a single disposal vault.
5) Up to 2,235 U3O8 drum pallets in receiving warehouse.
6) 74,700 grouted-U3O8 drums received per year.
   18,675 grouted-U3O8 drum pallets received per year (74,700 grouted-U3O8 drums / 4 drums per pallet).
   2,668 tranfers per year (18,675 grouted-U3O8 drum pallets per year / 7 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   74,700 drums per year / 8,840 drums per vault = 8.45 vaults per year.
   8,840 drums per vault / 5 bays per vault = 1,768 drums per bay.
   1,768 drums per bay / 4 drum levels per bay = 442 drums per level.
   74,700 drums per year / 442 drums per level = 169 levels per year.
7) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 2)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 3)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 169 Vaults								
Sump pump	1	26	169	1	10	Steel	0.053"	4,394
Vault monitoring equipment	1	26	169	1	20	Steel	0.053"	4,394

1) Cumulative inventory of a single disposal vault.
2) 1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
3) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 20 Trenches								
Transport pallets to trench	1	1	2,679	1	6	Steel	0.053"	2,679
Unload pallet from transport at trench	2	0.2	18,750	2	3	Steel	0.053"	7,500
Transfer pallet to disposal position	2	0.25	18,750	2	6	Steel	0.053"	9,375
Trench fill-in (by level)	12	8	260	3	3	Steel	0.053"	24,960
Trench fill-in (closure)	8	160	1	3	6	Steel	0.053"	1,280
Disposal area surveillance	1	8	520	3	10	Steel	0.053"	4,160
Trench Manager/staff	2	8	260	4	160	Steel	0.053"	4,160
Disposal management	2	8	260	3	20	Steel	0.053"	4,160
Security	1	2	1,095	3	50	Steel	0.053"	2,190

1) Seven pallets of grouted-U3O8 drums.
2) Single pallet with four grouted-U3O8 drums.
3) Cumulative inventory of a single disposal trench.
4) Up to 2,230 U3O8 drum pallets in receiving warehouse.
5) 75,000 grouted-U3O8 drums received per year.
   18,750 grouted-U3O8 drum pallets received per year (75,000 grouted-U3O8 drums / 4 drums per pallet).
   2,679 tranfers per year (18,750 grouted-U3O8 drum pallets per year / 7 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   1 trench per year.
6) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 2)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 3)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 20 Trenches								
Sump pump	1	26	40	1	10	Steel	0.053"	1,040
Monitoring equipment	1	26	20	1	20	Steel	0.053"	520

1) Cumulative inventory of a single disposal trench.
2) 1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
3) Materials include only the drum barrier.

MINED CAVITY DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
SUPPORT FACILITIES								
Ventilation operations	2	8	520	1	60	Steel	0.053"	8,320
Security	2	2	1,095	4	800	Steel	0.053"	4,380
DISPOSAL AREA								
Transport pallets to mine	1	1	2,668	1	6	Steel	0.053"	2,668
Unload pallet from transport	2	0.2	18,675	2	3	Steel	0.053"	7,470
Load pallet onto mine transport	2	0.2	18,675	2	3	Steel	0.053"	7,470
Transport pallets into mine	1	2	2,668	1	6	Steel	0.053"	5,336
Unload pallet to disposal position	2	0.25	18,675	3	15	Steel	0.053"	9,338
Disposal area surveillance	2	8	520	3	10	Steel	0.053"	8,320
Mine Manager/staff	2	8	260	4	160	Steel	0.053"	4,160
Disposal management	2	8	520	3	20	Steel	0.053"	8,320
Security	1	2	1,095	3	50	Steel	0.053"	2,190

1) Seven pallets of grouted-U3O8 drums.
2) Single pallet with four grouted-U3O8 drums.
3) Cumulative inventory of a single mine drift.
4) Up to 2,235 U3O8 drum pallets in receiving warehouse.
5) 74,700 grouted-U3O8 drums received per year.
   18,675 grouted-U3O8 drum pallets received per year (74700 grouted-U3O8 drums / 4 drums per pallet).
   2,668 tranfers per year (18675 grouted-U3O8 drum pallets per year / 7 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
6) Materials do not include walls between operating areas.

MINED CAVITY DISPOSAL FACILITY (GROUTED-U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 2)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 3)	THICKNESS	PERSON HOURS PER YEAR
SUPPORT FACILITIES								
HVAC	2	520	1	1	1,600	Steel	0.053"	1,040
DISPOSAL AREA								
Sump pump	2	52	1	1	10	Steel	0.053"	104
Force fan	2	52	1	1	20	Steel	0.053"	104
Exhaust fan	2	52	1	1	20	Steel	0.053"	104
Mine elevator	2	104	1	1	1,000	Steel	0.053"	208

1) Cumulative inventory of a single mine drift.
2) 1 hour per week (52) on active components (pumps) - includes instrumentation.
   2 hours per week (104) on conveyance devices (elevator) - includes instrumentation.
   10 hours per week (520) on HVAC.
3) Materials do not include walls between operating areas.

WASTEFORM DISPOSAL FACILITY (GROUTED-UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 13)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 14)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	5,250	1	3	Steel	0.095"	2,625
Transfer pallet to warehouse storage	2	0.2	5,250	1	6	Steel	0.095"	2,100
Transfer pallet to conveyor bay	2	0.2	5,250	1	6	Steel	0.095"	2,100
Load drum on conveyor to cementing building	2	0.05	21,000	2	3	Steel	0.095"	2,100
Warehouse storage surveillance	2	8	520	3	3	Steel	0.095"	8,320
Building Management	1	8	260	3	10	Steel	0.095"	2,080
Security	1	2	1,095	3	15	Steel	0.095"	2,190
CEMENTING BUILDING (2 shifts/ 5 days a week)								
DUO metering hopper operations	2	8	520	4	6	Steel	1/4"	8,320
Drum recycle transfer station operations	1	8	520	4,5	16	Steel	1/4", 1/2"	4,160
Cement hopper operations	1	8	520	6	40	Steel	1/4"	4,160
Pour stand operations	3	8	520	7	6	Steel	0.095"	12,480
Laboratory/Sampling Operations	3	8	520	5	6	Steel	1/2"	12,480
Decontaminate full drum exterior	1	0.5	32	7	3	Steel	0.095"	16
Load full drum on conveyor to curing building	1	0.25	32	7	3	Steel	0.095"	8
Drum/conveyance surveillance	2	8	520	8	3	Steel	0.095"	8,320
Building Management	3	8	260	6	20	Steel	1/4"	6,240
Security	1	2	1,095	6	30	Steel	1/4"	2,190
CURING BUILDING								
Drum/conveyance surveillance	3	8	520	9	3	Steel	0.095"	12,480
Security	1	2	1,095	9	15	Steel	0.095"	2,190

SUPPLY AND SHIPPING BUILDING								
Unload drum from conveyor onto pallet	1	0.05	31,600	7	3	Steel	0.095"	1,580
Transfer pallet to temporary storage position (12)	1	0.2	3,950	10	6	Steel	0.095"	790
Transfer pallet to shipping bay (12)	1	0.2	7,900	10	6	Steel	0.095"	1,580
Load pallet onto disposal transport	2	0.1	7,900	10	3	Steel	0.095"	1,580
New drum handling	1	8	260	11	60	Steel	0.095"	2,080
Decontaminate empty drum	1	0.5	168	11	60	Steel	0.095"	84
Predisposal storage surveillance	1	8	520	11	3	Steel	0.095"	4,160
Building Management	1	8	260	11	10	Steel	0.095"	2,080
Security	1	2	1,095	11	15	Steel	0.095"	2,190
ADMINISTRATION BUILDING								
Building Operations	16	8	260	3	160	Steel	0.095"	33,280
Security	2	8	1,095	3	160	Steel	0.095"	17,520

1) Single pallet with four UO2 drums.
2) Single UO2 drum.
3) Up to 1,313 UO2 drum pallets in receiving warehouse.
4) Content of single DUO hopper.
5) Content of single high shear mixer.
6) Four DUO hoppers.
7) Single grouted-UO2 drum.
8) Cumulative inventory of a single conveyor line.
9) Cumulative inventory of curing building (grouted-UO2 drums).
10) Single pallet of four grouted-UO2 drums.
11) Cumulative inventory of supply/shipping building (grouted-UO2 drums).
12) Grouted-UO2 drums: 1/2 loaded directly onto transports, 1/2 temporarily stored then transfered to transport.
13) 21,000 UO2 drums received per year.
    5,250 UO2 drum pallets received per year (21000 UO2 drums / 4 drums per pallet).
    168 rejected empty drums in recycle process are sent to decontamination station (0.8% rejection rate - assumption).
    31,600 grouted-UO2 drums produced per year.
    32 contaminated drums are decontaminated per year (0.1% contamination rate - assumption).
    260 workdays per year X 2 shifts per day = 520 shifts per year.
    365 days per year X 3 shifts per day = 1,095 shifts per year.
14) Materials do not include walls between operating areas.

WASTEFORM DISPOSAL FACILITY (GROUTED-UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 11)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 12)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead Crane	2	52	1	1	10	Steel	0.095"	104
HVAC	2	520	1	1	10	Steel	0.095"	1,040
Powdered Conveyor Belt to Cementing Building	2	104	1	1	10	Steel	0.095"	208
CEMENTING BUILDING								
Drum Elevator	2	104	2	2	10	Steel	0.095"	416
Metering system conveyor (auger/screw conveyor)	2	104	8	3	20	Steel	1/4"	1,664
DUO Metering hopper	2	52	4	4	1	Steel	1/4"	416
Drum Tipper	2	52	4	4	3	Steel	1/4"	416
Roller Conveyor	2	104	1	4	3	Steel	1/4"	208
Cement Metering hopper	2	52	4	5	20	Steel	0.095"	416
Bulk Hopper	2	52	1	5	30	Steel	0.095"	104
High Shear Mixers	2	52	4	6	3	Steel	1/2"	416
Empty Drum Conveyer	2	104	1	6,7	6	Steel	1/2",0.095"	208
Vibrator Pour Stand	2	52	4	7	3	Steel	0.095"	416
Roller Conveyor	2	104	5	8	3	Steel	0.095"	1,040
Vacuum Station Equipment	1	52	1	4,6	16	Steel	1/4",1/2"	52
Monitoring Station Equipment	1	26	4	8	3	Steel	0.095"	104
Decontamination Equipment	1	26	1	8	20	Steel	0.095"	26
HVAC	2	520	1	5	20	Steel	0.095"	1,040
HEPA	2	26	2	5	20	Steel	0.095"	104
CURING BUILDING								
Roller conveyor (powered) system	2	104	2	9	3	Steel	0.095"	416
Humidity Control System	2	26	1	9	20	Steel	0.095"	52
HVAC	2	520	1	9	20	Steel	0.095"	1,040

SUPPLY AND SHIPPING BUILDING								
Conveyor system for new drum transfers	2	104	1	10	60	Steel	0.095"	208
HVAC	2	520	1	10	60	Steel	0.095"	1,040
Dilute Acid Spray/Rinse/Drying System	1	52	1	10	60	Steel	0.095"	52
Decontamination Equipment	1	26	1	10	60	Steel	0.095"	26
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.095"	1,040

1) Up to 1313 UO2 drum pallets in receiving warehouse.
2) Single UO2 drum.
3) Four hoppers.
4) Single hopper.
5) Cumulative inventory of cement building setting conveyor lines.
6) Single high shear mixer.
7) Single grouted-UO2 drum.
8) Cumulative inventory of a single conveyor line (grouted-UO2 drums).
9) Cumulative inventory of curing building (grouted-UO2 drums).
10) Cumulative inventory of supply/shipping building (grouted-UO2 drums).
11) 2 hours per week (104) for complex systems with multiple active components (conveyors) - includes instrumentation.
    1 hour per week (52) on active components (cranes, mixers, pumps) - includes instrumentation.
    1/2 hour per week (26) on passive components (hoppers, monitoring equipment) - includes instrumentation.
    10 hours per week (520) on HVAC.
12) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (GROUTED-UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 6)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 7)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 35 Vaults								
Transport pallets to vault	1	1	1,975	1	6	Steel	0.095"	1,975
Unload pallet from transport at vault	2	0.2	7,900	2	3	Steel	0.095"	3,160
Transfer drum to disposal position	2	0.25	31,600	3	6	Steel	0.095"	15,800
Vault fill-in with gravel and compact	4	40	52	4	6	Steel	0.095"	8,320
Cement cover vault	12	160	1.73	4	10	Steel	0.095"	3,322
Earth fill on cement cover	8	80	1.73	4	20	Steel	0.095"	1,108
Disposal area surveillance	1	8	520	4	10	Steel	0.095"	4,160
Vault Manager/staff	2	8	260	5	160	Steel	0.095"	4,160
Disposal management	4	8	520	4	20	Steel	0.095"	16,640
Security	1	2	1,095	4	50	Steel	0.095"	2,190

1) Four pallets of grouted-UO2 drums.
2) Single pallet with four grouted-UO2 drums.
3) Single U02 drum.
4) Cumulative inventory of a single disposal vault.
5) Up to 1,313 UO2 drum pallets in receiving warehouse.
6) 31,600 grouted-UO2 drums received per year.
   7,900 grouted-UO2 drum pallets received per year (31,600 grouted-UO2 drums / 4 drums per pallet).
   1,975 tranfers per year (7,900 grouted-UO2 drum pallets per year / 4 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   31,600 drums per year / 18,275 drums per vault = 1.73 vaults per year.
   18,275 drums per vault / 5 bays per vault = 3,655 drums per bay.
   3,655 drums per bay / 6 drum levels per bay = 610 drums per level.
   31,600 drums per year / 610 drums per level = 52 levels per year.
7) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (GROUTED-UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 2)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 3)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 35 Vaults								
Sump pump	1	26	35	1	10	Steel	0.095"	910
Vault monitoring equipment	1	26	35	1	20	Steel	0.095"	910

1) Cumulative inventory of a single disposal vault.
2) 1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
3) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (GROUTED-UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 20 Trenches								
Transport pallets to trench	1	1	1,975	1	6	Steel	0.095"	1,975
Unload pallet from transport at trench	2	0.2	7,900	2	3	Steel	0.095"	3,160
Transfer pallet to disposal position	2	0.25	7,900	2	6	Steel	0.095"	3,950
Trench fill-in (by level)	4	8	260	3	3	Steel	0.095"	8,320
Trench fill-in (closure)	8	160	1	3	6	Steel	0.095"	1,280
Disposal area surveillance	1	8	520	3	10	Steel	0.095"	4,160
Trench Manager/staff	2	8	260	4	160	Steel	0.095"	4,160
Disposal management	2	8	260	3	20	Steel	0.095"	4,160
Security	1	2	1,095	3	50	Steel	0.095"	2,190

1) Four pallets of grouted-UO2 drums.
2) Single pallet with four grouted-UO2 drums.
3) Cumulative inventory of a single disposal trench.
4) Up to 1,313 UO2 drum pallets in receiving warehouse.
5) 31,600 grouted-UO2 drums received per year.
   7,900 grouted-UO2 drum pallets received per year (31,600 grouted-UO2 drums / 4 drums per pallet).
   1,975 tranfers per year (7,900 grouted-UO2 drum pallets per year / 4 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   1 trench per year.
6) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (GROUTED-UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 2)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 3)	THICKNESS	PERSON HOURS PER YEAR
DISPOSAL AREA - 20 Trenches								
Sump pump	1	26	40	1	10	Steel	0.095"	1,040
Monitoring equipment	1	26	20	1	20	Steel	0.095"	520

1) Cumulative inventory of a single disposal trench.
2) 1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
3) Materials include only the drum barrier.

MINED CAVITY DISPOSAL FACILITY (GROUTED-UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
SUPPORT FACILITIES								
Ventilation operations	2	8	520	1	60	Steel	0.095"	8,320
Security	2	2	1,095	4	800	Steel	0.095"	4,380
DISPOSAL AREA								
Transport pallets to mine	1	1	1,975	1	6	Steel	0.095"	1,975
Unload pallet from transport	2	0.2	7,900	2	3	Steel	0.095"	3,160
Load pallet onto mine transport	2	0.2	7,900	2	3	Steel	0.095"	3,160
Transport pallets into mine	1	2	1,975	1	6	Steel	0.095"	3,950
Unload pallet to disposal position	2	0.25	7,900	3	15	Steel	0.095"	3,950
Disposal area surveillance	2	8	520	3	10	Steel	0.095"	8,320
Mine Manager/staff	2	8	260	4	160	Steel	0.095"	4,160
Disposal management	2	8	520	3	20	Steel	0.095"	8,320
Security	1	2	1,095	3	50	Steel	0.095"	2,190

1) Four pallets of grouted-UO2 drums.
2) Single pallet with four grouted-UO2 drums.
3) Cumulative inventory of a single mine drift.
4) Up to 1,313 UO2 drum pallets in receiving warehouse.
5) 31,600 grouted-UO2 drums received per year.
7,900 grouted-UO2 drum pallets received per year (31,600 grouted-UO2 drums / 4 drums per pallet).
1,975 tranfers per year (7,900 grouted-UO2 drum pallets per year / 4 pallets per transfer).
260 workdays per year X 2 shifts per day = 520 shifts per year.
365 days per year X 3 shifts per day = 1,095 shifts per year.
6) Materials do not include walls between operating areas.

MINED CAVITY DISPOSAL FACILITY (GROUTED-UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 2)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 3)	THICKNESS	PERSON HOURS PER YEAR
SUPPORT FACILITIES								
HVAC	2	520	1	1	1,600	Steel	0.095"	1,040
DISPOSAL AREA								
Sump pump	2	52	1	1	10	Steel	0.095"	104
Force fan	2	52	1	1	20	Steel	0.095"	104
Exhaust fan	2	52	1	1	20	Steel	0.095"	104
Mine elevator	2	104	1	1	1,000	Steel	0.095"	208

1) Cumulative inventory of a single mine drift.
2) 1 hour per week (52) on active components (pumps) - includes instrumentation.
   2 hours per week (104) on conveyance devices (elevator) - includes instrumentation.
   10 hours per week (520) on HVAC.
3) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 6)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 7)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	8,938	1	3	Steel	0.053"	4,469
Transfer pallet to warehouse storage	2	0.2	8,938	1	6	Steel	0.053"	3,575
Transfer pallet to transport bay	2	0.2	8,938	1	6	Steel	0.053"	3,575
Load pallet on transport to disposal area	2	0.05	8,938	1	3	Steel	0.053"	894
Warehouse storage surveillance	2	8	520	2	3	Steel	0.053"	8,320
Building Management	1	8	260	2	10	Steel	0.053"	2,080
Security	1	2	1,095	2	15	Steel	0.053"	2,190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	2	800	Steel	0.053"	24,960
Security	2	8	1,095	2	800	Steel	0.053"	17,520
DISPOSAL AREA - 81 Vaults								
Transport pallets to vault	1	1	1,277	3	6	Steel	0.053"	1,277
Unload pallet from transport at vault	2	0.2	8,938	1	3	Steel	0.053"	3,575
Transfer drum to disposal position	2	0.25	35,750	4	6	Steel	0.053"	17,875
Vault fill-in with gravel and compact	4	40	81	81	6	Steel	0.053"	12,960
Cement cover vault	12	160	4.04	4.04	10	Steel	0.053"	7,757
Earth fill on cement cover	8	80	4.04	4.04	20	Steel	0.053"	2,586
Disposal area surveillance	1	8	520	5	10	Steel	0.053"	4,160
Disposal management	4	8	520	5	20	Steel	0.053"	16,640
Security	1	2	1,095	5	30	Steel	0.053"	2,190

1) Single pallet with four U3O8 drums.
2) Up to 2,235 U3O8 drum pallets in receiving warehouse.
3) Seven pallets of U3O8 drums.
4) Single U3O8 drum.
5) Cumulative inventory of a single disposal vault.
6) 35,750 U3O8 drums received per year.
   8,938 U3O8 drum pallets received per year (35,750 U3O8 drums / 4 drums per pallet).
   1,277 tranfers per year (8,938 U3O8 drum pallets per year / 7 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   35,750 drums per year /8,840 drums per vault = 4.04 vaults per year.
   8,840 drums per vault / 5 bays per vault = 1,768 drums per bay.
   1,768 drums per bay / 4 drum levels per bay = 442 drums per level.
   35,750 drums per year / 442 drums per level = 81 levels per year.
7) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 3)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 4)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead crane	2	52	1	1	10	Steel	0.053"	104
HVAC	2	520	1	1	10	Steel	0.053"	1,040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.053"	1,040
DISPOSAL AREA - 81 Vaults					3			
Sump pump	1	26	81	2	10	Steel	0.053"	2,106
Vault monitoring equipment	1	26	81	2	15	Steel	0.053"	2,106

1) Up to 2,235 U3O8 drum pallets in receiving warehouse.
2) Cumulative inventory of a single disposal vault.
3) 1 hour per week (52) on active components (cranes) - includes instrumentation.
1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
10 hours per week (520) on HVAC.
4) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	8,938	1	3	Steel	0.053"	4,469
Transfer pallet to warehouse storage	2	0.2	8,938	1	6	Steel	0.053"	3,575
Transfer pallet to transport bay	2	0.2	8,938	1	6	Steel	0.053"	3,575
Load pallet on transport to disposal area	2	0.05	8,938	1	3	Steel	0.053"	894
Warehouse storage surveillance	2	8	520	2	3	Steel	0.053"	8,320
Building Management	1	8	260	2	10	Steel	0.053"	2,080
Security	1	2	1,095	2	15	Steel	0.053"	2,190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	2	800	Steel	0.053"	24,960
Security	2	8	1,095	2	800	Steel	0.053"	17,520
DISPOSAL AREA - 20 Trenches								
Transport pallets to trench	1	1	1,277	3	6	Steel	0.053"	1,277
Unload pallet from transport at trench	2	0.2	8,938	1	3	Steel	0.053"	3,575
Transfer pallet to disposal position	2	0.25	8,938	1	6	Steel	0.053"	4,469
Trench fill-in (by level)	6	8	260	4	3	Steel	0.053"	12,480
Trench fill-in (closure)	8	160	1	4	6	Steel	0.053"	1,280
Disposal area surveillance	1	8	520	4	10	Steel	0.053"	4,160
Disposal management	2	8	260	4	20	Steel	0.053"	4,160
Security	1	2	1,095	4	50	Steel	0.053"	2,190

1) Single pallet with four U3O8 drums.
2) Up to 2,235 U3O8 drum pallets in receiving warehouse.
3) Seven pallets of U3O8 drums.
4) Cumulative inventory of a single disposal trench.
5) 35,750 U3O8 drums received per year.
   8,938 U3O8 drum pallets received per year (35,750 U3O8 drums / 4 drums per pallet).
   1,277 tranfers per year (8,938 U3O8 drum pallets per year / 7 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   1 trench per year.
6) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 3)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 4)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead crane	2	52	1	1	10	Steel	0.053"	104
HVAC	2	520	1	1	10	Steel	0.053"	1,040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.053"	1,040
DISPOSAL AREA - 20 Trenches								
Sump pump	1	26	20	2	10	Steel	0.053"	520
Monitoring equipment	1	26	20	2	20	Steel	0.053"	520

1) Up to 2,235 U3O8 drum pallets in receiving warehouse.
2) Cumulative inventory of a single disposal trench.
3) 1 hour per week (52) on active components (cranes) - includes instrumentation.
1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
10 hours per week (520) on HVAC.
4) Materials do not include walls between operating areas.

MINED CAVITY DISPOSAL FACILITY (U3O8 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	8,938	1	3	Steel	0.053"	4,469
Transfer pallet to warehouse storage	2	0.2	8,938	1	6	Steel	0.053"	3,575
Transfer pallet to transport bay	2	0.2	8,938	1	6	Steel	0.053"	3,575
Load pallet on transport to disposal area	2	0.05	8,938	1	3	Steel	0.053"	894
Warehouse storage surveillance	2	8	520	2	3	Steel	0.053"	8,320
Building Management	1	8	260	2	10	Steel	0.053"	2,080
Security	1	2	1,095	2	15	Steel	0.053"	2,190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	2	800	Steel	0.053"	24,960
Security	2	8	1,095	2	800	Steel	0.053"	17,520
SUPPORT FACILITIES								
Ventilation operations	2	8	520	3	60	Steel	0.053"	8,320
Security	2	2	1,095	2	800	Steel	0.053"	4,380
DISPOSAL AREA								
Transport pallets to mine	1	1	1,277	3	6	Steel	0.053"	1,277
Unload pallet from transport	2	0.2	8,938	1	3	Steel	0.053"	3,576
Load pallets onto mine transport	2	0.2	8,938	1	3	Steel	0.053"	3,576
Transport pallets into mine	1	2	1,277	3	6	Steel	0.053"	2,554
Unload pallet to disposal position	2	0.25	8,938	4	6	Steel	0.053"	4,469
Disposal area surveillance	2	8	520	4	10	Steel	0.053"	8,320
Disposal management	2	8	520	4	20	Steel	0.053"	8,320
Security	1	2	1095	4	50	Steel	0.053"	2,190

1) Single pallet with four U3O8 drums.
2) Up to 2,235 U3O8 drum pallets in receiving warehouse.
3) Seven pallets of U3O8 drums.
4) Cumulative inventory of a single mine drift.
5) 35,750 U3O8 drums received per year.
 8,938 U3O8 drum pallets received per year (35,750 U3O8 drums / 4 drums per pallet).
 1,277 tranfers per year (8,938 U3O8 drum pallets per year / 7 pallets per transfer).
 260 workdays per year X 2 shifts per day = 520 shifts per year.
 365 days per year X 3 shifts per day = 1,095 shifts per year.
6) Materials do not include walls between operating areas.

MINE CAVITY DISPOSAL FACILITY (U3O8 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 3)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 4)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead crane	2	52	1	1	10	Steel	0.053"	104
HVAC	2	520	1	1	10	Steel	0.053"	1,040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.053"	1,040
SUPPORT FACILITIES								
HVAC	2	520	1	2	1,600	Steel	0.053"	1,040
DISPOSAL AREA								
Sump pump	2	52	1	2	10	Steel	0.053"	104
Force fan	2	52	1	2	20	Steel	0.053"	104
Exhaust fan	2	52	1	2	20	Steel	0.053"	104
Mine elevator	2	104	1	2	1,000	Steel	0.053"	208

1) Up to 2,235 U3O8 drum pallets in receiving warehouse.
2) Cumulative inventory of a single mine drift.
3) 1 hour per week (52) on active components (cranes, pump, fans) - includes instrumentation.
   2 hours per week (104) on conveyance devices (elevator) - includes instrumentation.
   10 hours per week (520) on HVAC.
4) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 6)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 7)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	5,250	1	3	Steel	0.095"	2,625
Transfer pallet to warehouse storage	2	0.2	5,250	1	6	Steel	0.095"	2,100
Transfer pallet to transport bay	2	0.2	5,250	1	6	Steel	0.095"	2,100
Load pallet on transport to disposal area	2	0.05	5,250	1	3	Steel	0.095"	525
Warehouse storage surveillance	2	8	520	2	3	Steel	0.095"	8,320
Building Management	1	8	260	2	10	Steel	0.095"	2,080
Security	1	2	1,095	2	15	Steel	0.095"	2,190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	2	800	Steel	0.095"	24,960
Security	2	8	1,095	2	800	Steel	0.095"	17,520
DISPOSAL AREA - 23 Vaults								
Transport pallets to vault	1	1	1,313	3	6	Steel	0.095"	1,313
Unload pallet from transport at vault	2	0.2	5,250	1	3	Steel	0.095"	2,100
Transfer drum to disposal position	2	0.25	21,000	4	6	Steel	0.095"	10,500
Vault fill-in with gravel and compact	4	40	35	5	6	Steel	0.095"	5,600
Cement cover vault	12	160	1.15	5	10	Steel	0.095"	2,208
Earth fill on cement cover	8	80	1.15	5	20	Steel	0.095"	736
Disposal area surveillance	1	8	520	5	10	Steel	0.095"	4,160
Disposal management	4	8	520	5	20	Steel	0.095"	16,640
Security	1	2	1,095	5	50	Steel	0.095"	2,190

1) Single pallet with four UO2 drums.
2) Up to 1,313 UO2 drum pallets in receiving warehouse.
3) Four pallets of UO2 drums.
4) Single UO2 drum.
5) Cumulative inventory of a single disposal vault.
6) 21,000 UO2 drums received per year.
   5,250 UO2 drum pallets received per year (21,000 UO2 drums / 4 drums per pallet).
   1,313 tranfers per year (5,250 UO2 drum pallets per year / 4 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   21,000 drums per year / 18,275 drums per vault = 1.15 vaults per year.
   18,275 drums per vault / 5 bays per vault = 3,655 drums per bay.
   3,655 drums per bay / 6 drum levels per bay = 610 drums per level.
   21,000 drums per year / 610 drums per level = 35 levels per year.
7) Materials do not include walls between operating areas.

VAULT DISPOSAL FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 3)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 4)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead crane	2	52	1	1	10	Steel	0.095"	104
HVAC	2	520	1	1	10	Steel	0.095"	1,040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.095"	1,040
DISPOSAL AREA - 23 Vaults								
Sump pump	1	26	23	2	10	Steel	0.095"	598
Vault monitoring equipment	1	26	23	2	20	Steel	0.095"	598

1) Up to 1,313 UO2 drum pallets in receiving warehouse.
2) Cumulative inventory of a single disposal vault.
3) 1 hour per week (52) on active components (cranes) - includes instrumentation.
1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
10 hours per week (520) on HVAC.
4) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	5,250	1	3	Steel	0.095"	2,625
Transfer pallet to warehouse storage	2	0.2	5,250	1	6	Steel	0.095"	2,100
Transfer pallet to transport bay	2	0.2	5,250	1	6	Steel	0.095"	2,100
Load pallet on transport to disposal area	2	0.05	5,250	1	3	Steel	0.095"	525
Warehouse storage surveillance	2	8	520	2	3	Steel	0.095"	8,320
Building Management	1	8	260	2	10	Steel	0.095"	2,080
Security	1	2	1,095	2	15	Steel	0.095"	2,190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	2	800	Steel	0.095"	24,960
Security	2	8	1,095	2	800	Steel	0.095"	17,520
DISPOSAL AREA - 20 Trenches								
Transport pallets to trench	1	1	1,313	3	6	Steel	0.095"	1,313
Unload pallet from transport at trench	2	0.2	5,250	1	3	Steel	0.095"	2,100
Transfer pallet to disposal position	2	0.25	5,250	1	6	Steel	0.095"	2,625
Trench fill-in (by level)	3	8	260	4	3	Steel	0.095"	6,240
Trench fill-in (closure)	8	160	1	4	6	Steel	0.095"	1,280
Disposal area surveillance	1	8	520	4	10	Steel	0.095"	4,160
Disposal management	2	8	260	4	20	Steel	0.095"	4,160
Security	1	2	1,095	4	50	Steel	0.095"	2,190

1) Single pallet with four UO2 drums.
2) Up to 1,313 UO2 drum pallets in receiving warehouse.
3) Four pallets of UO2 drums.
4) Cumulative inventory of a single disposal trench.
5) 21,000 UO2 drums received per year.
   5,250 UO2 drum pallets received per year (21,000 UO2 drums / 4 drums per pallet).
   1,313 tranfers per year (5,250 UO2 drum pallets per year / 4 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
   1 trench per year.
6) Materials do not include walls between operating areas.

ENGINEERED TRENCH DISPOSAL FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 3)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 4)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead crane	2	52	1	1	10	Steel	0.095"	104
HVAC	2	520	1	1	10	Steel	0.095"	1,040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.095"	1,040
DISPOSAL AREA - 20 Trenches								
Sump pump	1	26	20	2	10	Steel	0.095"	520
Monitoring equipment	1	26	20	2	20	Steel	0.095"	520

1) Up to 1,313 UO2 drum pallets in receiving warehouse.
2) Cumulative inventory of a single disposal trench.
3) 1 hour per week (52) on active components (cranes) - includes instrumentation.
   1/2 hour per week (26) on passive components (monitoring equipment, sump pump) - includes instrumentation.
   10 hours per week (520) on HVAC.
4) Materials do not include walls between operating areas.

MINED CAVITY DISPOSAL FACILITY (UO2 DRUMS): OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER STATION	TIME PER OPERATION (HR)	OPERATIONS PER YEAR (NOTE 5)	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 6)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Unload/inspect arriving pallet	2	0.25	5,250	1	3	Steel	0.095"	2,625
Transfer pallet to warehouse storage	2	0.2	5,250	1	6	Steel	0.095"	2,100
Transfer pallet to transport bay	2	0.2	5,250	1	6	Steel	0.095"	2,100
Load pallet on transport to disposal area	2	0.05	5,250	1	3	Steel	0.095"	525
Warehouse storage surveillance	2	8	520	2	3	Steel	0.095"	8,320
Building Management	1	8	260	2	10	Steel	0.095"	2,080
Security	1	2	1,095	2	15	Steel	0.095"	2,190
ADMINISTRATION BUILDING								
Building Operations	12	8	260	2	800	Steel	0.095"	24,960
Security	2	8	1,095	2	800	Steel	0.095"	17,520
SUPPORT FACILITIES								
Ventilation operations	2	8	520	3	60	Steel	0.095"	8,320
Security	2	2	1,095	2	800	Steel	0.095"	4,380
DISPOSAL AREA								
Transport pallets to mine	1	1	1,313	3	6	Steel	0.095"	1,313
Unload pallet from transport	2	0.2	5,250	1	3	Steel	0.095"	2,100
Load pallets onto mine transport	2	0.2	5,250	1	3	Steel	0.095"	2,100
Transport pallets into mine	1	2	1,313	3	6	Steel	0.095"	2,626
Unload pallet to disposal position	2	0.25	5,250	4	6	Steel	0.095"	2,625
Disposal area surveillance	2	8	520	4	10	Steel	0.095"	8,320
Disposal management	2	8	520	4	20	Steel	0.095"	8,320
Security	1	2	1,095	4	50	Steel	0.095"	2,190

1) Single pallet with four UO2 drums.
2) Up to 1,313 UO2 drum pallets in receiving warehouse.
3) Four pallets of UO2 drums.
4) Cumulative inventory of a single mine drift.
5) 21,000 UO2 drums received per year.
   5,250 UO2 drum pallets received per year (21,000 UO2 drums / 4 drums per pallet).
   1,313 tranfers per year (5,250 UO2 drum pallets per year / 4 pallets per transfer).
   260 workdays per year X 2 shifts per day = 520 shifts per year.
   365 days per year X 3 shifts per day = 1,095 shifts per year.
6) Materials do not include walls between operating areas.

MINE CAVITY DISPOSAL FACILITY (UO2 DRUMS): MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS PER STATION	HOURS PER COMPONENT PER YEAR (NOTE 3)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (FT)	MATERIAL (NOTE 4)	THICKNESS	PERSON HOURS PER YEAR
PRODUCT RECEIVING WAREHOUSE								
Overhead crane	2	52	1	1	10	Steel	0.095"	104
HVAC	2	520	1	1	10	Steel	0.095"	1,040
ADMINISTRATION BUILDING								
HVAC	2	520	1	1	160	Steel	0.095"	1,040
SUPPORT FACILITIES								
HVAC	2	520	1	2	1600	Steel	0.095"	1,040
DISPOSAL AREA								
Sump pump	2	52	1	2	10	Steel	0.095"	104
Force fan	2	52	1	2	20	Steel	0.095"	104
Exhaust fan	2	52	1	2	20	Steel	0.095"	104
Mine elevator	2	104	1	2	1000	Steel	0.095"	208

1) Up to 1,313 UO2 drum pallets in receiving warehouse.
2) Cumulative inventory of a single mine drift.
3) 1 hour per week (52) on active components (cranes, pump, fans) - includes instrumentation.
   2 hours per week (104) on conveyance devices (elevator) - includes instrumentation.
   10 hours per week (520) on HVAC.
4) Materials do not include walls between operating areas.

APPENDIX E

Nevada Test Site Waste Acceptance Criteria

5.5 Waste Acceptance Criteria Statements

Address each of the following waste acceptance criteria (WAC). Provide a brief statement of the NVO-325 criteria objective. State the regulatory or other reference(s) as provided in the WAC and provide a brief discussion of how each waste stream will comply with the individual criteria. In addition, where compliance is procedurally controlled, reference the applicable procedure(s). For example:

1) **Closure:** The package closure shall be sturdy enough that it will not be breached under normal handling conditions and will not serve as a weak point for package failure (per NVO-325, 5.5.1.3.A).

   Compliance Method: Waste containers shall be closed with metal clips and banding, per procedure XXXX, to prevent breaching under normal handling conditions.

2) **Free Liquids:** LLW disposed at the NTS waste management sites shall contain as little free liquids as is reasonably achievable, but in no case shall the liquid equal or exceed 0.5 percent by volume of the external waste container (per NVO-325, 5.5.1.1.C).

   Compliance Method: This criteria is evaluated by process knowledge, waste segregation, visual verification, and evaluation of the waste stream (e.g., contaminated soil) utilizing the Paint Filter Test, per procedure XXXX, XXXX, and XXXX. Absorbent will be added, per procedure XXXX, as a precautionary measure to absorb any moisture that may form due to condensation attributed to the variations in temperature and humidity from state-of-generation to NTS. Packages will also be reviewed by Real-Time Radiography (RTR) prior to package certification. Any packages suspected of having greater that 0.5 percent free liquids will be segregated and marked to prevent inadvertent shipment to NTS.

5.5.1 Low-level Waste Acceptance Criteria

Defense waste accepted at NTS must be radioactive and meet the waste form criteria outlined below. These requirements are minimum requirements for all

- If absorbent materials are added to a waste for control of free liquids, the generator must calculate the volume of liquid in the waste and use a quantity of sorbent material sufficient to absorb a minimum of twice the calculated volume of the liquid. Please note when significant differences of temperature exist between the generating site and the disposing site, provisions for additional absorbent materials must be made for affected waste forms.
- To demonstrate compliance with the free liquids requirement, the generator may be required to use Method 9095 (Paint Filter Test) as described in "Test Methods For Evaluating Solid Wastes, Physical/Chemical Methods." (EPA Publication No. SW-846) The Paint Filter Test may not be applicable to certain waste forms; e.g., concrete. If the generator determines that the waste form is not conducive to the Paint Filter Test, documentation must be provided to substantiate the claim.

D. Particulates: Fine particulate wastes shall be immobilized so that the waste package contains no more than 1 weight percent of less-than-10-micrometer-diameter particles, or 15 weight percent of less-than-200-micrometer-diameter particles. Waste that is known to be in a particulate form or in a form that could mechanically or chemically be transformed to a particulate during handling and interim storage shall be immobilized.

When immobilization is impractical, other acceptable waste packaging shall be used, such as the following:

- Overpacking (i.e., 55-gallon drum inside 83- or 85-gallon drum);
- steel box with no liner;
- wooden box with a minimum of 6-mil sealed plastic liner;
- steel drum with a minimum of 6-mil sealed plastic liner.

E. Gases: LLW gases shall be stabilized or absorbed so that pressure in the waste package does not exceed 1.5 atmospheres at 20° C.

J. **Explosives and Pyrophorics:** LLW containing explosive and/or pyrophoric material in a form that may spontaneously explode or combust, if the container is breached, will not be accepted.

5.5.1.2 General Regulatory Waste Package Criteria

The NTS waste package criteria include regulatory criteria to meet applicable DOE, EPA, and DOT requirements and criteria established to meet site-specific requirements at NTS waste management sites. Defense waste shipped to NTS waste management sites for disposal or storage must be packaged in accordance with all DOE and DOT regulations. These include the requirements of DOE Order 1540.1, "Materials Transportation and Traffic Management"; Titles 49, CFR 173.448, "General Transportation Requirements"; 49 CFR 173.474, "Quality Control for Construction of Packaging," and 49 CFR 173.475, "Quality Control Requirements Prior to Each Shipment of Radioactive Materials."

A. **Design:** Type A packaging shall be designed to meet Title 49 CFR 173.411, "General Design Requirements," and Title 49 CFR 173.412, "Additional Design Requirements for Type A Packages." Type A packages must have been evaluated under the DOE Type A package Certification Program (see MLM-3245, "DOT 7A Type A Certification Document" or succeeding DOE publication). Type B packaging must meet the applicable requirements of Title 10 CFR 71. Strong, tight packaging used for shipping limited quantities and low specific activity LLW excepted by Titles 49 CFR 173.421 and 173.425, respectively, must be constructed so that it will not leak during normal transportation and handling conditions.

B. **Nuclear Safety:** The quantity of fissile radioactive materials shall be limited so that an infinite array of such packages will remain subcritical. This quantity shall be determined on the basis of a specific nuclear safety analysis, considering credible accident situations, and taking into account the actual materials in the waste. See Title 49 CFR 173.451, "Fissile Materials - General Requirements."

essential to reducing the number of waste shipments to the NTS and the space required for disposal. DOE/NV has adopted the following criteria to assure that the NTS RWMSs are operated safely and efficiently. The criteria shall be incorporated in the design of all waste packaging, including strong, tight containers.

A. **Closure:** The package closure shall be sturdy enough that it will not be breached under normal handling conditions and will not serve as a weak point for package failure.

B. **Strength:** Except for bulk waste, waste packaged in steel drums or SEALAND® containers, the waste package (packaging and contents) shall be capable of supporting a uniformly distributed load of 19,528 kg/m2 (4,000 lbs/ft2). This is required to support other waste packages and earth cover without crushing during stacking and covering operations.

C. **Handling:** All waste packages shall be provided with permanently attached skids, cleats, offsets, rings, handles, or other auxiliary lifting devices to allow handling by means of forklifts, cranes, or similar handling equipment. Lifting rings and other auxiliary lifting devices on the package are permissible, provided they are recessed, offset, or hinged in a manner that does not inhibit stacking the packages. The lifting devices must be designed to a 5:1 safety factor based on the ultimate strength of the material. All rigging devices that are not permanently attached to the waste package must have a current load test based on 125 percent of the safe working load.

D. **Size:** 1.2- x 1.2- x 2.1-m (4- x 4- x 7-ft) or 1.2- x 0.6- x 2.1-m (4- x 2- x 7-ft) (width, height, length) boxes or 208-liter (55-gallon) drums are required to be used. Bulk waste container approval is discussed in Section 5.5.4. While these sizes allow optimum stacking efficiency in disposal cells, other dimensions are acceptable with approval from DOE/NV on a case-by-case basis.

I. **Marking and Labeling:** Each waste package shall have the following information:

1. Marking and labeling as required in Title 49 CFR 172, subparts D and E.
2. Signed NV-211 "Packaging Certification" label (revision date January 27, 1989) (see Figure 8, page 76). If the waste is unpackaged bulk, a signed NV-211 label must accompany the shipment papers. These labels can be obtained from REECo/ WMD.
3. Shipment number in the following sequence: Two alpha character generator-site-designator codes assigned by WMD (see Appendix D); one alpha character for type of waste L for LLW, M for MW, T for TRU, or X for TRUMW; two numerical characters for current fiscal year; three numerical characters for shipment sequence. Example: MDL90001 would mean a shipment from EG&G Mound of LLW in fiscal year 1990 and the first shipment.
4. Package number shall be six characters (alpha, numeric, or combination) with no duplication within that shipment.
5. Approved 13-digit waste stream identification number (see Section 5.1).
6. Package weight in units of pounds and kilograms.

Note: Except for the required DOT labels and NV-211, these items must be clearly and legibly placed on the container using alphanumeric characters of at least one-half inch in height. The information that is included on the barcode label (see next section) does not need to be duplicated.

J. **Barcoding:** The shipment, package, and waste stream identification numbers shall be barcoded according to the following standards:

1. Code 39.
2. Medium to high density, high density preferred.

Figure 6A Barcode Label

A5L92Ø01

ØØØØØ1

LRY1ØØØØØØØØ1

MINIMUM REQUIREMENTS FOR HIGH DENSITY BARCODE LABEL

APPENDIX F

Hanford Waste Acceptance Criteria

3.0 LOW-LEVEL WASTE ACCEPTANCE CRITERIA

3.1 PROHIBITED WASTE

3.1.1 Regulatory Requirements

1. Waste will not be accepted for disposal when it contains free liquid in excess of one percent of the volume of the waste, or 0.5 percent of the volume of waste processed to a stable form (DOE Order 5820.2A III 3.i.(5)(b)).

2. Waste capable of detonation or of explosive decomposition or reaction at normal pressures and temperature, or of explosive reaction with water will not be accepted for disposal (DOE Order 5820.2A III 3.i.(5)(c)).

3. Waste capable of generating toxic gases, vapors, or fumes harmful to persons handling the waste will not be accepted for disposal (DOE Order 5820.2A III 3.i.(5)(d)).

4. Gaseous waste will not be accepted for disposal if it is packaged at a pressure in excess of 1.5 atmospheres (DOE Order 5820.2A III 3.i.(5)(e)).

5. Pyrophoric waste will not be accepted for disposal (DOE Order 5820.2A III 3.i.(5)(f)).

6. Waste exceeding the Class C limit as defined in 10 CFR 61.55 will not be accepted for disposal except as a special case justified by a specific performance assessment and with concurrence of DP-12 or NE-20, as applicable (DOE Order 5820.2A III 3.i.(4)).

3.1.2 Hanford Site Practices

1. Etiologic agents will not be accepted for disposal.

2. Gas cylinders or other pressure vessels will not be accepted that will exceed 1.5. atmospheres internal pressure during the life of the package (refer to Section 3.7.3.2 for package venting requirements).

3. Nonregulated free organic liquids will not be accepted for disposal. These materials will be accepted for storage and eventual treatment (refer to Section 3.9.2.2).

4. Packages containing more than one percent chelating compounds will not be accepted for disposal unless they have been solidified or stabilized (refer to Section 3.9.2; also see DOE Order 5820.2A III 3.e.(5)(g)).

5. Unidentified, uncharacterized, or poorly characterized waste will not be accepted.

3. Generator LLW certification programs shall be subject to a periodic audit by operators of facilities to which the waste is sent (DOE Order 5820.2A III 3.e.(4)).

4. It is the responsibility of WHC waste generators to review and concur with any Engineering and Construction Contractor (ECC) requirements specified by the radiological waste certification plan for the facility where solid wastes are generated. The waste stream certification documentation developed for a specific ECC job will cover interface duties and responsibilities between the ECC and the host facility (RLID 5820.2A 6.0 h.).

5. Each generator facility waste stream shall have passed formal compliance assessments of their facility LLW certification plan(s) prior to shipment to the WPD facilities. An assessment shall be performed within one calendar year of shipping a waste. Exceptions to this requirement will require written approval from RL/WMD (RLID 5820.2A III 3.f.(3)).

6. RL shall be notified at least 14 days prior to the assessment of each generator (RLID 5820.2A III 3.f.(6)).

7. Shipment of solid LLW to the Hanford Site solid LLW facilities shall not be made until the following have occurred: the generator prepares and approves a LLW certification plan; the generator transmits a copy of the plan to the WHC; and the generator waste streams have been assessed by the WHC to be in compliance with the established Hanford Site Solid Waste Acceptance Criteria (RLID 5820.2A III 3.h.(1)).

3.2.2 Hanford Site Practices

1. Waste generators are assigned an approval status based on the results of a periodic assessment explained below. Waste generators with APPROVED status may ship any radioactive waste stream subject to the requirements of this manual. Waste Generators with LIMITED approval status may only ship those waste streams for which approval has been granted. Those generators whose status is RESTRICTED must comply with all requirements and restrictions specified in the Assessment Report to ship waste; these will generally require package/shipment-specific surveillances. All shipments must be made in accordance with an approved SDAR. Proper funding shall be in place prior to shipment. Costs associated with TSD facilities efforts to support shipments made from a generator in RESTRICTED status shall be borne by the generator. Waste Generators with a NOT APPROVED status will not be allowed to ship waste.

2. The Hanford Site can only accept waste as authorized by RL. In those instances where a generator produces both government and commercial waste, the generator shall develop and implement procedures to ensure that the government and commercial waste are segregated.

d) NOT APPROVED. The generator was unable to demonstrate through their procedures and waste management documentation that their waste management program will ensure that the generator's waste will conform to the Hanford Site waste acceptance criteria. The generator is not allowed to ship waste.

3. The Waste Certification Assessment Program performs two kinds of assessments. Program and Waste Stream/Package Specific.

a) PROGRAM ASSESSMENT. This type of assessment is performed at the generator's site, to verify that the generator has a LLW certification program that will ensure that the generator's waste will meet the Hanford Site waste acceptance criteria. A program assessment is funded by the Hanford Site and scheduled with the generator's concurrence. Assessments are conducted annually, or as determined necessary by waste shipment frequency. The program assessment establishes approval status.

To gain APPROVED status, the generator must have written procedures that address the basic elements of a LLW certification program. Additionally, the generator must submit, for TSD facility review, documentation that provides objective evidence that the generator has implemented the procedures. The required elements of a satisfactory LLW certification program are as follows.

1) Waste characterization. The generator must address waste characterization in the waste management procedures. Waste Characterization shall be detailed for each waste stream shipped by the generator. As a minimum, the generator shall identify characterization methodology and sampling protocols; and calibration, documentation and recordkeeping requirements. Where process knowledge is used it shall be documented. The documentation shall describe the process and the logic that supports the characterization conclusions (refer to Section 3.4).

2) Waste Designation. The generator's procedures must require that waste destined for the Hanford Site be designated by an individual who is knowledgeable of the current Washington State Dangerous Waste Regulations, Chapter 173-303 WAC, designation requirements.

3) Waste Traceability. The generator's procedures must provide a system for controlling and recording the contents of waste packages destined for the Hanford Site. Typical systems consist of either locking packages and/or controlled access storage areas, coupled with an inventory sheet for each package.

4) Waste Segregation. The generator's procedures must

status are funded by the generator and scheduled by the TSD facility. The assessment will be scheduled according to the availability of resources. Funding must be in place before work is initiated.

The Waste Certification Assessment Program also performs random waste stream/package-specific assessments of APPROVED and APPROVED (LIMITED) generators to verify continued compliance with the Hanford Site waste acceptance criteria. Random waste stream/package-specific assessments can be initiated at the request of any TSD facility representative or regulator. In instances where the TSD receives a waste that is not properly characterized and/or designated, or not packaged, labeled and/or marked in accordance with the applicable SDAR, the TSD can promptly schedule and perform a waste stream/package-specific assessment of the shipping generator. These assessments can impact the generator's approval status.

To define the scope and content of the certification program, generators shall develop a LLW certification plan. The Waste Certification Assessment Program office has diverse examples of how generators have structured waste management programs and have defined them in certification plans, and is prepared to provide recommendations and reviews as requested by the generator. The format, content and approval of the certification plan will be the responsibility of the generator.

4. Assessment Logistics.

a) Assessment Announcements. The TSD facility shall formally announce all assessments sufficiently in advance to permit the generator to arrange for proper security and safety measures, and to ensure the health and safety of the assessment team during the visit to the generator's site. The assessment announcement shall include, a copy of the checklist that the TSD facility proposes to use during the assessment.

b) Assessment Reports. After the assessment is complete the TSD shall prepare an assessment report documenting the generator's approval status and any observations and/or findings identified during the assessment. A copy of the report shall be provided to the generator.

c) Assessment Team. The size and membership of a team shall reflect the complexity of the generator waste management program. At a minimum the team shall consist of one TSD representative. The TSD shall ensure that the assessment team has the experience and training required to perform a comprehensive assessment of the generator's waste management program.

3.3.3 Background

1. DOE Order 5820.2A requires that the TSD facility maintain secure auditable files that document the amount, type, and location of accountable nuclear material.

2. To comply with ALARA requirements, each package's surface dose rate must be supplied by the generator and kept on file by both the TSD facility and the generating facility. The surface dose rate documentation allows for the safe and effective handling and storage of radioactive waste.

3. The waste classification system is used to forecast waste volumes and will be used in designing LLW disposal facilities that meet the requirements of DOE Order 5820.2A. The radionuclide category also allows proper disposal of the waste material in accordance with the performance assessment. Therefore, LLW waste categorization is required to provide for the storage, treatment, or disposal of LLW.

4. To enable safe and effective handling of LLW, all documentation needs to be clearly labeled, and all documentation needs to be either typed or printed clearly with black ink.

5. The shipper of the waste is tracked by the solid waste data base as the generator of the waste. The shipper of the waste will be the organization contacted in case additional information is required by the TSD facility for treating, storing or disposing of the waste. Because of this, the shipper needs to maintain all of the records associated with the waste stream.

3.4 WASTE CHARACTERIZATION

3.4.1 Physical Characterization Requirements

3.4.1.1 Regulatory Requirements

1. Waste Characterization shall ensure that the physical characteristics of the waste are known and recorded during all stages of the waste management process (DOE Order 5820.2A III 3.d.(1)).

2. Physical characteristics of the waste shall be recorded on a waste record (DOE Order 5820.2A III 3.d.(2)(a)).

3.4.1.2 Hanford Site Practices

1. An inventory sheet shall be maintained for each waste package as the package is filled. This inventory shall include a physical description of the waste material that is added to the package.

the process knowledge, analyses, calculations and scaling factors used to determine the radionuclide content of each waste stream. The document shall be included as part of the generator's waste certification plan and will be reviewed as part of the generator's Waste Certification Assessment (refer to Section 3.2). Appendix K provides a sample radionuclide analysis plan for low enrichment uranium fuel processing. Generators of this and other types of waste should use Appendix K as a guide in developing a radionuclide characterization document tailored to their specific waste streams.

2. Once the radionuclide composition of a waste stream is accurately known, the limits of Table 3-1 shall be used in a sum of the fractions calculation to determine the disposal category. Refer to Appendix K for instructions and work sheets for determining the disposal category. See Appendix C Table C-7 for gram to curie conversion factors. If the above sum of the fractions calculation indicates that the waste is slightly above the Category 1 limit, the approach in Appendix P may be used to determine the disposal category. Indicate on the WSDR that Appendix P was used to calculate the disposal category if applicable.

3. The disposal category and the reportable radionuclides on the SWSDR must be reported as indicated below.

   a) Report all radionuclides not on table 3-1 if process knowledge or analysis indicates they exist at greater than one percent of the total curie amount in the waste.

   b) Report only those radionuclides from Table 3-1 that process knowledge indicates are present in the waste if they exist at greater than 1/100 of the Table 3-1 Category 1 limit. Activities less than minimum detectable analysis limits but greater then the above limit should be reported based on scaling factors or process knowledge.

   c) Daughter products in secular equilibrium with the parent radionuclide should not be reported. Report only the curie value of the parent radionuclide. This will make reporting consistent with NRC and DOT practices.

   d) Cases may occur where no radionuclides are detected but the waste material cannot be released for nonradioactive disposal (e.g., an item with inaccessible areas which cannot be surveyed). In such cases, report only Table 3-1 radionuclides and only those that would most likely be present based on process knowledge. Use the detection limit of the survey instrument involved and process knowledge to determine the reportable curie values. Indicate on the manifest article description that this is a "suspect waste."

Table 3-1. Category 1 and 3 Activity Limits for Disposal (Continued)

Nuclide	Activity Limits (Ci/m³)	
	Category 1	Category 3
^{237}Np*	1.9 E-04	4.0 E-02
^{238}Pu*	9.1 E-03	4.5 E+01
^{239}Pu*	3.6 E-03	7.7 E-01
^{240}Pu*	3.6 E-03	7.7 E-01
^{241}Pu	7.7 E-02	3.1 E+01
^{242}Pu*	3.8 E-03	8.3 E-01
^{244}Pu*	8.3 E-04	1.7 E-01
^{241}Am*	2.6 E-03	1.1 E+00
^{242m}Am*	2.6 E-03	2.4 E+00
^{243}Am*	1.3 E-03	2.8 E-01
^{243}Cm*	2.5 E-02	6.3 E+02
^{244}Cm*	2.3 E-01	2.9 E+02
^{245}Cm*	2.1 E-03	3.3 E-01
^{246}Cm*	3.3 E-03	7.7 E-01
^{247}Cm*	7.1 E-04	1.5 E-01
^{248}Cm*	9.1 E-04	2.0 E-01

° Limit for isotope in activated metal.
* Category 3 limit is the lower of this value and 100 nCi/g.
** A blank indicates that no upper limit exists for this isotope

g) Transportation category (e.g., Low Specific Activity [LSA], Limited Quantity, Type A in accordance with 49 CFR 173).

3.4.3.3 Background

1. To ensure that waste can be managed safely and effectively, the TSD facility must receive accurate information on the waste. In addition, without complete and accurate information, the waste may have to be resampled or integrated by the TSD facility (at the generators expense) to determine the composition of the waste.

3.5 CATEGORY 3 STABILIZATION

3.5.1 Regulatory Requirements

None

3.5.2 Hanford Site Practices

1. All Category 3 Waste shall be stabilized. Waste may be stabilized by enclosing it in a high-integrity container (HIC), by processing into a stable waste form, or may be shown by analysis to be inherently stable.

2. Category 3 LLW may be completely enclosed in a HIC to meet stability requirements. Approved HICs certified by the NRC or WHC shall be used to stabilize Category 3 LLW.

   Generators may elect to have conventionally packaged waste overpacked for burial in a large volume HIC purchased by WHC. A percentage of volume HIC fee will be charged for use of WHC-purchased HICs. Generators may also choose to have packages of their own design tested to the requirements of WHC specification HS-V-P-0036 for WHC certification as a HIC.

3. Category 3 LLW may be solidified using an NRC or WHC-approved process to meet stability criteria. The final processed waste form must satisfy the performance testing criteria of the NRC Technical Position on Waste Form Section C.2 and Appendix A.

4. Waste forms that are by design inherently stable, such as activated metal or thick pressure vessels, may provide stability equivalent to HICs or solidified waste forms. Each item shall be evaluated on a case-by-case basis. The stability guidance of 10 CFR Part 61 shall apply when evaluating the adequacy of inherently stable waste forms.

3.5.3 Background

1. In accordance with DOE Order 5820.2A each DOE LLW disposal facility has initiated a site-specific radiological performance assessment (PA) to evaluate the adequacy of current disposal

To support these goals, a general HIC specification, HS-V-P-0036, was developed for use onsite. Although based on the NRC Technical Position on Waste Form, HS-V-P-0036 has been tailored to Hanford Disposal needs by WHC and includes some modifications of NRC requirements.

- HS-V-P-0036 does not require testing to DOT Type A criteria. The WHC HIC is intended to be used as a load-in-place burial package as opposed to a transport package, so DOT type A testing was judged to be unnecessary.
- The WHC HIC does not require the lid closure to allow inspection of the contents. The WHC HIC is intended to be filled, sealed, grouted, and buried, making inspection of the contents unnecessary.
- The WHC HIC does not allow for passive vents to relieve pressure buildup. Once the waste is grouted, vents would be of little value. Consequently, the WHC HIC is not designed or intended to accept wastes with appreciable gas generation. This is in accordance with the Burial Ground SAR requirements and the 1.5 psig limit of section 3.1.1.4, so it was not considered restrictive.
- The WHC HIC does not require prototype testing to demonstrate the package's ability to withstand design loads. The intent of this requirement can be met by data and analysis.

3. Solidification entails thorough mixing of the waste with a solidification medium such as Portland cement or various polymers with the end product intended for burial without a package. The NRC criteria for solidified waste forms were considered acceptable for disposal at Hanford as written. The requirements of this section do not apply to containerized waste. For example, a waste package encased in cement does not meet waste solidification requirements; however, the concrete capsule may meet HIC requirements.

4. Placing a stable waste such as activated metal or a thick pressure vessel into another package for burial was considered overly conservative and unnecessarily expensive in some cases. Because of this, the option of demonstrating by analysis that a waste form will maintain structural stability and general identity for 300 years was added as a stability option. Because of the wide variety of waste that could fall under this category, the waste must be evaluated on a case-by-case basis.

3.6 GREATER THAN CATEGORY 3 STORAGE

3.6.1 Regulatory Requirements

1. Disposition of waste designated as Greater-Than-Class C, as defined in 10 CFR 61.55, must be handled as special cases.

3. Fifty-five-gallon drums should, if practical, be banded and palletized in groups of four by the generator.

   Palletizing is not required if it interferes with economical loading of the transport vehicle.

4. Packages used for stored LLW (e.g. nonhazardous organics) shall meet the same requirements as packages used for MW (refer to Chapter 4 for criteria).

5. The LLW shall provide at least two containment barriers to prevent the release of contamination. The following packages may be exempted (as specified in the applicable SDAR) from the double-containment requirement, but shall provide at least one containment barrier.

   a) Packages that have been demonstrated by engineering analysis or testing to meet the appropriate DOT requirements in 49 CFR 173, Subpart I

   b) Self-contained and other waste packages containing DOT LSA or limited quantities of radioactive materials that only require strong, tight packages

   c) Heavy-walled, high-pressure equipment that meets all of the following requirements.

      - A life expectancy in excess of 300 years, when buried at the Hanford Site.

      - External wall thickness of 2.54 cm (1 in.) or more carbon or stainless steel with openings welded or otherwise securely closed using 2.54 cm (1 in.) thick or heavier covers, or an approved equivalent.

   Examples of items meeting these criteria include steam generators, high-pressure preheaters, high-pressure circulating pumps (canned-rotor type), high-pressure tanks, reactor vessels, and large-diameter piping.

6. Plastic bags or sheeting used for primary containment shall be 10-mil nylon reinforced plastic or as approved in the SDAR.

7. Packages used for LLW storage shall be designed to withstand the weight of two layers of 55-gal drums stacked on top with 454 kg (1,000 lb) in each drum. Packages used for LLW disposal must be able to withstand the weight of three layers of 55-gal drums each with the same weight as above.

8. All packages used for disposal of LLW, with the exception of plastic wrap, shall be constructed of metal or shall be fire retardant. All exterior surfaces of wooden packages shall be treated for fire retardation with a fire-retardant material having a maximum flame-spread index of 25 when tested to American

able to hold this load to allow efficient use of the CWC storage area.

8. The use of metal or fire retardant materials meets the combustible requirements for radioactive waste packages.

9. The use of drag-off boxes presents unacceptable risks that are not associated with other types of waste packages. For this reason only liftable waste packages will be accepted. Bulk disposal involves placement of bulk, noncontainerized LLW into the burial ground. At one time, small equipment, piping, and other nonhomogeneous materials were disposed in this fashion. In the past, this practice has resulted in contamination spread and other problems for the burial ground operations personnel. As a result, bulk disposal is limited to soil, vegetation, building rubble, and other relatively homogeneous waste materials.

3.7.2 Rigging Requirements

3.7.2.1 Regulatory Requirements

1. Lead shall not be used in fabricating the rigging (Chapter 173-303 WAC).

3.7.2.2 Hanford Site Practices

1. Packages used for LLW that are designed to be unloaded by crane shall be equipped with lifting devices designed to safely lift the fully loaded package.

2. Below the hook lifting devises shall meet the requirements of ANSI/ASME B30.20 (ANSI/ASME, 1985). Slings and rigging shall meet the requirements of ASME B30.9 (ASME, 1990) and Occupational Safety and Health Administration (OSHA) 1910.184 (OSHA 1992).

3. Rigging details shall be included in generator WSDR, and provided to WHC by the generator at least 2 weeks before each shipment if special rigging or lifting is required. An additional copy shall be sent with the shipment. Details shall include a sketch showing overall dimensions, lift points, weights at each lift point, and centers of gravity of the object. If available, sketches of strong backs or lift rigs used for loading shall be furnished where applicable.

4. Remote handled (RH) radioactive packages shall include sacrificial rigging provided by the shipper. The rigging shall be packaged in such a manner that it may be attached to handling equipment without exposing field personnel to excessive radioactivity.

5. The inner packages of waste packages inside returnable overpacks shall be suitably rigged such that personnel shall not be exposed to a radioactive field in excess of 100 mrem/hr while removing

3.7.3.2 Hanford Site Practices

1. The internal void space of any LLW package disposed at Hanford Site TSD facilities shall not exceed 10 percent of the total internal volume of the waste package. For the purpose of this requirement, the internal void space shall include any opening within the waste matrix that exceeds 5 cm (2 in.) in all dimensions. Spaces smaller than 5 cm (2 in.) such as small horizontal planar spaces (e.g., the space between a waste package and its overpack) do not need to be included in the void calculation. Spaces larger than 5 cm (2 in.) must be eliminated either by vacuum compression, compaction of the waste, or by filling with an approved void space filler (refer to Appendix G).

The following waste packages may be exempted from this requirement in the applicable SDAR.

a) Waste packages that will be crushed or filled during the scheduled burial procedure

b) LLW packages that are intended for storage and later treatment

c) High-efficiency particulate air (HEPA) filters, not covered by any other exemption, that pose hazards to personnel during filling and crushing operations

d) Waste packages for which the waste generator provides evidence that personnel exposure and potential contamination spread during the void space filling process is a greater threat than subsidence

e) Heavy-walled (high-pressure) vessels meeting one or more of the following criteria.

- Nominal wall thickness of 2.54 cm (1 in.) or more stainless or carbon steel
- For purposes of this exception, all penetrations in heavy-wall vessels shall be sealed with welded or otherwise secured plates at least 2.54 cm (1 in.) thick (including weld section), or no less than the nominal vessel wall, whichever is less. Examples of items that meet these criteria include high-pressure steam generators, high-pressure feed water heaters, reactor vessels, pumps, and heavy-walled pipe
- The vessel contains a high proportion of internals, such as tube bundles, that make satisfactory void-filling impractical.

f) Packages for which the generator has supplied an engineering analysis, which demonstrates that the intent of this section will not be compromised. The final determination shall be or to reach explosive concentrations of hydrogen and oxygen or other explosive gases shall be vented. Vents shall be sized to ensure adequate passage of generated gas. Catalyst packs to deplete free oxygen in LLW packages and prevent flammable concentrations of hydrogen and oxygen may be required in addition to, or in lieu of, vents. If required, the use of catalysts and/or vents will be specified in the applicable SDAR. If used, the catalyst packs will be palladium on alumina or platinum on silica, depending on the potential amount of moisture present in the waste package. The amount of catalyst required will be based on the amount of potential hydrogen generation and will be specified in the applicable SDAR. Liners other than plastic bags shall be provided with positive gas communication to the outer package.

6. Criticality safety limits for waste packages that contain more than 15 g of ^{235}U will be determined by WHC Criticality Engineering Analysis on a case-by-case basis. These limits will be indicated in the SDAR. Waste packages containing 15 g of ^{235}U or less will not require a separate criticality safety analysis.

3.7.3.3 Background

1. Significant void space within waste packages that are buried in the ground eventually results in subsidence of the surface of the burial ground. This subsidence may result in contamination spread and damage to the final cover and may impose a significant safety hazard to personnel working within the burial ground. The 10 percent void space limit is based on a similar requirement for dangerous waste landfills in 40 CFR 264.315.

   All void space will not result in subsidence. For example, Hanford Site soils are approximately 30 percent void space. The voids in soil, however, are small relative to the soil particle size. The 2-in. diameter limit on void space was chosen to provide a convenient, easy to measure lower limit on void space. Any opening smaller than that is not considered to be significant.

   There are a number of waste types that would pose an extreme hazard to personnel attempting to fill the void space. This hazard is actually greater than the hazard posed by subsidence. This type of material is exempt from the void space requirement. In addition there are waste types that by their nature will not collapse in the foreseeable future. These types of waste are also exempt from the void space requirement.

2. The radiation dose from waste packages is limited to reduce exposure to personnel handling the waste packages. The upper limit for CH waste is 200 mrem/hour at contact or any accessible surface. This number is taken from the DOT limit for exclusive use only shipments (49 CFR 173.441 (b)). Small spots with dose rates up to 1,000 mrem/hour at contact are allowable if appropriate notification and precautions are taken.

3. A fissile material label shall be used to identify waste containers holding one or more grams of fissile material. This requirement applies to Hanford site waste only and does not apply to ^{235}U in natural or depleted uranium.

3.8.3 Background

1. See Chapter 4.

2. The positioning of the "Radioactive Waste" marking makes the marking visible from any direction. The wording is dictated by the Hanford Site Radiological Control Manual.

3. The fissile material labeling requirement comes from the Nuclear Criticality Safety Manual WHC-CM-4-29. Off site waste generators must comply with Department of Transportation labeling requirements.

3.9 SPECIFIC WASTE REQUIREMENTS

3.9.1 Regulatory Requirements

1. Liquid wastes or wastes containing free liquids must be converted into a form that contains as little freestanding and noncorrosive liquid as is reasonably achievable (DOE Order 5820.2A III 3.i.(5)(b)). Also refer to Section 3.1 of this document.

2. Free liquid shall be less than 1 percent of the volume of the waste when the waste is in a disposal package, or 0.5 percent of the volume of waste processed to a stable form (DOE Order 5820.2A III 3.i.(5)(b)).

3. Pyrophoric materials contained in waste shall be treated, prepared, and packaged to be nonflammable (DOE Order 5820.2A III 3.i.(5)(f)).

3.9.2 Hanford Site Practices

1. All liquids disposed of as LLW shall be solidified, absorbed, or otherwise bound in the waste matrix by inert materials. Small amounts of residual liquid are allowed in accordance with Section 3.9.1.

   If liquids are bound by absorption, the absorbent material shall be placed in direct contact with the liquid. The quantity of absorbent material shall be sufficient to absorb twice the volume of liquid potentially present or as specified in the SDAR applicable to that waste. Refer to Appendix G for approved absorbents.

   Absorbed or stabilized organic liquids may be accepted for disposal if the generator provides evidence that the organic

5. All ion exchange resins disposed as LLW shall be thoroughly drained and stable and shall not react with their surroundings to create excessive heat or corrosive-reactive products. Ion exchange resins with the potential for gas generation shall comply with Section 3.7.3.2.5 Adequate data will be required from the generator to determine if the resin is also a dangerous waste. Because of the unique problems associated with organic resin disposal, contact Generator Services for separate instructions before packaging this waste form for disposal.

6. Waste items accepted for burial shall not have unreacted alkali metal contamination that would require regulation of the material as an MW.

7. Chelating agents that compose less than 1 percent of the waste matrix by weight or have been solidified or stabilized will be approved for disposal only on a case-by-case basis. The generator shall provide evidence that the chelating agents will not result in mobilization of radioisotopes.

8. Radioactive animal carcasses are to be packaged in accordance with the following procedure provided by the State of Washington.

   a) All packages must meet the performance based packaging requirements or DOT performance specification 7A. The final package will be a double-walled metal package with the outer package having a capacity at least 40 percent greater than the inner package (e.g., a 30-gal drum in a 55-gal drum or a 55-gal drum in an 85-gal drum).

   b) Line the inner drum with a 4-mil plastic liner.

   c) Place the animal carcass into the inner metal drum with absorbent and lime. Ratio. one part lime to ten parts absorbent.

   d) Seal plastic liner and inner drum.

   e) Place a minimum of 7.6 cm (3 inches) of absorbent on the bottom of the outer drum.

   f) Place the inner metal drum inside the outer metal drum.

   g) Place enough absorbent between the inner and outer drum to completely fill the void space.

   h) Seal the outer drum.

9. Waste generators shall include the fact that a waste is classified as part of their initial request for approval to store or dispose of the waste. To provide adequate security the request must include sufficient information about the nature of the classification, the type of packaging, and the way in which the waste will be shipped (i.e., SST or other method).

Chapter 173-303 WAC. Data provided should describe any materials absorbed on the resin in processing and chemical compositions of column washes. Nitrated organic resins are not normally suitable for disposal because of the potential for violent reaction.

6. Reactive metals cannot be disposed in the burial ground unless they are treated to remove the reactivity characteristic.

7. Disposal of chelating agents can result in migration of radionuclides through the soil. For this reason, chelating agents are not accepted if they exceed 1 percent of the waste unless it is shown that they will not cause radionuclide migration.

8. Decomposition of animal carcasses can result in package pressurization and other hazards to personnel handling the waste. The risks can be reduced by treating the waste with slaked lime. If calcium hydroxide is the only dangerous material present and it does not exceed 10 percent by weight of the waste, the carcass is not subject to regulation as a DW. Other methods of preserving carcasses may result in the material becoming a MW (Stanley 1989).

9. Some forms of LLW are classified for security reasons. Special packaging, shipping, and handling requirements for this waste form will be managed on a case-by-case basis and will be provided in the SDAR.

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Section 7.0

Supplemental Accident Analysis

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1.0 Background and Summary

A spectrum of technology options for the disposition of depleted uranium hexafluoride have been analyzed and reported in Sections 6.1 through 6.13 of this *Engineering Analysis Report*. The Engineering Data Input Reports in these sections include an analysis of postulated accidents related to the transportation, conversion, manufacturing, storage, or use option being considered. Preliminary radiological and nonradiological hazardous accident scenarios that bound and represent potential accidents for each facility are described, covering frequencies of occurrence in the following categories:

- Likely accidents: $\geq 10^{-2}$/yr
- Unlikely accidents: 10^{-2} - 10^{-4}/yr
- Extremely unlikely accidents: 10^{-4} - 10^{-6}/yr

Many of the reports in Section 6 include the temporary storage (1-3 months) of full UF_6 cylinders in yards upon arrival at the conversion facilities or of emptied UF_6 cylinders in low hazard category buildings following conversion or transfer into a new cylinder before cylinder cleaning. The accidents associated with UF_6 cylinder handling and storage functions are common to most technology options and disposition functions. Accordingly, these accidents were not included in Sections 6.1 through 6.13, but are consolidated and described here in Section 7. In addition, the previous reports did not consider accidents with a frequency of occurrence below 10^{-6}/yr. These are commonly referred to as "incredible" accidents. Several plausible accidents in the 10^{-6} - 10^{-7}/yr range are described here in Section 7.

Six accidents involving the temporary storage of UF_6 cylinders are presented in 2.0. These accidents, whose frequencies range from likely to incredible, include high probability/small release events, and low probability/large release events. Releases to the environment range from kilogram to tonne quantities of uranium and a fraction of a kilogram to hundreds of kilogram quantities of anhydrous hydrogen fluoride (AHF). Events initiated by external forces (e.g., an aircraft crash) as well as events initiated by internal forces (e.g., mishandling a cylinder) are presented.

Four incredible accidents which are unrelated to the temporary storage of depleted UF_6 cylinders are presented in 3.0. Two of these accidents reflect the large stored inventories of hazardous chemicals, either a byproduct (AHF) or a process reagent (ammonia) for the conversion options (Sections 6.4 - 6.10). The third accident reflects the large in-process inventory of molten uranium metal found in the radiation shielding application where manufacturing depleted uranium metal radiation shields is considered (Section 6.11).

The final incredible accident analyzed is related to the long-term storage option for UF_6 cylinders and uranium oxide drums in a low hazard building (Section 6.12).

2.0 Cylinder Yard Accidents

Table 2-1, found at the end of this section, summarizes the frequency and source term data for accidents in UF_6 cylinder yards. The assigned frequencies correspond to a generic site. Frequencies for the existing cylinder yard sites may be different.

Depleted UF_6 is a solid at temperatures below 133.8°F at one atmosphere, so it must be heated and containment breached for it to readily escape. A cylinder of solid depleted UF_6 at ambient temperature (75°F) would contain UF_6 vapor in the space in the upper third of the cylinder (assuming the cylinder is 62% filled with solid).

It is assumed that all UF_6 released to the atmosphere reacts with moisture in the air or water vapor generated by combustion (for accidents involving fires) to form airborne uranium oxyfluoride (UO_2F_2) in the respirable range and hydrogen fluoride (HF). Each kilogram of UF_6 released results in the formation of 0.875 kg UO_2F_2 and 0.227 kg HF according to the following reaction:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$$

The rate and extent of the reaction would depend on the exposed surface area of UF_6 and the moisture content in the air. The rate of reaction would decline and eventually become very low as a solid crust of UO_2F_2 is formed on the surface of the solid UF_6.

Three accidents have been analyzed in which corroded cylinders (48 inch diameter, nominal 14 ton capacity) containing solid depleted UF_6 rupture during their handling. Solid UF_6 is released to the ground either under dry conditions (section 2.1) or, in two cases, under wet conditions (section 2.2). Three accidents involving fire-induced rupture of UF_6 cylinders have also been analyzed. Two accidents involve a vehicle crash in the cylinder yard (sections 2.3.1 and 2.3.2). The third accident involves a fire induced by the crash of a small aircraft (section 2.3.3). These accidents are derived from analyses performed by Lockheed Martin Engineering Systems in the *K-25 Site UF_6 Cylinder Storage Yards Final Safety Analysis Report* (LMES).[1]

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[1]Lockheed Martin Energy Systems, Inc. *K-25 Site UF_6 Cylinder Storage Yards Final Safety Analysis Report.* K/D-SAR-29. February 28, 1997.

2.1 Corroded Cylinder Spill Under Dry Conditions

It is postulated that solid depleted UF_6 is spilled over a 4 ft^2 area. The solid UF_6 sublimes at a rate governed by heat transfer considerations and meteorology conditions. Summer and Class B stability conditions are assumed. A steady state sublimation rate of 3×10^{-3} kg UF_6/sec is estimated. Over the assumed 60 minute release duration, 10.7 kg UF_6 is released to the atmosphere. The UF_6 reacts with moisture in the air to form 9.4 kg UO_2F_2 and 2.4 kg HF. Mitigation is assumed to occur within 60 minutes. It is conservatively assumed that the rate of UO_2F_2 crust formation on the solid UF_6 surface, which would reduce the sublimation rate, is unimportant over the 60-minute release period. This accident is judged to be anticipated.

2.2 Corroded Cylinder Spill Under Wet Conditions

2.2.1 Rain

During a rainfall, it is postulated that solid UF_6 is spilled over a 4 ft^2 area (level pavement). The rain immediately reacts with the surface of the UF_6 to give solid UO_2F_2 (ground deposition) and HF which is released to the atmosphere. A precipitation rate of 1.0 in./hr (heavy rainfall) and water penetration of the interior (top and bottom) of the UF_6 pile are assumed. Over the one hour maximum duration of the release, the water reacts with 188 kg UF_6 to form 164 kg of UO_2F_2 (ground deposition) and 42.7 kg HF, which is released to the atmosphere. This accident is judged to be unlikely.

2.2.2 Water Pool

It is postulated that solid UF_6 (4 ft^2 area) is spilled in a level pool of standing water which is a 3.0 in. deep. The available water reacts with the excess solid UF_6 immersed in the pool to immediately form 243 kg UO_2F_2 solid (ground deposition) and 63 kg HF. It is conservatively assumed that all of the HF formed is released to the atmosphere, i.e., none of the HF dissolves and remains in the water pool. A small additional contribution of HF (3.6 kg) is released over the one hour maximum duration of the accident due to water penetration into the sides of the spill. Therefore, the total HF release is 66.6 kg. This accident is judged to be extremely unlikely.

2.3 Fires

Three fire accidents with UF_6 cylinders have been analyzed. The first two accidents involve vehicle induced fire events for a full cylinder (2.3.1) and a heels cylinder (2.3.2). These accidents are judged to be extremely unlikely and the frequency is relatively independent of site features and location. The third accident (2.3.3) involves a fire induced by the crash of a small aircraft into a full cylinder. The aircraft accident frequency is significantly dependent on the cylinder yard size, site features, and location. Consistent with this *Engineering Analysis Report* scope, a generic site was selected for the analysis of the aircraft accident.

2.3.1 Vehicle Induced Fire/Three 48G Cylinders

It is postulated that a vehicle with a large fuel inventory crashes into a UF_6 cylinder storage pad. The vehicle fuel leaks out and ignites. The fire (1475 °F), assumed to last 30 minutes, fully engulfs three 48G cylinders. The model 48G cylinders are thin-walled [5/16"] cylinders with a nominal 14 ton capacity. The pressure in the cylinder rises due to volumetric expansion of the depleted UF_6 during heating, and after 12.2 minutes from the onset of the fire, the three cylinders undergo hydraulic (thermal) rupture. At the time of rupture, it is assumed that all the vapor and liquid UF_6 in each of the cylinders (1742 kg) is immediately released (puff). The liquid would flash to a mixture of solid and vapor, and it is assumed that the solid would evaporate prior to ground deposition near the release point. The UF_6 from each cylinder reacts with water vapor to give 1524 kg UO_2F_2 and 395 kg HF.

During the remaining 17.8 minutes of the fire, there is a continuous/constant sublimation release of UF_6 vapor to the environment. The UF_6 released (1351 kg) from each cylinder reacts with water vapor to form 1182 kg UO_2F_2 and 307 kg HF.

At the end of the fire, the heat content of the cylinder provides energy for further sublimation. In this post-fire phase, the cylinder wall temperature decreases from its end-of-fire temperature as heat is transferred to the environment and the solid UF_6 inside the cylinder. Therefore, this phase is roughly characterized by an exponential decay release. Nearly 80% of the UF_6 released during this phase occurs in the first 20 minutes after the end of the fire. The post-fire release continues until the wall temperature reaches the UF_6 sublimation temperature (133.8°F). At this point, no significant further fire-induced sublimation is assumed to occur. The cumulative UF_6 release from each cylinder over this period (91 minutes from the end of the fire) is 541 kg. The UF_6 reacts with water vapor to form 474 kg UO_2F_2 and 123 kg HF.

In order to bound the release, no mitigation is assumed. It is expected that a fire fighting capability would be available before the end of the fire to extinguish the fire and cool the cylinder walls to minimize the post-fire release.

The total source term would be about 20% larger for a fire involving 48Y cylinders. The model 48Y cylinders are thick-walled (5/8") with a nominal 14 ton capacity. The source term is larger due to the larger initial release (puff) and the larger post-fire release, which continues until the wall temperature reaches the UF_6 sublimation temperature (133.8°F). This last phase would be about 114 minutes longer for the thick-walled cylinders. However, as described in Section 6.1 of this *Engineering Analysis Report*, the 14 ton thick-walled cylinders such as the 48Y constitute less than 1% of the cylinders containing depleted UF_6, while the 14 ton thin-walled cylinders such as the 48G account for about 85% of the cylinders containing depleted UF_6.

2.3.2 Vehicle Induced Fire/Two Heels Cylinders

It is postulated that a vehicle crashes into a storage area containing emptied cylinders with a 10 kg heel of depleted UF_6 in each cylinder. It is assumed that internal pressures in the cylinders are below atmospheric pressure. The impact breaches two cylinders causing air to enter the cylinders. The vehicle fuel leaks out, ignites, and heats the cylinders. There is adequate energy to completely sublimate the small amount of solid UF_6 in the cylinder. The elevated temperature of the cylinder wall causes pressurization, resulting in the expulsion of most of the air/UF_6. It is estimated that about 7 kg UF_6 per cylinder is released through the breach over a period of 10 minutes or less. This UF_6 reacts with water vapor in the air to form 6.1 kg UO_2F_2 and 1.6 kg HF. Therefore, the combined release is 12.2 kg UO_2F_2 and 3.2 kg HF.

2.3.3 Small Aircraft Induced Fire/Two 48G Cylinders

The impact of an aircraft with a depleted uranium-containing facility is an external initiating event that can lead to a significant release of hazardous materials. This analysis considers a small aircraft (<12,500 pounds) crash into a depleted UF_6 cylinder storage pad, which is common to all Conversion Facilities for the temporary storage of incoming full depleted UF_6 cylinders.

It is reasonable to assume that the generic site for conversion would not be located close to an airport or beneath a Federal airway. The frequency of the crash would then correspond to a general aviation en route accident. On this basis and the cylinder yard size, the frequency of such an event is $<10^{-6}$/yr.

It is postulated that, due to the high density of the aircraft engine, the impact ruptures one cylinder. The fuel leaks out of the aircraft, ignites, and engulfs the ruptured cylinder and an adjacent cylinder. For simplicity, the interval between cylinder rupture by impact and the onset of the fire is neglected. The fire (1475 °F) is assumed to last 30 minutes. As described in 2.3.1, the fire causes the adjacent cylinder to undergo hydraulic (thermal) rupture with a puff release (12.2 min), followed by a constant sublimation release over the remaining duration of the fire (17.8 min), and finally an exponential decay release during the post-fire cooling phase (91 min).

For the cylinder ruptured by the impacting engine, a continuous release due to sublimation occurs over the entire duration of the fire. The depleted UF_6 sublimation releases during the initial 15 minutes of the fire when the cylinder wall temperature is increasing are 87 kg (0-5 min), 300 kg (5-10 min), and 376 kg (10-15 min); thereafter, the release rate is essentially constant during the remainder of the fire. Thus, the UF_6 released over the time period 0 -12.2 min (~550 kg) when the second cylinder hydraulically ruptures is obtained by interpolation of this data. The 550 kg UF_6 would react with water vapor to form 481 kg UO_2F_2 and 125 kg HF.

The source term shown in Table 2-1 for the 12.2-30 min period corresponds to the sum of the continuous releases for the initially ruptured and hydraulically (thermally) ruptured cylinders. The continuous release (roughly, exponential decay) for the post-fire phase (t > 30 minutes) is essentially the same (541 kg UF_6) for both cylinders.

This accident involving two cylinders is considered to be very conservative. The fuel inventory for a small aircraft is limited, and the fuel spill would have to be optimally distributed for the ensuing fire to suitably engulf both cylinders. In order to bound the release, no mitigation is assumed. It is expected that a fire fighting capability would be available before the end of the fire to extinguish the fire and cool the cylinder walls to minimize the post-fire release.

The total source term would be about 15% larger for a fire involving 48Y cylinders (thick walled) for the reasons stated above in section 2.3.1. However, as described in Section 6.1 of this *Engineering Analysis Report*, the 14 ton thick-walled cylinders such as the 48Y constitute less than 1% of the cylinders containing depleted UF_6, while the 14 ton thin-walled cylinders such as the 48G account for about 85% of the cylinders containing depleted UF_6.

3.0 Process and Facility Incredible Accidents

Four incredible accidents were analyzed. They are:

- Anhydrous hydrogen fluoride (AHF) storage building: Natural phenomena-initiated tank rupture with release of AHF - no credit for active safety features
- Ammonia (NH_3) outside storage: Natural phenomena-initiated tank rupture with release of NH_3 - no credit for active safety features
- U-metal fabrication building: Natural phenomena-initiated failure of molten uranium metal containing furnaces with oxidation to UO_2 and release - no credit for active safety features
- UF_6 cylinder storage building: External (aircraft) initiated fire and rupture of two 48G cylinders with release of UF_6 generating uranium UO_2F_2 and HF

As indicated, installed active safety features are assumed to be inoperative during the severe accidents. Water sprays would substantially reduce the AHF and NH_3 releases due to their reduced vapor pressure in aqueous solution. At later stages of design, passive safety features would be considered. These include underground spill tanks and limestone absorbers.

Table 3-1, found at the end of this section, summarizes the frequency and source term data for these incredible accidents.

3.1 Tank Ruptures

All conversion options (except those which neutralize the by-product acid) result in the production and storage of major amounts of AHF. Large quantities of NH_3 are used as a reagent during the conversion of UF_6 to uranium oxides (Sections 6.5, 6.7, and 6.8 of this *Engineering Analysis Report*) and to uranium metal (Sections 6.9 and 6.10 of this *Engineering Analysis Report*).

3.1.1 Anhydrous Hydrogen Fluoride Tank Rupture

Anhydrous hydrogen fluoride is stored at the generic conversion facilities in a one-story reinforced concrete structure. This facility provides space for tank storage of one months production of the AHF byproduct. An air refrigeration system maintains the building temperature in the range of 45-55 °F to limit vaporization in the event of a spill. Also, a water spray system and diked floor are provided to mitigate the effects of a spill. The AHF storage building is designed for the performance category PC-4 Design Basis Earthquake (DBE). All safety class systems, structures, and components (SSCs) are designed to withstand the DBE.

It is postulated that a large seismic or equivalent beyond design basis event causes a rupture in a filled AHF storage tank. In addition, the reinforced concrete building structure is severely breached with the result there is no secondary containment. The liquid hydrogen fluoride fills the diked area (750 ft^2). The AHF and building structure are assumed to be at 55 °F before the accident. Since the structure has a large thermal mass, it is assumed there is no significant increase in temperature of the liquid HF over the duration of the accident . The evaporation rate depends on wind speed, which is taken as 1.5 m/s.

The AHF evaporation rate is estimated to be a constant 30 kg/min (ground level) over the entire two-hour accident duration, with no active mitigation (water sprays). The total release is then 3600 kg. The two-hour duration is based on responding personnel experiencing problems such as lack of water pressure, obstruction by debris, and AHF plume exposure.

3.1.2 Ammonia Tank Rupture

Ammonia is stored as a liquid in one or more pressure vessels located outdoors. The fabrication and installation of the tanks follows ANSI Standard K61.1, which requires ASME Code Fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and to contain leakage.

It is postulated that a large seismic event or equivalent beyond design basis event causes an effective one inch diameter hole in the tank. The tank is assumed to be full (approximately 25,000 gallons) and at a temperature of 90 °F. The liquid ammonia release rate is estimated to be 2680 kg/min. The release lasts for 20 minutes at which time the tank would have emptied. Upon release, it is estimated that about 25% of the liquid would adiabatically flash to vapor. Based on industrial experience with chlorine gas (similar boiling point), a like quantity (25%) is released to the atmosphere as a finely dispersed entrained liquid. To bound the release rate, the remainder of the liquid is assumed to be rapidly evaporated by heat transfer from the diked surface. The total release over the 20-minute accident duration is 53,600 kg NH_3.

3.2 U-Metal Furnace Failure

The options described in Sections 6.9-6.10 (conversion to uranium metal) and 6.11(manufacture of uranium oxide and uranium metal radiation shields) of this *Engineering Analysis Report* contain significant in-process inventories of liquid uranium metal. The largest inventory, and therefore the bounding accident, is in the manufacture of uranium metal shields. Uranium metal can be used as a replacement for lead as a gamma shield in casks designed for spent nuclear fuel and high-level waste. Uranium metal billets are melted in eight induction furnaces located above the cask. The uranium would then be poured into the annulus in the structure of the preheated cask and allowed to fill the void area.

It is postulated that a large seismic event or equivalent beyond design basis event causes a common mode catastrophic failure of the eight furnaces feeding one cask. This results in a total liquid uranium metal spill of 24 tonnes. In addition, the reinforced concrete structure facility containing the furnaces is assumed to be severely breached with the result there is no secondary containment. The spilled liquid uranium (1132 °C) rapidly oxides to uranium dioxide when exposed to air at elevated temperatures. The uranium dioxide forms a stable oxide layer on the exposed surfaces of the molten uranium. Since the induction furnaces are normally water cooled, the released cooling water causes localized steam explosions. It is assumed that 10% of the of the uranium oxidizes and is available for release, i.e., on an exposed surface. DOE Handbook 3010-94 gives a respirable airborne fraction of 6×10^{-3} for a violent uranium release situation. This results in a puff (< 1 min.) release of about 16 kg UO_2 to the atmosphere.

3.3 Small Aircraft Induced Fire/Storage Facility

Several facility options for the long-term storage of depleted uranium are described in Section 6.12 of this *Engineering Analysis Report.* One facility option is storage in an above ground, low hazard building. The chemical form options for above ground storage are UF_6, U_3O_8, and sintered UO_2. The preconceptual design call for the phased construction over about 20 years of equally sized storage buildings, with the number of buildings governed by the uranium chemical form (bulk density).

The impact of an aircraft with a depleted uranium-containing facility is an external initiating event that can lead to a significant release of hazardous materials. This analysis considers a small aircraft (<12,500 pounds) crash into a UF_6 cylinder storage building (low hazard design structure).

It is reasonable to assume that the generic site for conversion would not be located close to an airport or beneath a Federal airway. The frequency of the crash would then correspond to a general aviation en route accident. On this basis and the storage building size, the frequency of such an event is $<10^{-6}$/yr. Because the crash of a small aircraft will not cause a major breach of the large storage structure and therefore provide a large direct path for a release to the environment, the uranium source term will be less than that for an equivalent outside yard event.

This aircraft accident is mechanistically the same as described in Section 2.3.3 for the impact of a small aircraft with a cylinder yard. After building penetration by the aircraft, it is postulated that due to the high density of the aircraft engine, the crash ruptures one cylinder. The fuel leaks, ignites, and engulfs the ruptured cylinder and an adjacent cylinder. The fire (1475 °F) is assumed to last 30 minutes. The total UF_6 release and the UF_6 releases from each of the cylinders are the same as before (Section 2.3.3).

The UF_6 released from both cylinders reacts with water vapor to form UO_2F_2 and HF. It is assumed that one third of the UO_2F_2 is released from the building, with the remainder plating out in the building. The lighter, volatile HF is assumed to be entirely released from the building.

This accident involving two cylinders is considered to be very conservative. The fuel inventory for a small aircraft is limited, and the fuel spill would have to be optimally distributed for the ensuing fire to suitably engulf both cylinders.

In order to bound the release, no mitigation is assumed. It is expected that a fire fighting capability would be available before the end of the fire to extinguish the fire and cool the cylinder walls to minimize the post-fire release.

The total source term would be about 15% larger for a fire involving 48Y cylinders (thick walled). However, as described in Section 6.1 of this *Engineering Analysis Report*, the 14 ton thick-walled cylinders such as the 48Y constitute less than 1% of the cylinders containing depleted UF_6, while the 14 ton thin-walled cylinders such as the 48G account for about 85% of the cylinders containing depleted UF_6.

Table 2-1 UF_6 Cylinder Yard Accidents

Accident	Frequency (yr^{-1})	UF_6 at Risk[(a)] (kg)	Source Term (kg)		Release Interval (min)	Release Type
			UO_2F_2[(b)]	HF		
2.1 Corroded Cylinder Spill-Dry Conditions	$>10^{-2}$	10.7	9.4	2.4	0-60	Continuous
2.2.1 Corroded Cylinder Spill - Rain	10^{-2}-10^{-4}	188	164[(c)]	42.7	0-60	Continuous
2.2.2 Corroded Cylinder Spill - Water Pool	10^{-4}-10^{-6}	294	257[(c)]	66.6	0-60	Continuous
2.3.1 Vehicle Induced Fire/ Three 48G Cylinders	10^{-4}-10^{-6}	10,901 (total)	0	0	0-12.2	None
			4573	1186	12.2	Puff
			3545	920	12.2-30	Continuous
			1421	369	30-121	Exponential decay[(d)]
2.3.2 Vehicle Induced Fire/ Two 48G Heels Cylinders	10^{-4}-10^{-6}	14	12.2	3.2	0-10	Continuous
2.3.3 Small Aircraft Induced Fire/ Two 48G Cylinders	$<10^{-6}$	6100 (total)	481	125	0-12.2	Continuous[(d)]
			1524	395	12.2	Puff
			2386	618	12.2-30	Continuous
			947	246	30-121	Exponential decay[(d)]

(a) Inventory x damage factor
(b) Except as noted, respirable airborne quantity released to atmosphere
(c) Ground deposition
(d) See text in section describing accident

Table 3-1 Process and Facility Incredible Accidents

Accident	Frequency (yr^{-1})	Material at Risk [(a)] (kg)	Source Term (kg)[(b)]	Release Interval (min)	Release Type
3.1.1 AHF Tank Rupture	10^{-6}-10^{-7}	3600	3,600 (AHF)	0-120	Continuous
3.1.2 NH_3 Tank Rupture	10^{-6}-10^{-7}	53,600	53,600 (NH_3)	0-20	Continuous
3.2 U-Metal Furnace Failure	10^{-6}-10^{-7}	24,000	16 (UO_2)	<1	Puff
3.3 Small Aircraft Induced Fire/ Storage Building	$<10^{-6}$	6100 (UF_6)	UO_2F_2 : 160 HF : 125	0-12.2	Continuous[(c)]
			UO_2F_2 : 508 HF : 395	12.2	Puff
			UO_2F_2 : 795 HF : 618	12.2-30	Continuous
			UO_2F_2 : 316 HF : 246	30-121	Exponential decay[(c)]

(a) Inventory x damage factor
(b) Respirable airborne quantity released to atmosphere
(c) See text in section describing accident

Section 8.0
Parametric Analysis

Section 8.0
Parametric Analysis

Table of Contents

1.0 Introduction

The *Data Requirements Report* for the Engineering Analysis Project, which established the baseline data requirements for the Cost Analysis Project and PEIS, included parametric analysis as a data element. A parametric analysis considering two throughput variations was performed for the cylinder transfer facility option before the completion of the predecisional draft EAR. The need for parametric analysis of other options being considered for the long-term management of depleted UF_6 was determined after the end of the scoping period for the PEIS (March 25, 1996). Specific options from the conversion, use, storage and disposal modules were selected so that parametric data would be available for at least one option in each module. Data requirements and a schedule for performing these analyses were finalized in early June 1996, and preliminary analyses were completed in October 1996. This parametric analysis considers key data elements for lower operating throughputs. The baseline (100% capacity) facilities had a throughput of 28,000 metric tonnes per year (MT/yr) of depleted UF_6. This section of the EAR provides data for facilities with throughputs that are 50% (14,000 MT/yr) and 25% (7,000 MT/yr) of the baseline capacity.

2.0 Defluorination with Anhydrous HF Production Facility

The Defluorination/Anhydrous HF Facility converts depleted uranium hexafluoride (UF_6) into triuranium oxide (U_3O_8) for stable, long-term storage or disposal. The process also produces anhydrous hydrogen fluoride (AHF) and calcium fluoride of sufficient purity to be sold commercially. The facility description and other data are provided in Section 6.4 of this *Engineering Analysis Report* (EAR). General assumptions, design bases, facility description and process descriptions have not changed. Major changes due to the decreased capacity are provided in this section.

2.1 Summary

Process feed and output materials vary linearly with the facility UF_6 throughput. Thus, the Empty Cylinder Storage Building, UF_6 Cylinder Storage Pad, HF Storage Building and U_3O_8 Storage Building are substantially smaller at the lower capacities. The Process Building size reduction is much less because only a few pieces of equipment were eliminated and the space around equipment to allow inspection and maintenance does not change.

The boiler and cooling tower capacities are lower because less steam and cooling water are required by the HF distillation process. Consequently boiler stack emissions and water usage are lower. Electrical power consumption is less because the refrigeration units that supply coolant to the HF condenser are smaller. Smaller buildings have lower HVAC loads, and this also contributes to the lower utility usage.

The number of employees during operation is slightly lower because there are fewer UF_6 cylinders and U_3O_8 drums to handle. The amount of low level waste produced is greatly reduced because less process liquid from HF distillation is grouted.

2.2 Parametric Analysis

2.2.1 Mass Balance and Process Equipment

The process mass balance for the 50% and 25% cases changes in direct proportion (linearly) with the depleted UF_6 feed input. The number of process equipment and the number of parallel equipment trains were not changed from the baseline case. An exception is that the number of autoclaves was decreased based on the new feed rates. The sizes of the other equipment were reduced based on the new throughput. Some examples follow.

The cross-sectional area of Reactor No. 1, a fluidized bed, was scaled linearly with the UF_6 feed rate. The length and diameter of Reactor No. 2, a rotary kiln, was adjusted to provide enough shell area for heat transfer and enough volume for residence time at the lower U_3O_8 production rates. The sizes of surge tanks and storage tanks were adjusted to maintain the same residence time at reduced throughputs.

2.2.2 Data Summary

The data input for the 50% and 25% capacity cases is shown in Table 2-1. The table also includes data for the 100% baseline case, which was taken from tables and figures in Section 6.4 of this EAR.

2.2.3 Employment Needs

Employment needs for the facility during both operation and construction are shown in Tables 2-2 to 2-4 for the 100%, 50% and 25% cases.

2.2.4 Site Plan

Building sizes and the site size were reduced because less space is needed to satisfy storage capacity criteria and because equipment are smaller. The site plans for the 100%, 50% and 25% cases during operation are shown in Figures 2-1 to 2-3. The site plans during construction are shown in Figures 2-4 to 2-6.

Table 2-1: Parametric Data Base
Defluorination with Anhydrous HF Production

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
UF6 feed (metric tons, MT)	28,000	14,000	7,000
U3O8 product (MT)	22,326	11,163	5,582
Byproducts			
Anhydrous HF (MT)	9,237	4,619	2,309
CaF2 (MT)	419	210	105
Empty UF6 Cylinders (number)	2,322	1,161	581
Grouted waste (MT)	931	466	233
Treated off-gas & ventilation air (MT)	2,555,000	2,142,000	1,789,000
Treated wastewater (MT)	65,800	40,900	29,200
Cooling tower water vapor (MT)	61,500	35,400	21,300
Boiler fluegas (MT)	47,500	28,600	20,400
STORAGE REQUIREMENTS			
Feed cylinder storage (mo.)	1	1	1
Empty cylinder storage (mo.)	3	3	3
Product storage (mo.)	1	1	1
Byproduct storage (mo.)	1	1	1
LAND USE REQUIREMENTS			
Construction area (acres)	20.0	15.8	13.6
Length (ft)	1,210	1,010	940
Width (ft)	720	680	630
Plant area (acres)	13.0	10.5	8.9
Length (ft)	1,000	900	775
Width (ft)	565	510	500

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
CONSTRUCTION RESOURCES (total)			
Construction period (yr)	4	4	4
Utilities			
Electricity (MWh)	30,000	28,000	25,000
Peak demand (MW)	1.5	1.3	1.0
Water (gal)	8,000,000	7,000,000	6,500,000
Concrete (yd3)	18,000	17,000	16,000
Steel (tons)	6,000	6,000	5,000
Monel (tons)	25	15	12
Inconel (tons)	10	7	5
Diesel fuel (gal)	750,000	675,000	600,000
Gasoline (gal)	750,000	675,000	600,000
Propane (gal)	4,000	3,800	3,500
OPERATIONS RESOURCES (annual)			
Utilities			
Electricity (GWh)	11.4	8.5	6.7
Peak demand (MW)	1.5	1.1	0.85
Liquid fuel (gal)	6,000	6,000	5,800
Natural gas (million scf)	118	71	51
Raw water (million gal)	34	21	14
Chemicals (lb)			
Calcium hydroxide (Hydrated lime)	1,270,000	635,000	317,500
Cement	862,000	431,000	215,500
Detergent	500	450	400
Hydrochloric acid (37%)	11,100	6,000	3,600
Sodium hydroxide (50%)	8,800	4,800	2,800
Sodium hypochlorite	3,200	2,000	1,300
Cooling tower chemicals (total)	6,500	3,750	2,250

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
FACILITY AIR RELEASE POINTS			
Process Building Stack			
Height (ft)	100	100	100
Diameter (in)	85	78	71
Temperature (•F)	80	80	80
Flow velocity (ft/s)	60	60	60
Boiler Stack			
Height (ft)	100	100	100
Diameter (in)	25	21	19
Temperature (•F)	500	500	500
Flow velocity (ft/s)	60	60	60
CONSTRUCTION EMISSIONS AND WASTES			
Criteria Pollutants - peak construction yr (tons)			
SOx	1.7	1.5	1.4
NOx	28	25	22
HCs	8	7	6
CO	190	171	152
PM-10	40	32	27
Wastes (total)			
Hazardous solids (yd3)	50	50	40
Hazardous liquids (gal)	20,000	18,000	15,000
Nonhazardous solids - steel (tons)	30	30	25
Nonhazardous solids - concrete+other (yd3)	900	900	790
Nonhazardous liquids - sanitary+other (gal)	3,800,000	3,600,000	3,300,000

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
AIR EMISSIONS DURING OPERATIONS (annual)			
Criteria Pollutants (lb)			
Release point: Boiler Stack			
SOx	70	43	31
NOx	9,600	5,800	4,200
HCs	200	120	90
CO	4,800	2,850	2,100
PM-10	360	214	153
Release point: Grade			
SOx	50	50	39
NOx	380	380	350
HCs	320	320	270
CO	2,500	2,500	2,400
PM-10	80	80	72
Other Pollutants (lb)			
HF (Process Building stack)	900	540	337
U3O8 (Process Building stack)	3.3	2.0	1.2
Treatment chemicals (Cooling tower)	1,320	750	450
Minerals (Cooling tower)	13,400	7,800	4,700
RADIOLOGICAL EMISSIONS DURING OPERATIONS (annual)			
Depleted uranium in Proc Bldg stack gas (ci)	0.000500	0.000300	0.000175
Depleted uranium in liq at effluent outfall (ci)	0.001000	0.000700	0.000500
LOW LEVEL WASTE DURING OPERATION (annual)			
Combustible solid			
Total weight (lb)	216,000	204,000	197,000
Volume (yd3)	100	95	92
Uranium (U3O8) wt. (lb)	26	24	23

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Packages (55 gal drums)	370	350	338
Metal, surface contaminated			
Total weight (lb)	65,000	39,000	23,000
Volume (yd3)	40	24	14
Uranium (U3O8) wt. (lb)	77	46	27
Packages (55 gal drums)	148	89	52
Noncombustible compactible solid			
Total weight (lb)	7,600	6,300	5,200
Volume (yd3)	41	35	29
Uranium (U3O8) wt. (lb)	637	388	227
Packages (4 x 2 x 7 ft boxes)	20	17	14
Noncombustible noncompactible solid			
Total weight (lb)	2,053,000	1,026,500	513,250
Volume (yd3)	609	305	152
Uranium (U3O8) wt. (lb)	821	411	205
Packages (55 gal drums)	2,236	1,118	559
Other			
Total weight (lb)	3,500	3,500	3,500
Volume (yd3)	2.2	2.2	2.2
Uranium (U3O8) wt. (lb)	4	4	4
Packages (55 gal drums)	8	8	8
HAZARDOUS WASTE DURING OPERATION (annual)			
Organic liquids			
Total weight (lb)	4,500	4,000	3,600
Volume (yd3)	3.0	2.7	2.4
Haz. matl (solvent/oil/paint) wt. (lb)	4,500	4,000	3,600
Packages (55 gal drums)	11	10	9

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Inorganic process debris			
Total weight (lb)	8,100	7,300	6,500
Volume (yd3)	5.0	4.5	4.0
Haz. matl (HF+NaOH) wt. (lb)	16	15	13
Packages (55 gal drums)	19	17	15
Combustible debris			
Total weight (lb)	540	540	540
Volume (yd)	1.0	1.0	1.0
Haz. matl (HF+NaOH) wt. (lb)	2	2	2
Packages (55 gal drums)	4	4	4
Other			
Total weight (lb)	970	970	970
Volume (yd3)	0.6	0.6	0.6
Haz. matl (mercury) wt. (lb)	trace	trace	trace
Packages (55 gal drums)	2	2	2
MIXED LLW DURING OPERATION (annual)			
Total weight (lb)	1,890	1,890	1,890
Total volume (yd3)	1.5	1.5	1.5
Total uranium (U3O8) wt. (lb)	2.1	2.1	2.1
Total haz. matl (acetone) wt. (lb)	2.1	2.1	2.1
Total packages (55 gal drums)	6	6	6
NONHAZARDOUS WASTE DURING OPERATION (annual)			
Sanitary liquid (gal)	1,300,000	1,250,000	1,200,000
Other liquid (gal)	15,300,000	9,600,000	6,500,000
Other solid (yd3)	500	480	460
Recyclable solid (yd3)	200	190	180

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
TRANSPORTATION SUMMARY-INPUT MATERIALS			
UF6			
Packages/yr	2,322	1,161	581
Packages/shipment (rail)	48	48	48
Packages/shipment (truck)	1	1	1
Shipments/yr (rail)	49	25	13
Shipments/yr (truck)	2,322	1,161	581
HCl			
Packages/yr	21	11	7
Packages/shipment (truck)	11	6	7
Shipments/yr (truck)	2	2	1
NaOH			
Packages/yr	13	7	4
Packages/shipment (truck)	7	7	4
Shipments/yr (truck)	2	1	1
TRANSPORTATION SUMMARY-OUTPUT MATERIALS			
U3O8			
Packages/yr	35,700	17,850	8,925
Packages/shipment (rail)	320	320	320
Packages/shipment (truck)	28	28	28
Shipments/yr (rail)	112	56	28
Shipments/yr (truck)	1,275	638	319
Anhydrous HF			
Packages/yr	243	122	61
Packages/shipment (rail)	12	10	5
Shipments/yr (rail)	20	13	13
LLW in 55 gal drums			
Packages/yr	2,762	1,565	957
Packages/shipment (truck)	40	40	40

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Shipments/yr (truck)	69	40	24
LLW in boxes			
Packages/yr	20	17	14
Packages/shipment (truck)	10	9	7
Shipments/yr (truck)	2	2	2
Hazardous waste			
Packages/yr	36	33	30
Packages/shipment (truck)	18	17	15
Shipments/yr (truck)	2	2	2
Mixed waste			
Packages/yr	6	6	6
Packages/shipment (truck)	6	6	6
Shipments/yr (truck)	1	1	1
Empty UF6 cylinders			
Packages/yr	2,322	1,161	581
Packages/shipment (rail)	48	48	48
Packages/shipment (truck)	6	6	6
Shipments/yr (rail)	49	25	13
Shipments/yr (truck)	387	194	97

**Table 2-2: On-Site Employment During Operation
Defluorination with Anhydrous HF Production**

Labor Category	Number of Employees[1]
Officials and Managers	6/6/6
Professionals	6/6/6
Technicians	29/29/29
Office and Clerical	20/20/20
Craft Workers (Maintenance)	10/9/8
Operators	91/81/77
Line Supervision	15/15/14
Security	26/26/26
TOTAL EMPLOYEES (for all on-site facilities)	203/192/186

[1] Numbers correspond to 100%/50%/25% capacity cases.

**Table 2-3: Number and Location of Employees During Operation[1]
Defluorination with Anhydrous HF Production**

Facility	Shift 1	Shift 2	Shift 3	Shift 4[2]
Process Building	33/32/31	24/23/22	24/23/22	24/23/22
HF Storage Building	2/2/2	1/1/1	1/1/1	1/1/1
U_3O_8 Storage Building	3/1/1	1/1/1	1/1/1	1/1/1
CaF_2 Storage Building	1/1/1	0/0/0	0/0/0	0/0/0
Cylinder Storage Pad & Building	7/5/3	3/2/2	3/2/2	3/2/2
Utilities/Services/Admin Areas	40/40/40	10/10/10	10/10/10	10/10/10
TOTAL EMPLOYEES	86/81/78	39/37/36	39/37/36	39/37/36

[1] Numbers correspond to 100%/50%/25% capacity cases.

[2] The 4th shift allows coverage for 7 days per week operations.

Table 2-4: Number of Construction Employees Needed by Year [1]
Defluorination with Anhydrous HF Production

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170/170/140	250/230/200	420/380/340	170/170/140
Construction Management and Support Staff	30/30/30	50/40/40	80/70/60	30/30/30
TOTAL EMPLOYEES	200/200/170	300/270/240	500/450/400	200/200/170

1 Number of employees shown are for the peak of the year. Average for the year is 60% of the peak. Numbers correspond to 100%/50%/25% capacity cases.

Figure 2-1: Site Map for Defluorination/AHF Facility - 100% Capacity

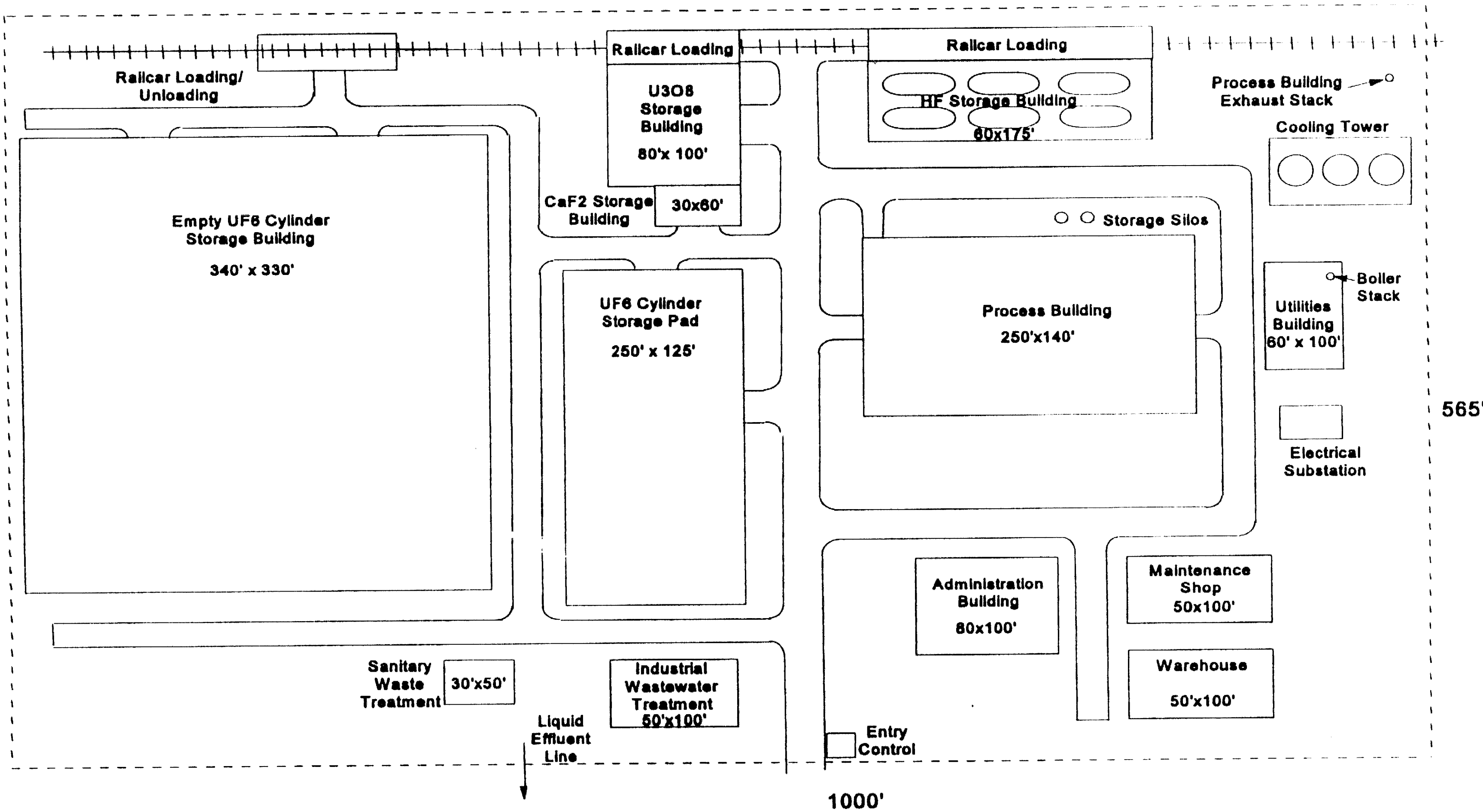


Figure 2-2: Site Map for Defluorination/AHF Facility - 50% Capacity

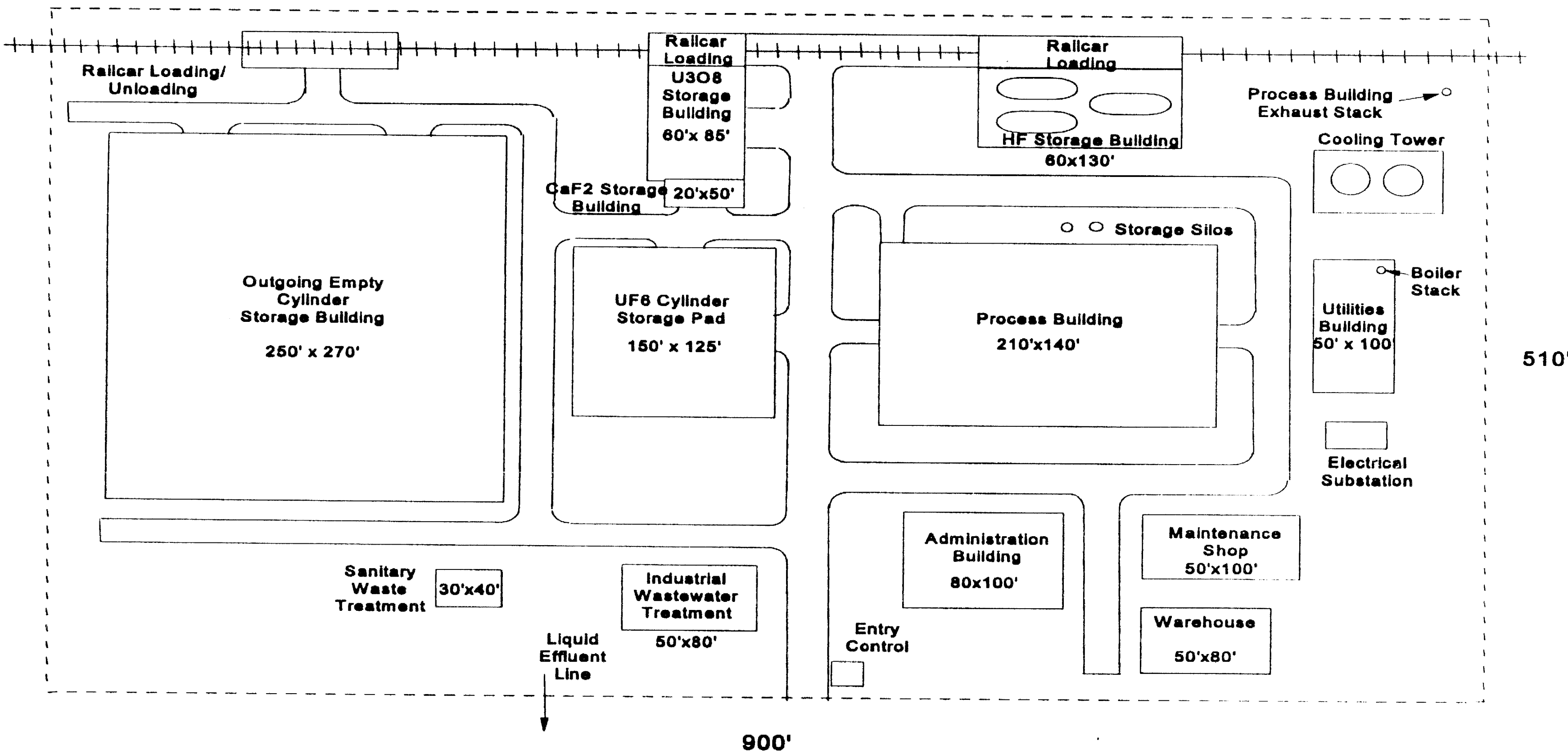


Figure 2-3: Site Map for Defluorination/AHF Facility - 25% Capacity

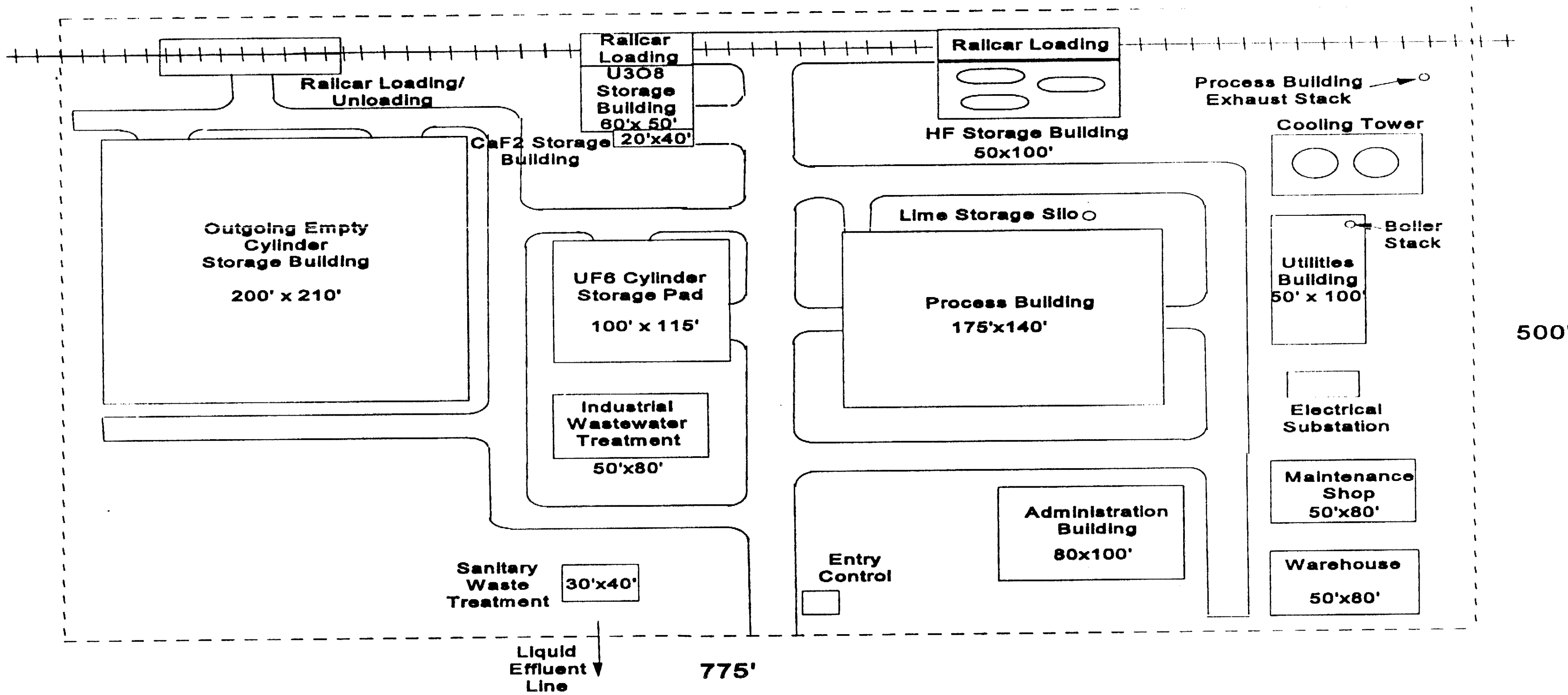


Figure 2-4: Site Map for Defluorination/AHF Facility During Construction - 100% Capacity

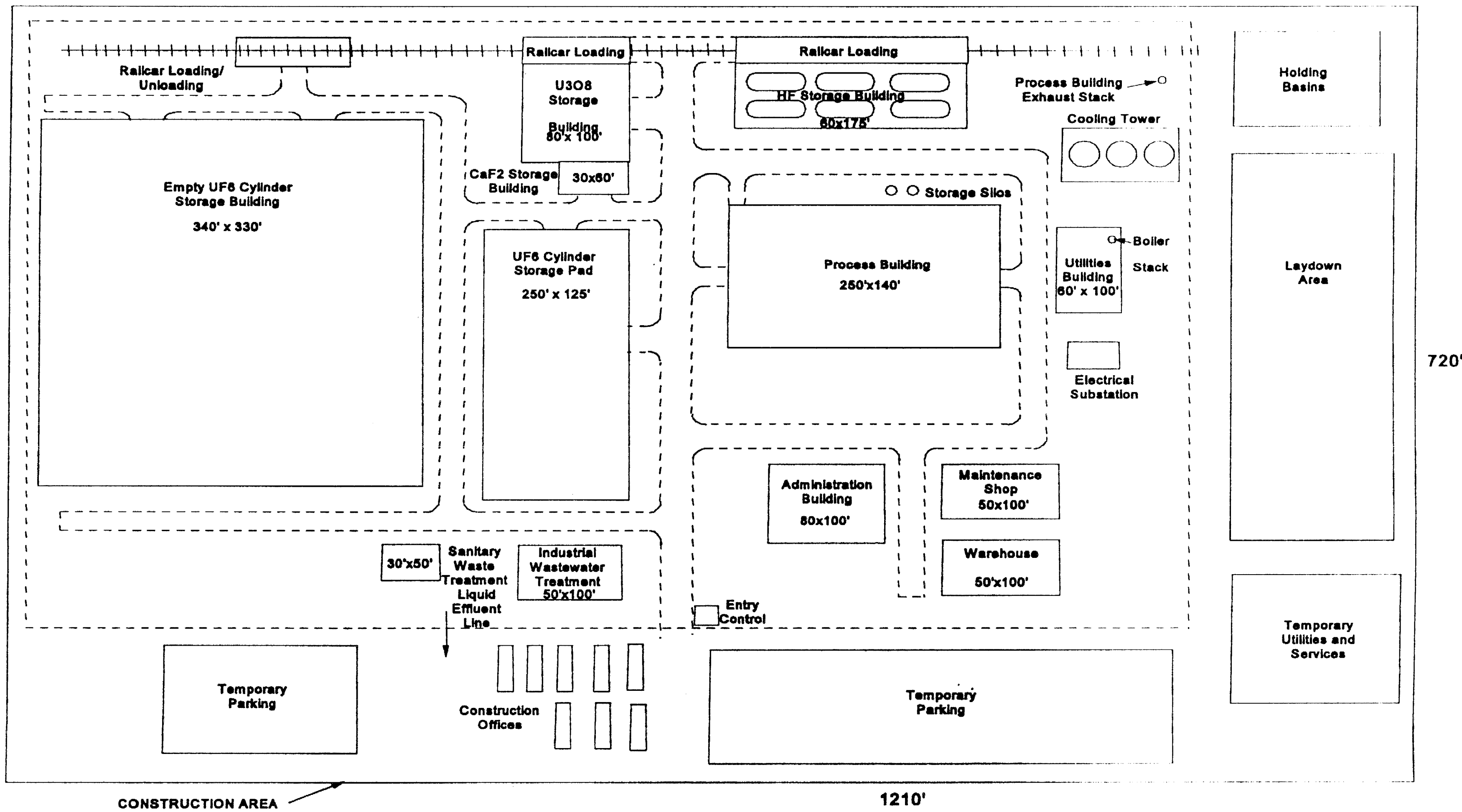


Figure 2-5: Site Map for Defluorination/AHF Facility During Construction - 50% Capacity

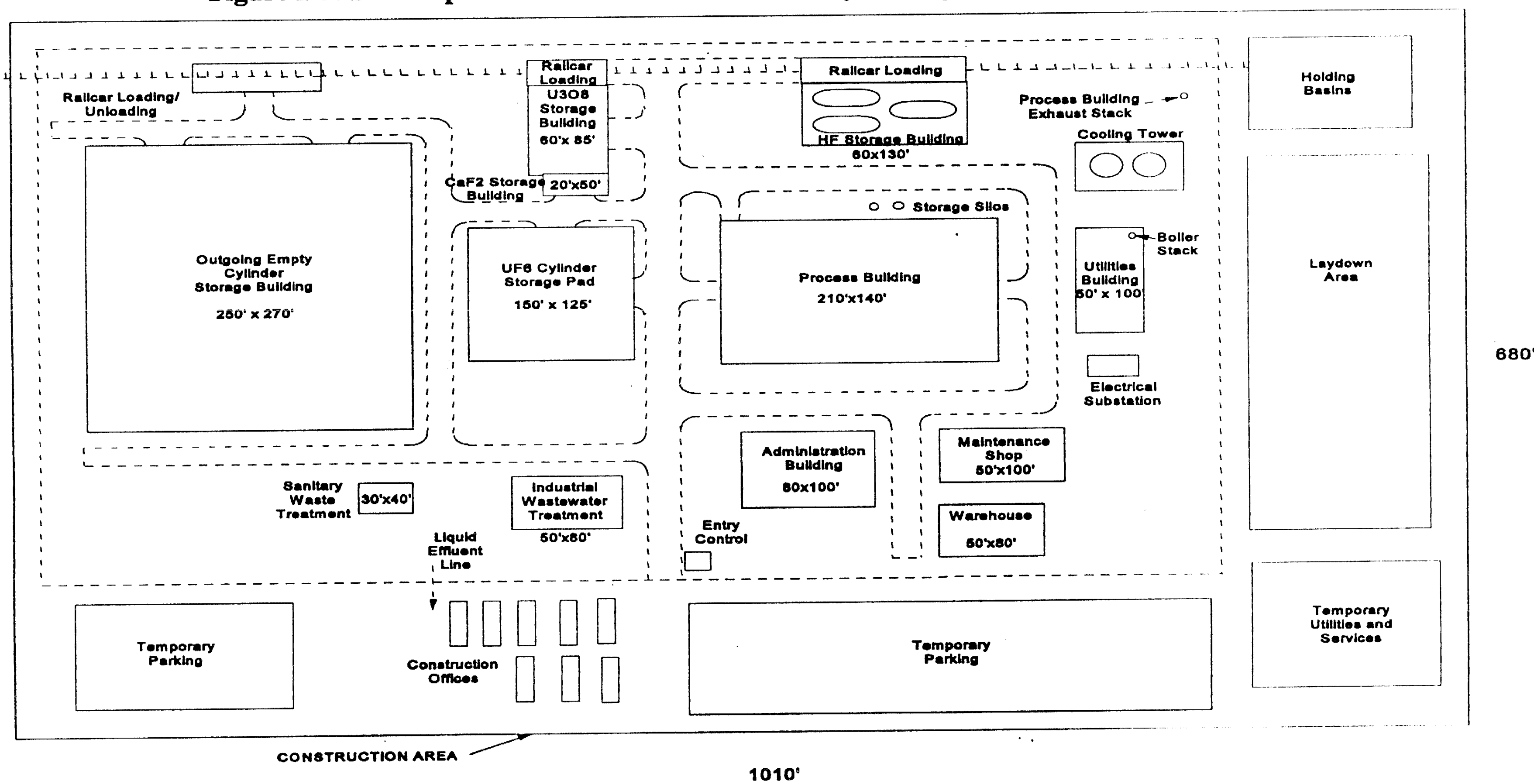
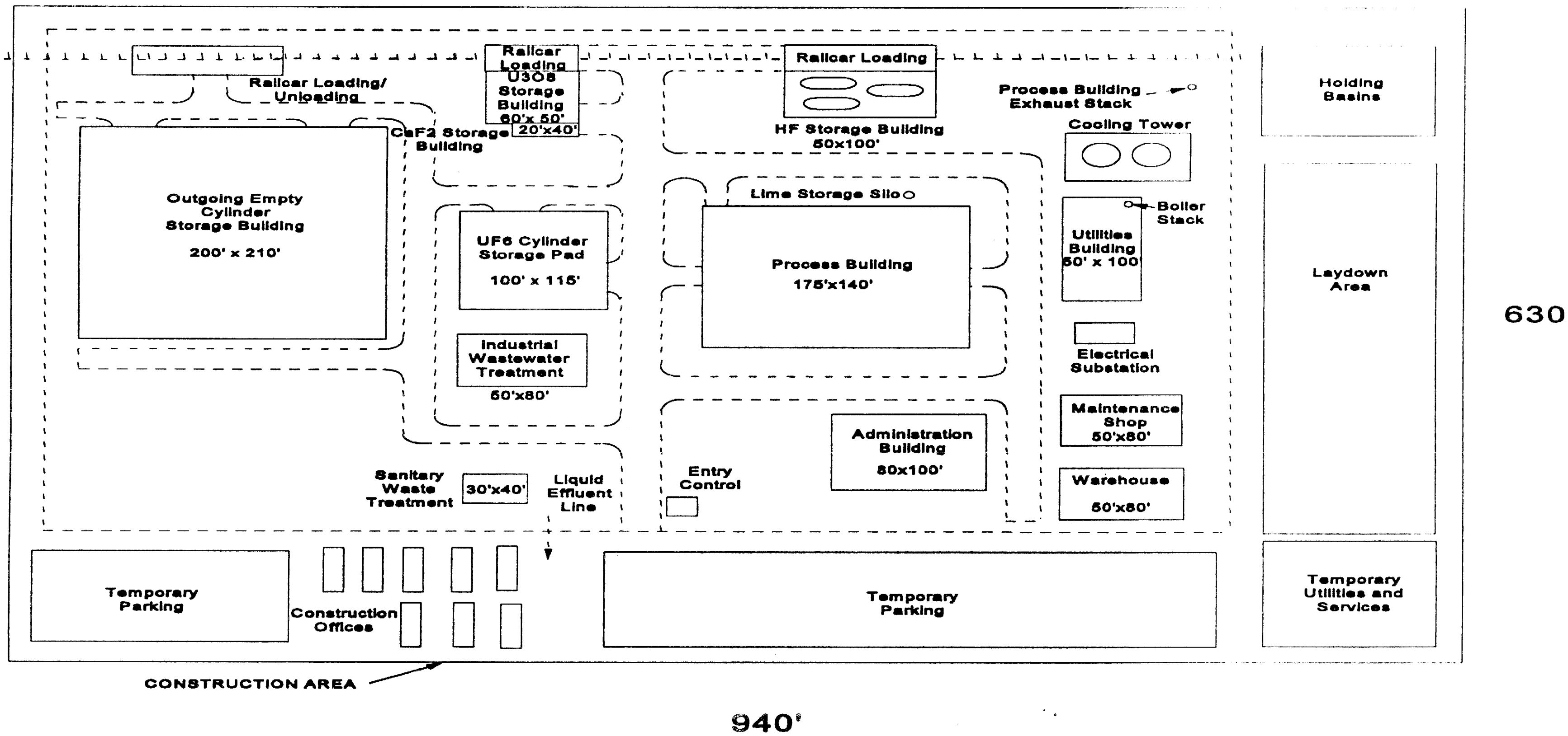


Figure 2-6: Site Map for Defluorination/AHF Facility During Construction - 25% Capacity



2.3 Accident Analysis

Most of the accidents associated with the facility remain unchanged. However some accidents have changed because their source term was dependent on the facility throughput. These accidents are shown in Tables 2-5 and 2-6. The narrative for these accidents, with revisions underlined, follows. Note that accidents associated with transfer of HF from the Process Building to the HF Storage Building do not change because the transfer is a batch operation at the same flow rate.

Table 2-5: Bounding Postulated Accident Summary
Defluorination with Anhydrous HF Production

Accident	Frequency	Respirable Airborne Material Released to Environment[1]
Earthquake	Extremely Unlikely	41/21/11 lb U_3O_8
HF System Leak	Anticipated	216/108/54 lb HF
Loss of Cooling Water	Anticipated	22/11/5.5 lb HF

Table 2-6: Accident Source Terms and Parameters
Defluorination with Anhydrous HF Production

Accident	Effective Material at Risk[1]	Respirable Airborne Fraction	Fraction of Respirable Airborne Material Released to Environment	Release Duration
Earthquake	205,000/102,500/ 51,250 lb U_3O_8	2.0×10^{-4}	1.0	30 min
HF System Leak	540/270/135 lb HF	1.0	0.4	15 min
Loss of Cooling Water	22/11/5.5 lb HF	1.0	1.0	2 min

[1] Quantities correspond to 100%/50%/25% capacity cases

2.3.1 Earthquake

The U_3O_8 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for these facilities would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 2,974/1,487/744 (100%/50%/25% case) drums each containing 1,380 lb of U_3O_8. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum covers are lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Approximately 0.02% of this powder could be expected to become respirable airborne. Thus, approximately 41/21/11 lb of U_3O_8 is released to the environment. The release point is at grade.

2.3.2 HF Distillation System Leak

Gaseous HF is produced from the conversion reactions. The HF is separated in a distillation column to form anhydrous (~100%) HF and 45 wt% HF in water. The boiling point of anhydrous HF is 67°F and that of 45 wt% HF is 230°F. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the distillation column overhead vapor line carrying anhydrous HF leaks 5% of its flowing contents for 10 minutes, thus releasing 540/270/135 lb (100%/50%/25% case) of HF into the process building. After the leak is detected by air monitoring instruments, the distillation column operation and reactor feed are halted to stop the leak. It is assumed that 40% of the HF vapor 216/108/54 lb is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

2.3.3 Loss of Cooling Water

The distillation column and conversion reactors operate at pressures up to 15 psig. Pressure relief valves are provided to protect vessels and equipment. Loss of cooling water to the distillation column condenser would cause the pressure in the column to rise and the relief valve to open. The relief valve outlet is piped to a bed of limestone to neutralize the HF vapor before discharging to atmosphere.

It is postulated that cooling water is lost and 100% of the overhead vapor flows through the relief valve for 1 minute, releasing 1,100/550/275 lb (100%/50%/25% case) of HF. High temperature and pressure alarms and interlocks would shut down the heat input to the column to stop the release. Assuming that the limestone bed has a 98% removal efficiency for HF, about 22/11/5.5 lb of HF would be released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

3.0 Ceramic UO_2 with Anhydrous HF Facility

The Ceramic UO_2/Anhydrous HF Facility converts depleted uranium hexafluoride (UF_6) into dense uranium dioxide (UO_2) for reuse, long-term storage or disposal. The process also produces anhydrous hydrogen fluoride (AHF) and calcium fluoride of sufficient purity to be sold commercially. The facility description and other data are provided in Section 6.6 of this EAR. General assumptions, design bases, facility description and process descriptions have not changed. Major changes due to the decreased capacity are provided in this section.

3.1 Summary

Process feed and output materials vary linearly with the facility UF_6 throughput. Thus, the Empty Cylinder Storage Building, UF_6 Cylinder Storage Pad, HF Storage Building, UO_2 Storage Building are substantially smaller at the lower capacities. The Process Building size reduction is much less because only a few pieces of equipment were eliminated and the space around equipment to allow inspection and maintenance was not changed.

The boiler and cooling tower capacities are lower because less steam and cooling water are required by the HF distillation process. Consequently boiler stack emissions and water usage are lower. Electrical power consumption is less because the UO_2 sintering furnaces are smaller and the refrigeration units that supply coolant to the HF condenser are smaller. Smaller buildings have lower HVAC loads, and this also contributes to the lower utility usage.

The number of employees during operation is slightly lower because there are fewer UF_6 cylinders, and UO_2 drums to handle. The amount of low level waste is greatly reduced because less process liquid from HF distillation is produced and grouted.

3.2 Parametric Analysis

3.2.1 Mass Balance and Process Equipment

The process mass balance for the 50% and 25% cases changes in direct proportion (linearly) with the depleted UF_6 feed input. The number of process equipment items and the number of parallel equipment trains were not changed from the baseline case. An exception is that the number of autoclaves was decreased based on the new feed rates. The sizes of the other equipment were reduced based on the new throughput. Some examples follow.

The cross-sectional area of Reactor No. 1, a fluidized bed, was scaled linearly with the UF_6 feed rate. The length and diameter of Reactor No. 2, a rotary kiln, was adjusted to provide enough shell area for heat transfer and enough volume for residence time at the lower UO_2 production rates. The internal area of the sintering furnaces was scaled linearly with the UO_2 rate. The sizes of surge tanks and storage tanks were adjusted to maintain the same residence time at reduced throughputs.

3.2.2 Data Summary

The data input for the 50% and 25% capacity cases is shown in Table 3-1. The table also includes data for the 100% baseline case, which was taken from tables and figures in the Section 6.6 of this EAR.

3.2.3 Employment Needs

Employment needs for the facility during both operation and construction are shown in Tables 3-2 to 3-4 for the 100%, 50% and 25% cases.

3.2.4 Site Plan

Building sizes and the site size were reduced because less space is needed to satisfy storage capacity criteria and because equipment is smaller. The site plans for the 100%, 50% and 25% cases during operation are shown in Figures 3-1 to 3-3. The site plans during construction are shown in Figures 3-4 to 3-6.

Table 3-1: Parametric Data Base
Ceramic UO_2 with Anhydrous HF Facility

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
UF6 feed (metric tons, MT)	28,000	14,000	7,000
UO2 product (MT)	21,477	10,739	5,369
Byproducts			
Anhydrous HF (MT)	9,236	4,618	2,309
CaF2 (MT)	421	211	105
Empty UF6 Cylinders (number)	2,322	1,161	581
Grouted waste (MT)	931	466	233
Treated off-gas & ventilation air (MT)	3,840,000	3,390,000	2,620,000
Treated wastewater (MT)	80,800	52,700	36,200
Cooling tower water vapor (MT)	83,500	49,100	29,200
Boiler fluegas (MT)	46,200	31,200	20,800
STORAGE REQUIREMENTS			
Feed cylinder storage (mo.)	1	1	1
Empty cylinder storage (mo.)	3	3	3
Product storage (mo.)	1	1	1
Byproduct storage (mo.)	1	1	1
LAND USE REQUIREMENTS			
Construction area (acres)	24	19.4	15.8
Length (ft)	1,350	1,175	1,030
Width (ft)	775	720	670
Plant area (acres)	14.6	12.9	10
Length (ft)	1,125	1,000	870
Width (ft)	565	560	500
CONSTRUCTION RESOURCES (total)			
Construction period (yr)	4	4	4
Utilities			
Electricity (MWh)	35,000	33,000	30,000
Peak demand (MW)	1.5	1.5	1.5
Water (gal)	10,000,0000	9,000,000	8,000,000
Concrete (yd3)	21,000	20,000	18,000
Steel (tons)	8,000	7,000	6,000
Monel (tons)	25	15	12
Inconel (tons)	10	7	5
Diesel fuel (gal)	800,000	800,000	750,000

		UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)		**100%**	**50%**	**25%**
Gasoline (gal)		800,000	800,000	750,000
Propane (gal)		4,400	4,200	4,000
OPERATIONS RESOURCES (annual)				
Utilities				
	Electricity (GWh)	30	20	13
	Peak demand (MW)	4	2.6	1.7
	Liquid fuel (gal)	7,000	6,800	6,600
	Natural gas (million scf)	116	78	52
	Raw water (million gal)	44	27	18
Chemicals (lb)				
	Pelletizing lubricant	236,000	118,000	59,000
	Calcium hydroxide (Hydrated lime)	1,270,000	635,000	317,500
	Cement	862,000	431,000	215,500
	Detergent	600	550	500
	Ammonia	2,900,000	1,450,000	725,000
	Hydrochloric acid (37%)	8,900	5,200	3,100
	Sodium hydroxide (50%)	7,000	4,100	2,400
	Sodium hypochlorite	4,300	2,800	1,800
	Cooling tower chemicals (total)	8,800	5,200	3,100
FACILITY AIR RELEASE POINTS				
Process Building Stack				
	Height (ft)	100	100	100
	Diameter (in)	104	98	86
	Temperature (°F)	80	80	80
	Flow velocity (ft/s)	60	60	60
Boiler Stack				
	Height (ft)	100	100	100
	Diameter (in)	27	24	20
	Temperature (°F)	500	500	500
	Flow velocity (ft/s)	60	60	60
CONSTRUCTION EMISSIONS AND WASTES				
Criteria Pollutants - peak construction yr (tons)				
	SOx	1.8	1.8	1.7
	NOx	30	30	28
	HCs	8.2	8.2	7.7
	CO	200	200	190
	PM-10	50	40	33

		UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)		**100%**	**50%**	**25%**
Wastes (total)				
	Hazardous solids (yd3)	60	60	50
	Hazardous liquids (gal)	25,000	23,000	20,000
	Nonhazardous solids - steel (tons)	40	40	30
	Nonhazardous solids - concrete+other (yd3)	1,130	1,020	900
	Nonhazardous liquids - sanitary+other (gal)	5,000,000	4,600,000	3,900,000
AIR EMISSIONS DURING OPERATIONS (annual)				
Criteria Pollutants (lb)				
	Release point: Boiler Stack			
	SOx	70	47	31
	NOx	9,300	6,300	4,200
	HCs	200	130	90
	CO	4,600	3,200	2,100
	PM-10	350	230	160
	Release point: Grade			
	SOx	54	49	44
	NOx	460	430	405
	HCs	410	370	330
	CO	2,700	2,680	2,670
	PM-10	92	87	82
Other Pollutants (lb)				
	HF (Process Building stack)	900	540	337
	UO2 (Process Building stack)	12	8	4
	Treatment chemicals (Cooling tower)	1,800	1,000	620
	Minerals (Cooling tower)	18,400	10,800	6,400
RADIOLOGICAL EMISSIONS DURING OPERATIONS (annual)				
Depleted uranium in Proc Bldg stack gas (ci)		0.0020	0.0012	0.0007
Depleted uranium in liq at effluent outfall (ci)		0.0020	0.0014	0.0010
LOW LEVEL WASTE DURING OPERATION (annual)				
Combustible solid				
	Total weight (lb)	248,000	236,000	230,000
	Volume (yd3)	115	110	107
	Uranium (UO2) wt. (lb)	28	27	26
	Packages (55 gal drums)	425	405	394

		UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)		**100%**	**50%**	**25%**
Metal, surface contaminated				
	Total weight (lb)	73,000	44,000	25,000
	Volume (yd3)	45	27	16
	Uranium (UO2) wt. (lb)	82	49	29
	Packages (55 gal drums)	166	100	58
Noncombustible compactible solid				
	Total weight (lb)	13,000	11,000	8,100
	Volume (yd3)	62	55	43
	Uranium (UO2) wt. (lb)	2,500	1,500	870
	Packages (4 x 2 x 7 ft boxes)	30	27	21
Noncombustible noncompactible solid				
	Total weight (lb)	2,053,000	1,026,500	513,250
	Volume (yd3)	609	305	152
	Uranium (UO2) wt. (lb)	821	411	205
	Packages (55 gal drums)	2,236	1,118	559
Other				
	Total weight (lb)	3,500	3,500	3,500
	Volume (yd3)	2.2	2.2	2.2
	Uranium (UO2) wt. (lb)	4	4	4
	Packages (55 gal drums)	8	8	8
HAZARDOUS WASTE DURING OPERATION (annual)				
Organic liquids				
	Total weight (lb)	4,500	4,000	3,600
	Volume (yd3)	3	2.7	2.4
	Haz. matl (solvent/oil/paint) wt. (lb)	4,500	4,000	3,600
	Packages (55 gal drums)	11	10	9
Inorganic process debris				
	Total weight (lb)	8,100	7,300	6,500
	Volume (yd3)	5	4.5	4
	Haz. matl (HF+NaOH) wt. (lb)	16	15	13
	Packages (55 gal drums)	19	17	15
Combustible debris				
	Total weight (lb)	540	540	540
	Volume (yd)	1	1	1
	Haz. matl (HF+NaOH) wt. (lb)	2	2	2
	Packages (55 gal drums)	4	4	4

		UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)		**100%**	**50%**	**25%**
Other				
	Total weight (lb)	970	970	970
	Volume (yd3)	0.6	0.6	0.6
	Haz. matl (mercury) wt. (lb)	trace	trace	trace
	Packages (55 gal drums)	2	2	2
MIXED LLW DURING OPERATION (annual)				
Total weight (lb)		1,890	1,890	1,890
Total volume (yd3)		1.5	1.5	1.5
Total uranium (UO2) wt. (lb)		2.1	2.1	2.1
Total haz. matl (acetone) wt. (lb)		2.1	2.1	2.1
Total packages (55 gal drums)		6	6	6
NONHAZARDOUS WASTE DURING OPERATION (annual)				
Sanitary liquid (gal)		1,490,000	1,420,000	1,380,000
Other liquid (gal)		19,800,0000	12,500,000	8,200,000
Other solid (yd3)		570	545	530
Recyclable solid (yd3)		230	220	210
TRANSPORTATION SUMMARY-INPUT MATERIALS				
UF6				
	Packages/yr	2,322	1,161	581
	Packages/shipment (rail)	48	48	48
	Packages/shipment (truck)	1	1	1
	Shipments/yr (rail)	49	25	13
	Shipments/yr (truck)	2,322	1,161	581
HCl				
	Packages/yr	16	10	6
	Packages/shipment (truck)	8	5	6
	Shipments/yr (truck)	2	2	1
NaOH				
	Packages/yr	10	6	4
	Packages/shipment (truck)	5	6	4
	Shipments/yr (truck)	2	1	1
NH3				
	Packages/yr	56	28	14
	Packages/shipment (rail)	1	1	1
	Shipments/yr (rail)	56	28	14

		UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)		**100%**	**50%**	**25%**
TRANSPORTATION SUMMARY-OUTPUT MATERIALS				
UO_2				
	Packages/yr	32,150	16,075	8,038
	Packages/shipment (rail)	304	304	304
	Packages/shipment (truck)	24	24	24
	Shipments/yr (rail)	106	53	27
	Shipments/yr (truck)	1,340	670	335
Anhydrous HF				
	Packages/yr	243	122	61
	Packages/shipment (rail)	12	10	5
	Shipments/yr (rail)	20	13	13
LLW in 55 gal drums				
	Packages/yr	2,835	1,631	1,019
	Packages/shipment (truck)	40	40	40
	Shipments/yr (truck)	71	41	26
LLW in boxes				
	Packages/yr	30	27	21
	Packages/shipment (truck)	10	9	11
	Shipments/yr (truck)	3	3	2
Hazardous waste				
	Packages/yr	36	33	30
	Packages/shipment (truck)	18	17	15
	Shipments/yr (truck)	2	2	2
Mixed waste				
	Packages/yr	6	6	6
	Packages/shipment (truck)	6	6	6
	Shipments/yr (truck)	1	1	1
Empty UF6 cylinders				
	Packages/yr	2,322	1,161	581
	Packages/shipment (rail)	48	48	48
	Packages/shipment (truck)	6	6	6
	Shipments/yr (rail)	49	25	13
	Shipments/yr (truck)	387	194	97

Table 3-2: On-Site Employment During Operation
Ceramic UO_2 with Anhydrous HF Facility

Labor Category	Number of Employees[1]
Officials and Managers	8/8/8
Professionals	8/8/8
Technicians	34/34/34
Office and Clerical	22/22/22
Craft Workers (Maintenance)	11/10/9
Operators	103/94/90
Line Supervision	17/16/15
Security	26/26/26
TOTAL EMPLOYEES (for all on-site facilities)	229/218/212

[1] Numbers correspond to 100%/50%/25% capacity cases.

Table 3-3: Number and Location of Employees During Operation[1]
Ceramic UO_2 with Anhydrous HF Facility

Facility	Shift 1	Shift 2	Shift 3	Shift 4[2]
Process Building	47/46/45	28/27/26	22/21/20	28/27/26
HF Storage Building	2/2/2	1/1/1	1/1/1	1/1/1
UO_2 Storage Building	3/1/1	1/1/1	1/1/1	1/1/1
CaF_2 Storage Building	1/1/1	0/0/0	0/0/0	0/0/0
Cylinder Storage Pad and Building	7/5/3	3/2/2	3/2/2	3/2/2
Utilities/Services/Admin Areas	40/40/40	10/10/10	10/10/10	10/10/10
TOTAL EMPLOYEES	100/95/92	43/41/40	43/41/40	43/41/40

[1] Numbers correspond to 100%/50%/25% capacity cases.

[2] The 4th shift allows coverage for 7 days per week operations.

Table 3-4: Number of Construction Employees Needed by Year [1]
Ceramic UO_2 with Anhydrous HF Facility

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170/170/170	290/270/250	510/480/420	250/220/170
Construction Management and Support Staff	30/30/30	60/60/50	90/90/80	50/40/30
TOTAL EMPLOYEES	200/200/200	350/330/300	600/570/510	300/260/200

[1] Number of employees shown are for the peak of the year. Average for the year is 60% of the peak. Numbers correspond to 100%/50%/25% capacity cases.

Figure 3-1: Site Map for Ceramic UO_2/AHF Facility - 100% Capacity

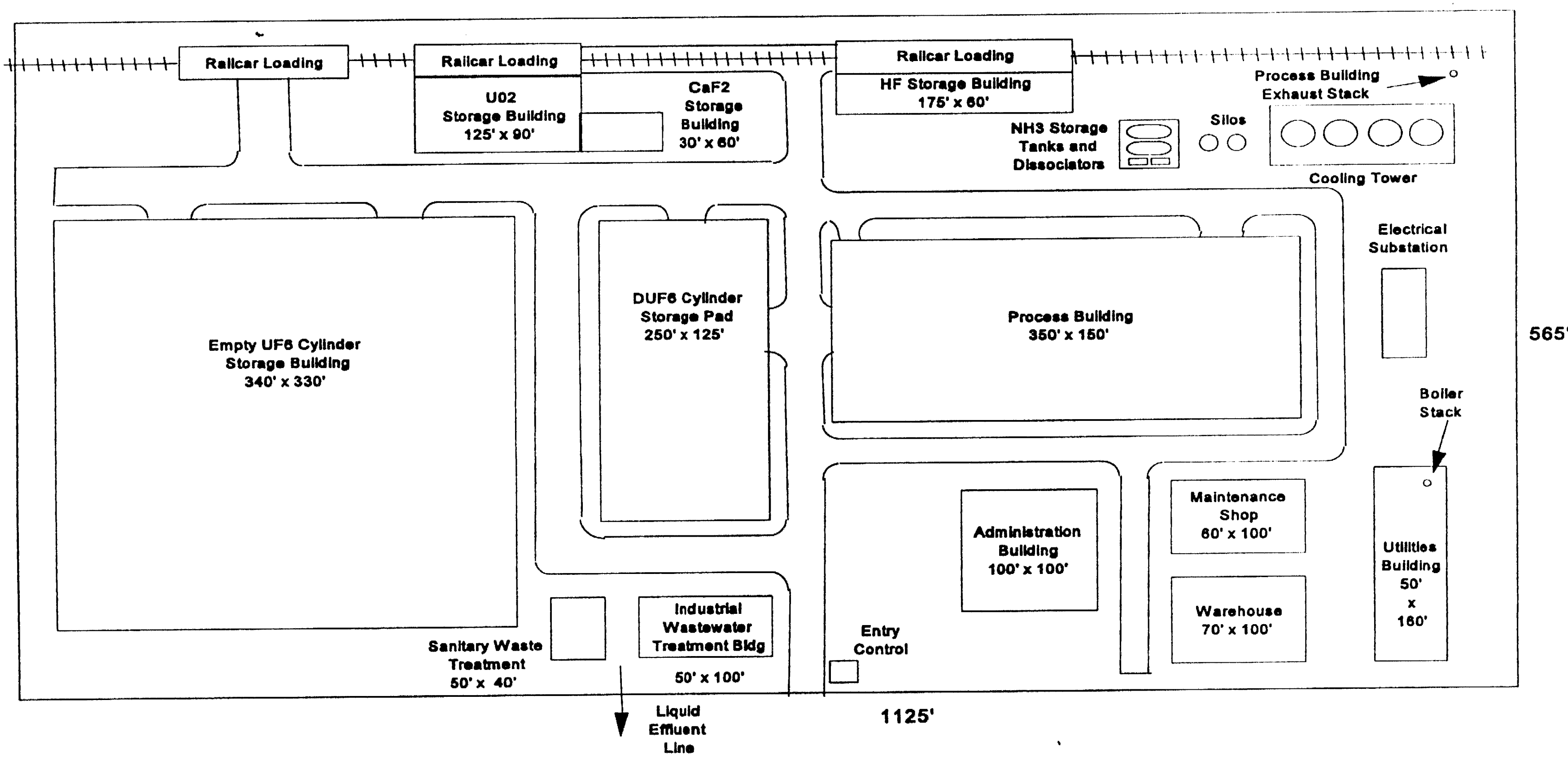


Figure 3-2: Site Map for Ceramic UO_2/AHF Facility - 50% Capacity

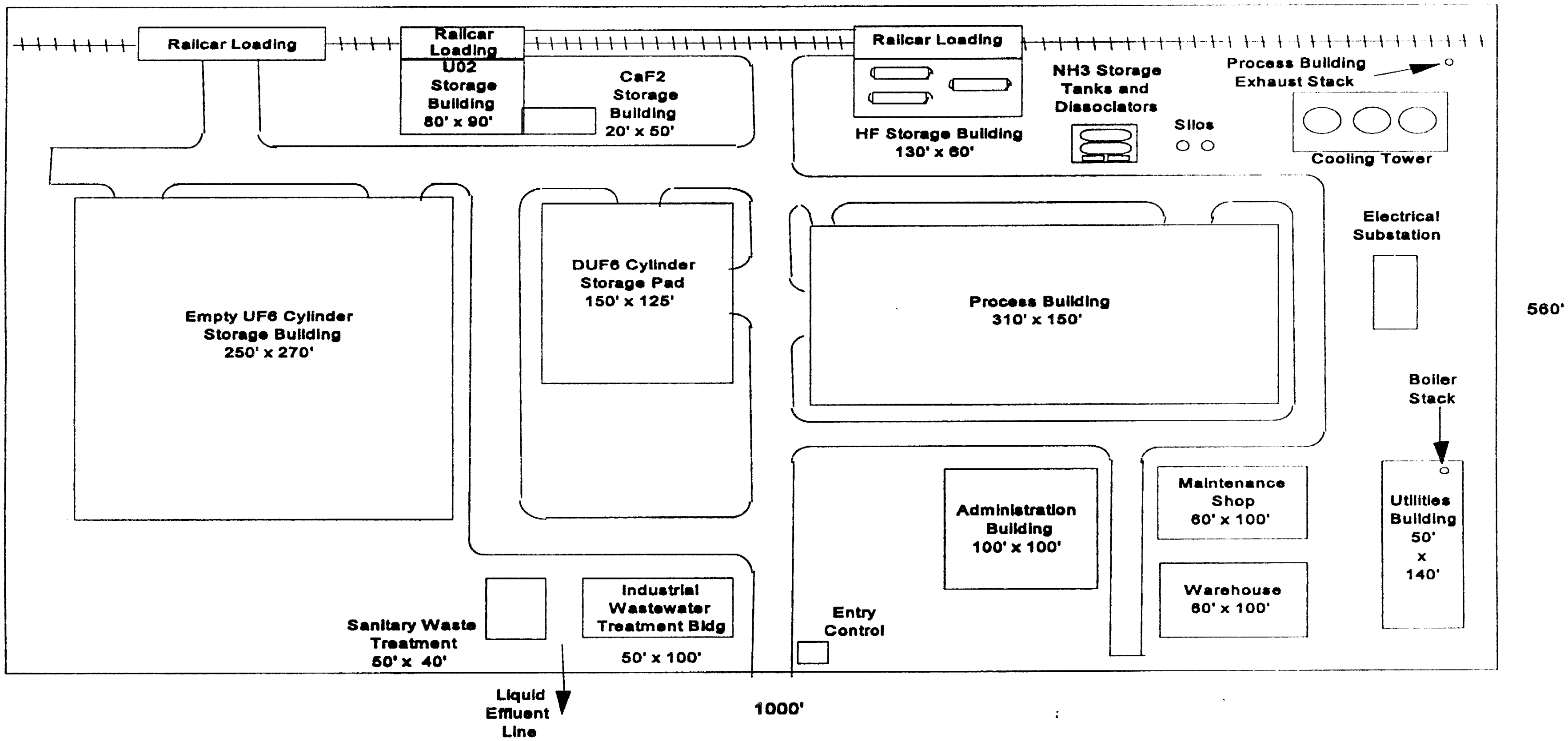


Figure 3-3: Site Map for Ceramic UO_2/AHF Facility - 25% Capacity

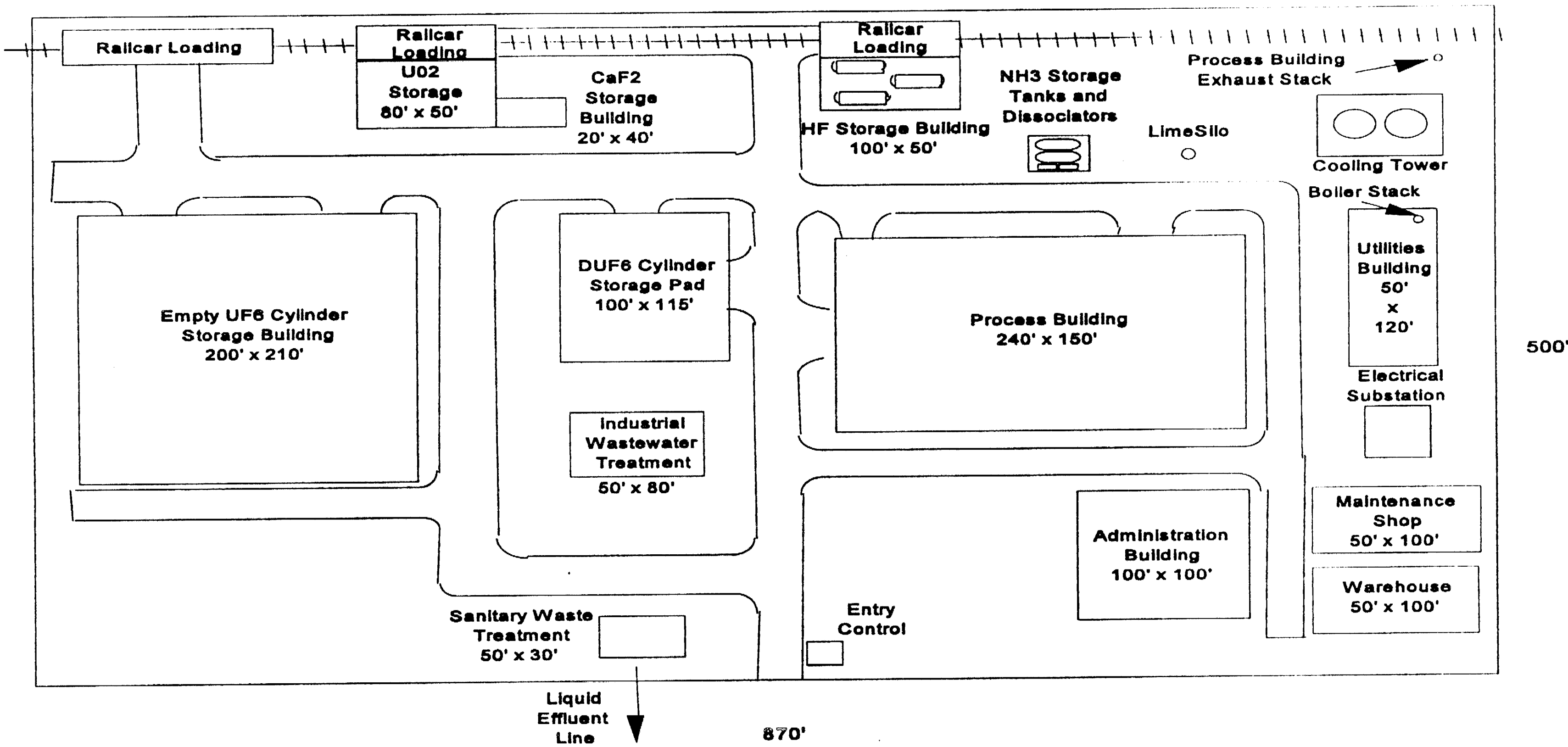


Figure 3-4: Site Map for Ceramic UO_2/AHF Facility Construction - 100% Capacity

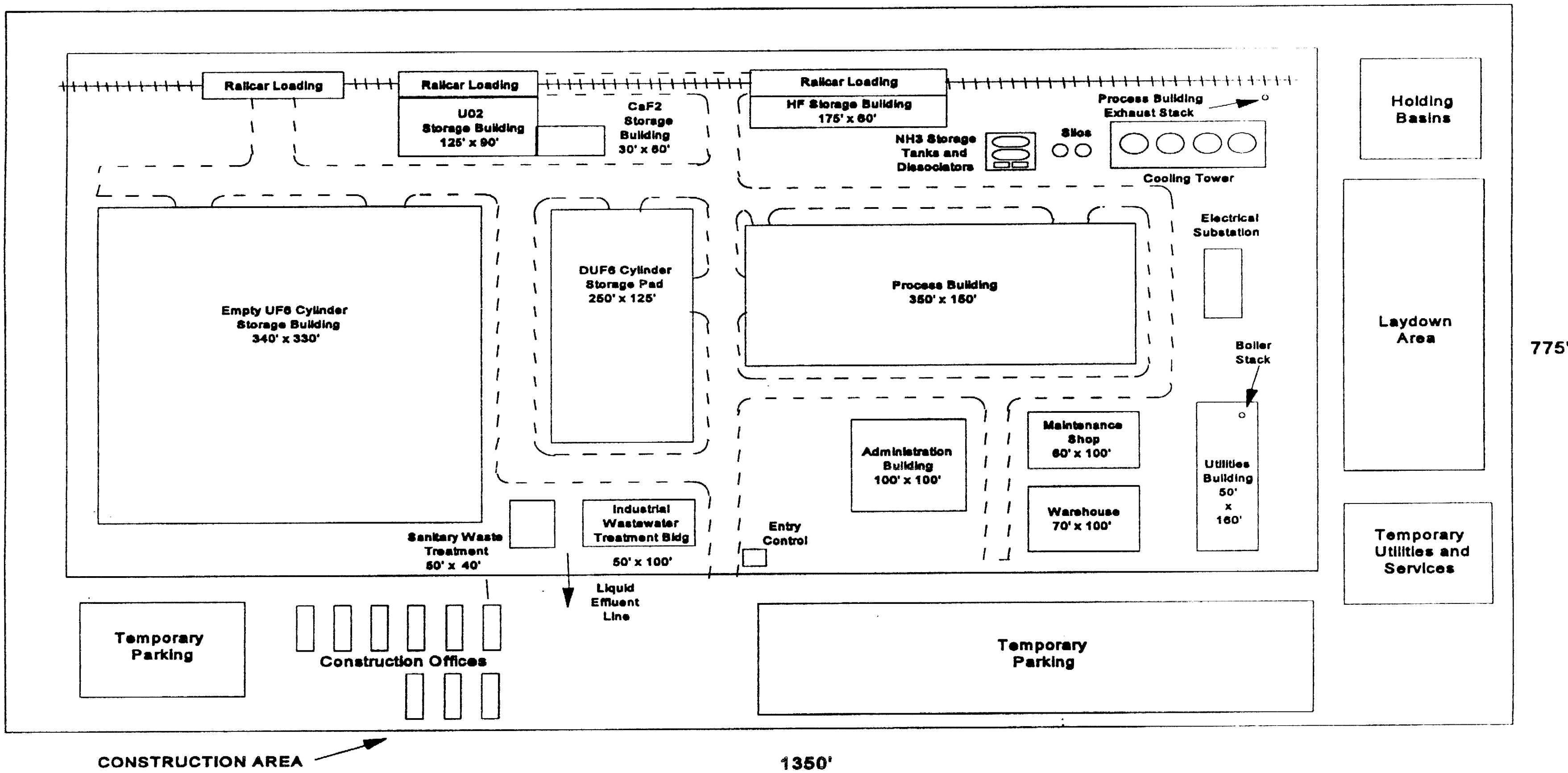


Figure 3-5: Site Map for Ceramic UO_2/AHF Facility Construction - 50% Capacity

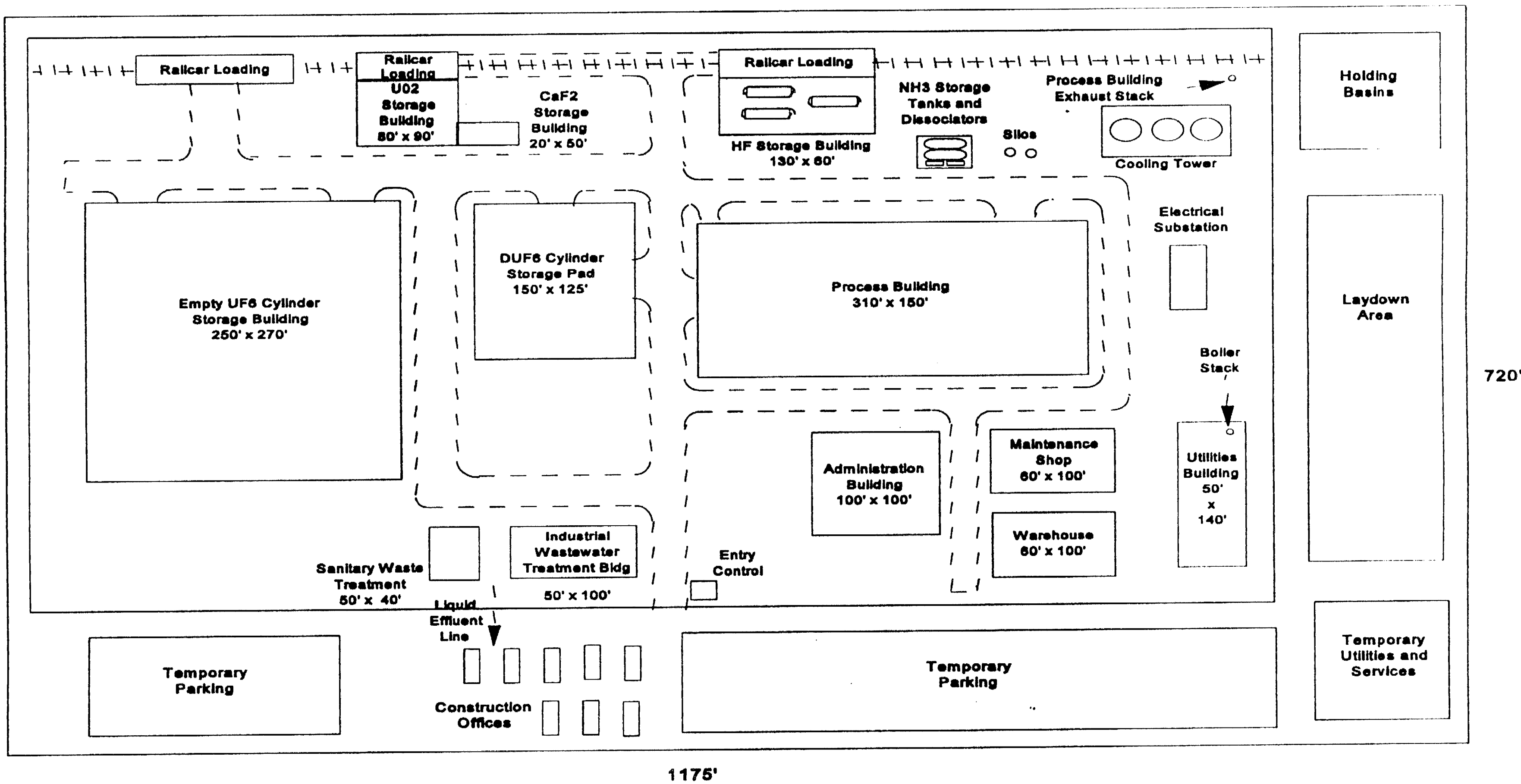
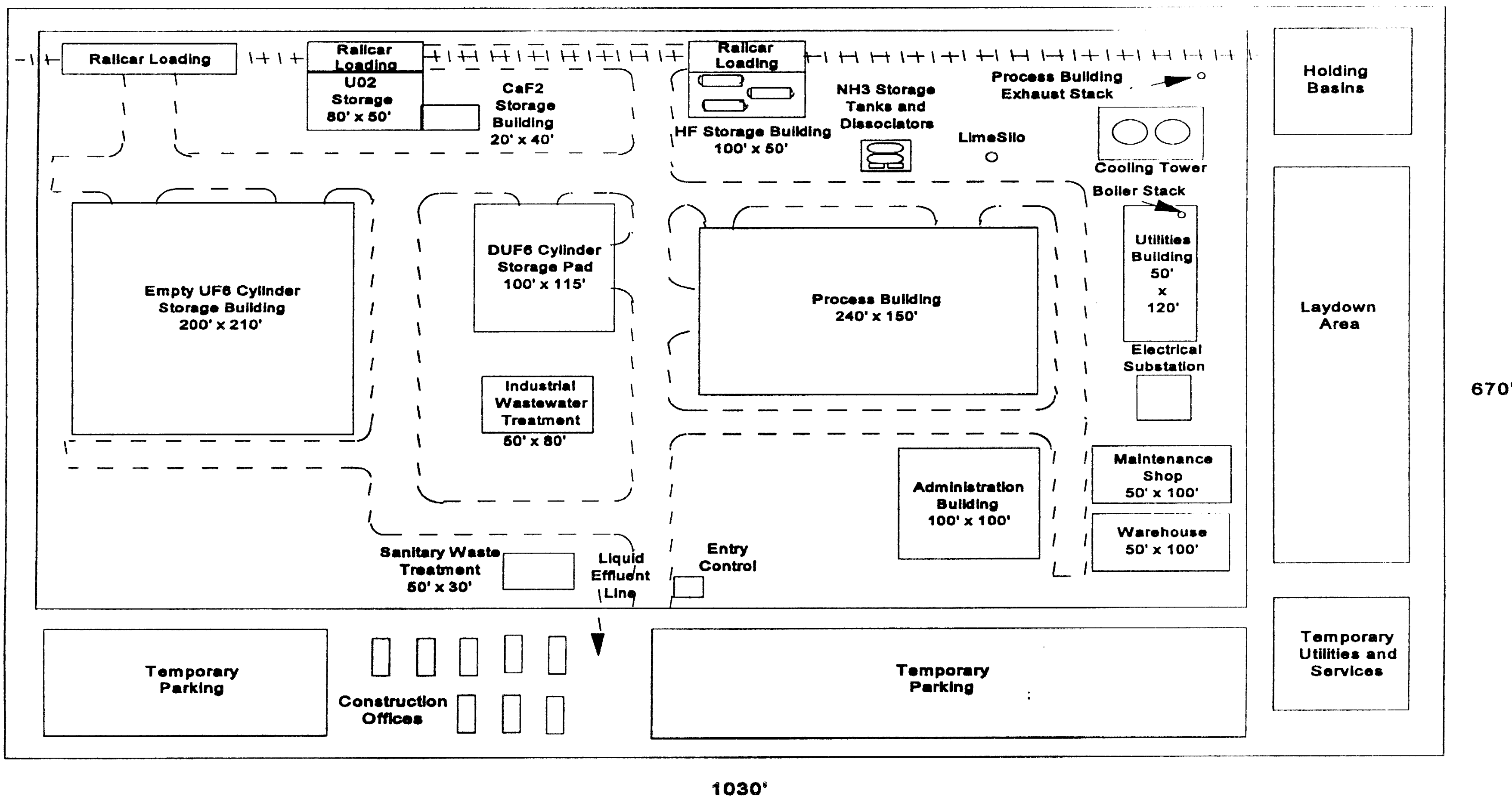


Figure 3-6: Site Map for Ceramic UO_2/AHF Facility Construction - 25% Capacity



3.3 Accident Analysis

Most of the accidents associated with the facility remain unchanged. However some accidents have changed because their source term was dependent on the facility throughput. These accidents are shown in Tables 3-5 and 3-6. The narrative for these accidents, with revisions underlined, follows. Note that accidents associated with transfer of HF from the Process Building to the HF Storage Building do not change because the transfer is a batch operation at the same flow rate.

Table 3-5: Bounding Postulated Accident Summary for Ceramic UO_2 with Anhydrous HF Facility

Accident	Frequency	Respirable Airborne Material Released to Environment[1]
Earthquake	Extremely Unlikely	9.8/4.9/2.5 lb UO_2
HF System Leak	Anticipated	216/108/54 lb HF
Loss of Cooling Water	Anticipated	22/11/5.5 lb HF
Hydrogen Explosion	Extremely Unlikely	0.25/0.13/0.07 lb UO_2 7/3.5/1.8 lb HF

[1] Quantities correspond to 100%/50%/25% capacity cases.

Table 3-6: Accident Source Terms and Parameters
Ceramic UO_2 with Anhydrous HF Facility

Accident	Effective Material at Risk[1]	Respirable Airborne Fraction	Fraction of Respirable Airborne Material Released to Environment	Release Duration
Earthquake	197,000/98,500/ 49,250 lb UO_2	5×10^{-3}	1 x 10	30 min
HF System Leak	540/270/135 lb HF	1.0	0.4	15 min
Loss of Cooling Water	22/11/5.5 lb HF	1.0	1.0	2 min
Hydrogen Explosion	5,000/2,500/ 1,250 lb UO_2 7/3.5/1.8 lb HF	0.051	1×10^{-3} 1	30 min

[1] Quantities correspond to 100%/50%/25% capacity cases.

3.3.1 Earthquake

The UO_2 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 2,680/1,340/670 (100%/50%/25% cases) drums each containing 1,470 lb of UO_2. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum cover is lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Assuming a conservative average fall height of 8 ft, approximately 0.005% of the pellets are fractured into respirable particles which are assumed to subsequently exhibit powder-like behavior and could be expected to become airborne. Thus, approximately 9.8/4/9/2/5 lb of UO_2 is released to the environment. Thus, approximately 9.8/4.9/2.5 lb of UO_2 is released to the environment. The release point is at grade.

Gaseous HF is produced from the conversion reactions. The HF is separated in a distillation column to form anhydrous (~100%) HF and 45 wt% HF water. The boiling point of anhydrous HF is 67°F and that of 45 wt% HF is 230°F. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the distillation column overhead vapor line carrying anhydrous HF leaks 5% of its flowing contents for 10 minutes, thus releasing 540/270/135 lb of HF into the process building. After the leak is detected by air monitoring instruments, the distillation column operation and reactor feed is halted to stop the leak. It is assumed that about 40% of the HF vapor 216/108/54 lb is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

3.3.2 Loss of Cooling Water

The distillation column and conversion reactors operate at pressures up to 15 psig. Pressure relief valves are provided to protect vessels and equipment. Loss of cooling water to the distillation column condenser would cause the pressure in the column to rise and the relief valve to open. The relief valve outlet is piped to a bed of limestone to neutralize the HF vapor before discharging to atmosphere.

It is postulated that cooling water is lost and 100% of the overhead vapor flows through the relief valve for 1 minute, releasing 1,100/550/275 lb of HF. High temperature and pressure alarms and interlocks would shut down the heat input to the column to stop the release. Assuming that the limestone bed has a 98% removal efficiency for HF, about 22/11/5.5 lb of HF would be released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

3.3.3 Hydrogen Explosion

Hydrogen is fed to Reactor No. 2 as a reagent, to react with UO_2F_2. There are two reactors in parallel, and each reactor receives about 33/17/9 lb/hr of hydrogen.

Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. Steam is also fed to the reactor. The reactor vapor space normally contains excess unreacted hydrogen, steam, HF and nitrogen. There is normally no air in the reactor.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the reactor, air to leak into the reactor, and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

The reactor is assumed to contain about 10,000/5,000/2,500 lb of UO_2 during normal operation (3 hour residence time). It is assumed that 50% of the material is released into the room, of which 100% becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the material. Thus 0.25/0.13/0.07 lb of UO_2 is discharged through the Process Building exhaust stack. The reactor also contains 7/3.5/1.8 lb of HF that is released through the stack. This accident is judged to be extremely unlikely.

4.0 Continuous Reduction to Uranium Metal Facility

The Continuous Reduction to Uranium Metal Facility converts depleted uranium hexafluoride (UF_6) into uranium metal for reuse. The process also produces anhydrous hydrogen fluoride of sufficient purity to be sold commercially. The facility description and other data are provided in Section 6.10 of this EAR. General assumptions, design bases, facility description and process descriptions have not changed. Major changes due to the decreased capacity are provided in this section.

4.1 Summary

Process feed and output materials vary linearly with the facility UF_6 throughput. Thus, the Empty Cylinder Storage Building UF_6 Cylinder Storage Pad, HF Storage Building, Mg Metal Storage Building, MgF_2 Storage Building and Uranium Product Storage Building are substantially smaller at the lower capacities. The Process Building size reduction is much less because only a few pieces of equipment were eliminated and the space around equipment to allow inspection and maintenance was not changed.

The cooling tower capacity is lower because less cooling water is required by the salt quench tank coolers and the NaC1 crystallizer condensate cooler. Consequently water usage is lower. Electrical power consumption is less because less electricity is consumed by the continuous UF_4 reduction to metal reactors and the vapor compressor for NaC1 crystallization. Steam usage is less because there is less NaC1 and MgF_2 to dry. Smaller buildings have lower HVAC loads, and this also contributes to the lower steam and cooling water usage.

The number of employees during operation is slightly lower because there are fewer UF_6 cylinders, Mg metal drums, MgF_2 drums and uranium product boxes to handle.

4.2 Parametric Analysis

4.2.1 Mass Balance and Process Equipment

The process mass balance for the 50% and 25% cases changes in direct proportion (linearly) with the depleted UF_6 feed input. The number of process equipment items and the number of parallel equipment trains were not changed from the baseline case. Exceptions are that the number of autoclaves was decreased based on the new feed rates, and the number of UF_4 reduction to metal reactors was decreased from three to two in the 25% case. The sizes of the other equipment were reduced based on the new throughput. Some examples follow.

The cross-sectional area of the UF_6 to UF_4 reactor was scaled linearly with the UF_6 feed rate. The cross-sectional pool area of the continuous UF_4 to metal reduction reactor was scaled linearly with the uranium metal production rate. The sizes of surge tanks and storage tanks were adjusted to maintain the same residence time at reduced throughputs.

4.2.2 Data Summary

The data input for the 50% and 25% capacity cases is shown in Table 4-1. The table also includes data for the 100% baseline case, which was taken from tables and figures in the Draft Engineering Analysis Report.

4.2.3 Employment Needs

Employment needs for the facility during both operation and construction are shown in Tables 4-2 to 4-4 for the 100%, 50% and 25% cases.

4.2.4 Site Plan

Building sizes and the site size were reduced because less space is needed to satisfy storage capacity criteria and because equipment is smaller. The site plans for the 100%, 50% and 25% cases during operation are shown in Figures 4-1 to 4-3. The site plans during construction are shown in Figures 4-4 to 4-6.

Table 4-1: Parametric Data Base
Continuous Reduction to Uranium Metal Facility

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
UF6 feed (metric tons, MT)	28,000	14,000	7,000
Uranium metal product (MT)	19,516	9,758	4,879
Byproducts			
Anhydrous HF (MT)	3,121	1,561	780
CaF2 (MT)	118	59	30
Empty UF6 Cylinders (number)	2,322	1,161	581
MgF2 waste (MT)	10,097	5,049	2,524
Treated off-gas & ventilation air (MT)	3,830,000	3,390,000	2,950,000
Treated wastewater (MT)	102,000	62,100	41,900
Cooling tower water vapor (MT)	106,000	59,500	35,800
Boiler fluegas (MT)	40,200	28,000	20,900
STORAGE REQUIREMENTS			
Feed cylinder storage (mo.)	1	1	1
Empty cylinder storage (mo.)	3	3	3
Product storage (mo.)	1	1	1
Byproduct storage (mo.)	1	1	1
LAND USE REQUIREMENTS			
Construction area (acres)	26.3	21.3	16.9
Length (ft)	1,350	1,120	1,020
Width (ft)	850	830	720
Plant area (acres)	15.4	13.5	11.9
Length (ft)	1,080	950	880
Width (ft)	620	620	590
CONSTRUCTION RESOURCES (total)			
Construction period (yr)	4	4	4
Utilities			
Electricity (MWh)	35,000	34,000	33,000
Peak demand (MW)	1.5	1.5	1.5
Water (gal)	10,000,000	9,000,000	8,000,000
Concrete (yd3)	20,000	19,000	18,000
Steel (tons)	9,000	7,000	6,000
Monel (tons)	110	65	35
Titanium (tons)	10	5	2.5
Diesel fuel (gal)	800,000	800,000	750,000

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Gasoline (gal)	800,000	800,000	750,000
Propane (gal)	4,400	4,200	4,000
OPERATIONS RESOURCES (annual)			
Utilities			
Electricity (GWh)	44	30	19
Peak demand (MW)	6.0	4.0	2.5
Liquid fuel (gal)	6,500	6,500	6,250
Natural gas (million scf)	100	70	52
Raw water (million gal)	55	32	21
Chemicals (lb)			
Magnesium	8,400,000	4,200,000	2,100,000
Iron	1,300,000	650,000	325,000
Sodium chloride	514,000	257,000	128,500
Calcium hydroxide	250,000	125,000	62,500
Detergent	600	550	500
Ammonia	2,400,000	1,200,000	600,000
Hydrochloric acid (37%)	9,500	5,500	3,400
Sodium hydroxide (50%)	7,500	4,300	2,700
Sodium hypochlorite	5,300	3,200	2,200
Cooling tower chemicals (total)	11,200	6,300	3,800
FACILITY AIR RELEASE POINTS			
Process Building Stack			
Height (ft)	100	100	100
Diameter (in)	104	98	91
Temperature (°F)	80	80	80
Flow velocity (ft/s)	60	60	60
Boiler Stack			
Height (ft)	100	100	100
Diameter (in)	26	23	21
Temperature (°F)	500	500	500
Flow velocity (ft/s)	60	60	60
CONSTRUCTION EMISSIONS AND WASTES			
Criteria Pollutants - peak construction yr (tons)			
SOx	1.8	1.8	1.7
NOx	30	30	28
HCs	8.2	8.2	7.7
CO	200	200	190
PM-10	50	41	32

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Wastes (total)			
Hazardous solids (yd3)	60	60	50
Hazardous liquids (gal)	25,000	23,000	20,000
Nonhazardous solids - steel (tons)	40	40	30
Nonhazardous solids - concrete+other (yd3)	1,130	1,020	900
Nonhazardous liquids - sanitary+other (gal)	5,000,000	4,600,000	4,000,000
AIR EMISSIONS DURING OPERATIONS (annual)			
Criteria Pollutants (lb)			
Release point: Boiler Stack			
SOx	60	42	31
NOx	8,100	5,700	4,200
HCs	170	120	90
CO	4,000	2,800	2,100
PM-10	300	210	160
Release point: Grade			
SOx	54	54	49
NOx	440	440	410
HCs	400	400	360
CO	2,500	2,500	2,460
PM-10	86	86	81
Other Pollutants (lb)			
HF (Process Building stack)	300	184	118
UF4 (Process Building stack)	3.8	2.3	1.3
U3O8 (Process Building stack)	1.2	0.7	0.4
Treatment chemicals (Cooling tower)	2,280	1,260	760
Minerals (Cooling tower)	23,000	13,000	7,800
RADIOLOGICAL EMISSIONS DURING OPERATIONS (annual)			
Depleted uranium in Proc Bldg stack gas (ci)	0.00070	0.00042	0.00025
Depleted uranium in liq at effluent outfall (ci)	0.00100	0.00070	0.00050
LOW LEVEL WASTE DURING OPERATION (annual)			
Combustible solid			
Total weight (lb)	216,000	201,000	195,000
Volume (yd3)	100	93	90
Uranium (U3O8) wt. (lb)	26	24	23
Packages (55 gal drums)	370	344	333

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Metal, surface contaminated			
Total weight (lb)	57,000	34,000	20,000
Volume (yd3)	35	21	12
Uranium (U3O8) wt. (lb)	67	40	24
Packages (55 gal drums)	129	78	45
Noncombustible compactible solid			
Total weight (lb)	12,000	9,900	8,500
Volume (yd3)	62	55	48
Uranium (U3O8) wt. (lb)	220	135	80
Uranium (UF4) wt. (lb)	750	460	270
Packages (4 x 2 x 7 ft boxes)	30	27	23
Other (Failed reactors)			
Total weight (lb)	120,000	90,000	54,000
Volume (yd3)	48	34	23
Uranium (U metal) wt. (lb)	981	440	230
Packages (boxes)	4.5	4.5	3
Package size (ft)	6x6x8	5x5x8	5x5x8
Other (Labpacks)			
Total weight (lb)	3,500	3,500	3,500
Volume (yd3)	2.2	2.2	2.2
Uranium (U3O8) wt. (lb)	4	4	4
Packages (55 gal drums)	8	8	8
HAZARDOUS WASTE DURING OPERATION (annual)			
Organic liquids			
Total weight (lb)	4,500	4,000	3,600
Volume (yd3)	3.0	2.7	2.4
Haz. matl (solvent/oil/paint) wt. (lb)	4,500	4,000	3,600
Packages (55 gal drums)	11	10	9
Inorganic process debris			
Total weight (lb)	8,100	7,300	6,500
Volume (yd3)	5.0	4.5	4.0
Haz. matl (HF+NaOH) wt. (lb)	16	15	13
Packages (55 gal drums)	19	17	15
Combustible debris			
Total weight (lb)	540	540	540
Volume (yd)	1.0	1.0	1.0
Haz. matl (HF+NaOH) wt. (lb)	2	2	2
Packages (55 gal drums)	4	4	4

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
Other			
Total weight (lb)	970	970	970
Volume (yd3)	0.6	0.6	0.6
Haz. matl (mercury) wt. (lb)	trace	trace	trace
Packages (55 gal drums)	2	2	2
MIXED LLW DURING OPERATION (annual)			
Total weight (lb)	1,890	1,890	1,890
Total volume (yd3)	1.5	1.5	1.5
Total uranium (U3O8) wt. (lb)	2.1	2.1	2.1
Total haz. matl (acetone) wt. (lb)	2.1	2.1	2.1
Total packages (55 gal drums)	6	6	6
NONHAZARDOUS WASTE DURING OPERATION (annual)			
Sanitary liquid (gal)	1,360,000	1,270,000	1,230,000
Other liquid (gal)	25,500,000	15,200,000	9,900,000
Other solid			
MgF2 (yd3)	7,990	4,000	2,000
Administrative waste (yd3)	525	490	475
Recyclable solid (yd3)	215	200	195
TRANSPORTATION SUMMARY-INPUT MATERIALS			
UF6			
Packages/yr	2,322	1,161	581
Packages/shipment (rail)	48	48	48
Packages/shipment (truck)	1	1	1
Shipments/yr (rail)	49	25	13
Shipments/yr (truck)	2,322	1,161	581
HCl			
Packages/yr	18	10	7
Packages/shipment (truck)	9	5	7
Shipments/yr (truck)	2	2	1
NaOH			
Packages/yr	11	7	4
Packages/shipment (truck)	6	7	4
Shipments/yr (truck)	2	1	1
NH3			
Packages/yr	46	23	12
Packages/shipment (rail)	1	1	1
Shipments/yr (rail)	46	23	12

	UF6 THROUGHPUT CASES		
INPUT/OUTPUT SUMMARY (annual)	**100%**	**50%**	**25%**
TRANSPORTATION SUMMARY-OUTPUT MATERIALS			
Uranium metal			
Packages/yr	30,100	15,050	7,525
Packages/shipment (rail)	320	320	320
Packages/shipment (truck)	28	28	28
Shipments/yr (rail)	94	47	24
Shipments/yr (truck)	1,075	538	269
Anhydrous HF			
Packages/yr	82	41	21
Packages/shipment (rail)	6	3	2
Shipments/yr (rail)	14	14	13
LLW in 55 gal drums			
Packages/yr	507	430	386
Packages/shipment (truck)	40	40	40
Shipments/yr (truck)	13	11	10
LLW in boxes			
Packages/yr	35	32	26
Packages/shipment (truck)	7	7	7
Shipments/yr (truck)	5	5	4
Hazardous waste			
Packages/yr	36	33	30
Packages/shipment (truck)	18	17	15
Shipments/yr (truck)	2	2	2
Mixed waste			
Packages/yr	6	6	6
Packages/shipment (truck)	6	6	6
Shipments/yr (truck)	1	1	1
Empty UF6 cylinders			
Packages/yr	2,322	1,161	581
Packages/shipment (rail)	48	48	48
Packages/shipment (truck)	6	6	6
Shipments/yr (rail)	49	25	13
Shipments/yr (truck)	387	194	97

Table 4-2: On-Site Employment During Operation
Continuous Reduction to Uranium Metal Facility

Labor Category	Number of Employees[1]
Officials and Managers	8/8/8
Professionals	8/8/8
Technicians	29/29/29
Office and Clerical	20/20/20
Craft Workers (Maintenance)	11/10/9
Operators	91/79/75
Line Supervision	15/14/13
Security	27/27/27
TOTAL EMPLOYEES (for all on-site facilities)	209/195/189

[1] Numbers correspond to 100%/50%/25% capacity cases.

Table 4-3: Number and Location of Employees During Operation [1]
Continuous Reduction to Uranium Metal Facility

Facility	Shift 1	Shift 2	Shift 3	Shift 4[2]
Process Building	38/37/36	22/21/20	22/21/20	22/21/20
HF Storage Building	2/2/2	1/1/1	1/1/1	1/1/1
Mg Metal Storage Building	1/1/1	1/0/0	1/0/0	1/0/0
Uranium Product Storage Building	3/1/1	1/1/1	1/1/1	1/1/1
MgF2 Storage Building	1/1/1	1/1/1	1/1/1	1/1/1
Cylinder Storage Pad and Building	7/5/3	3/2/2	3/2/2	3/2/2
Utilities/Services/ Admin Areas	40/40/40	10/10/10	10/10/10	10/10/10
TOTAL EMPLOYEES	92/87/84	39/36/35	39/36/35	39/36/35

[1] Numbers correspond to 100%/50%/25% capacity cases.
[2] The 4th shift allows coverage for 7 days per week operations.

**Table 4-4: Number of Construction Employees Needed by Year [1]
Continuous Reduction to Uranium Metal Facility**

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170/170/170	290/270/250	510/490/430	250/220/170
Construction Management and Support Staff	30/30/30	60/60/50	90/90/80	50/40/30
TOTAL EMPLOYEES	200/200/200	350/330/300	600/580/510	300/260/200

1 Number of employees shown are for the peak of the year. Average for the year is 60% of the peak. Numbers correspond to 100%/50%/25% capacity cases.

Figure 4-1: Site Map for Continuous Reduction to Uranium Metal Facility - 100% Capacity

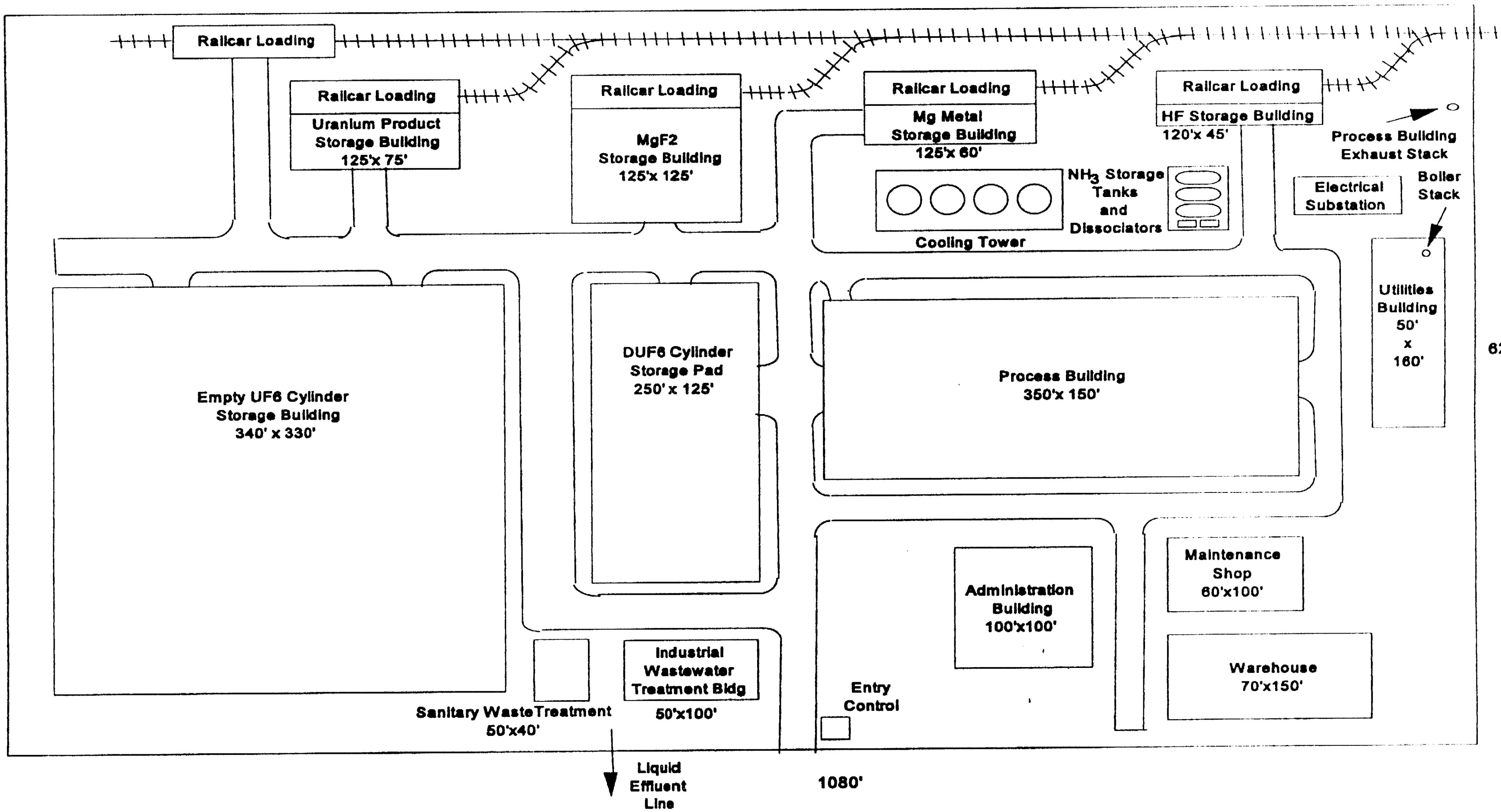


Figure 4-2: Site Map for Continuous Reduction to Uranium Metal Facility - 50% Capacity

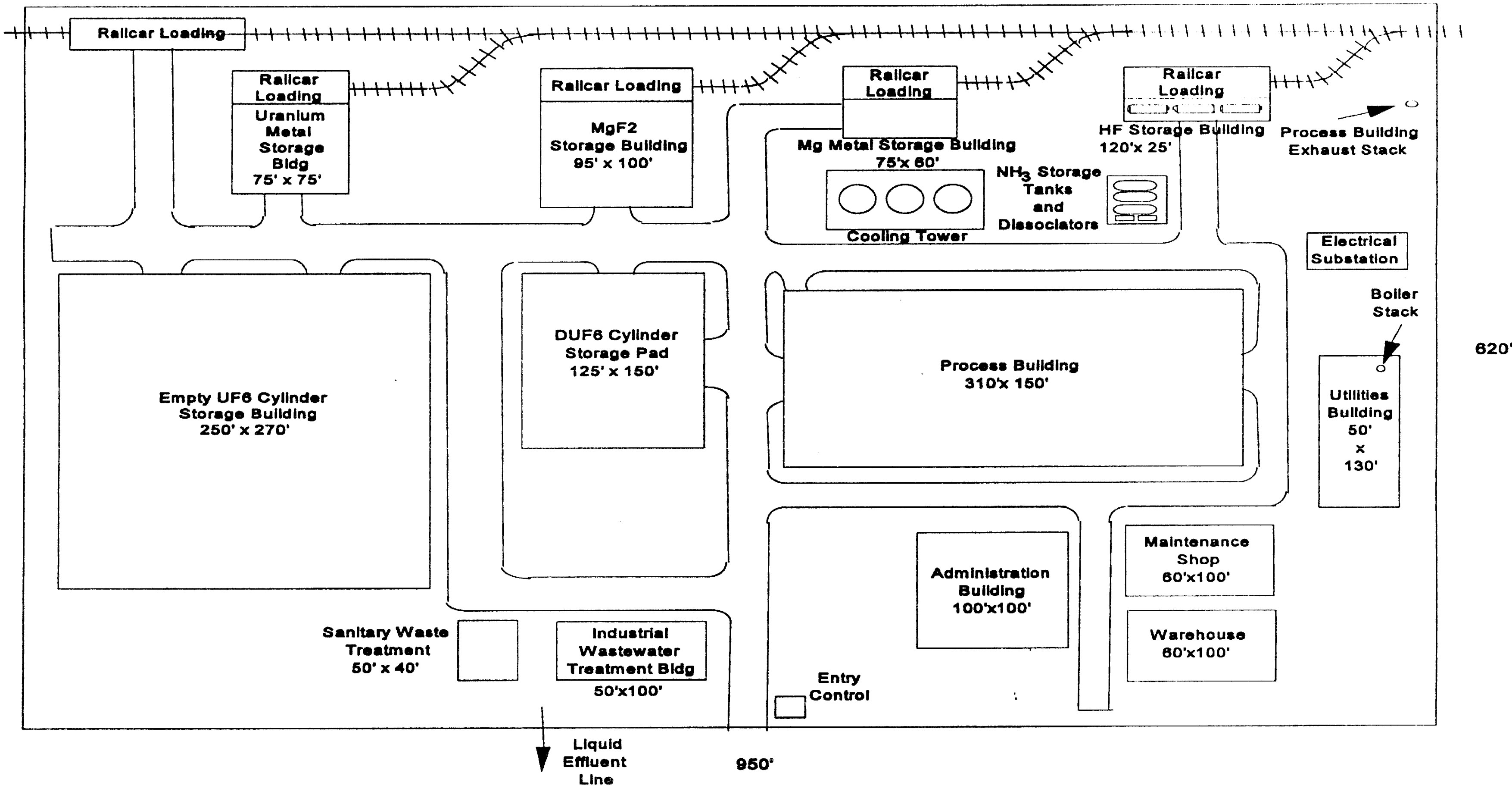


Figure 4-3: Site Map for Continuous Reduction to Uranium Metal Facility - 25% Capacity

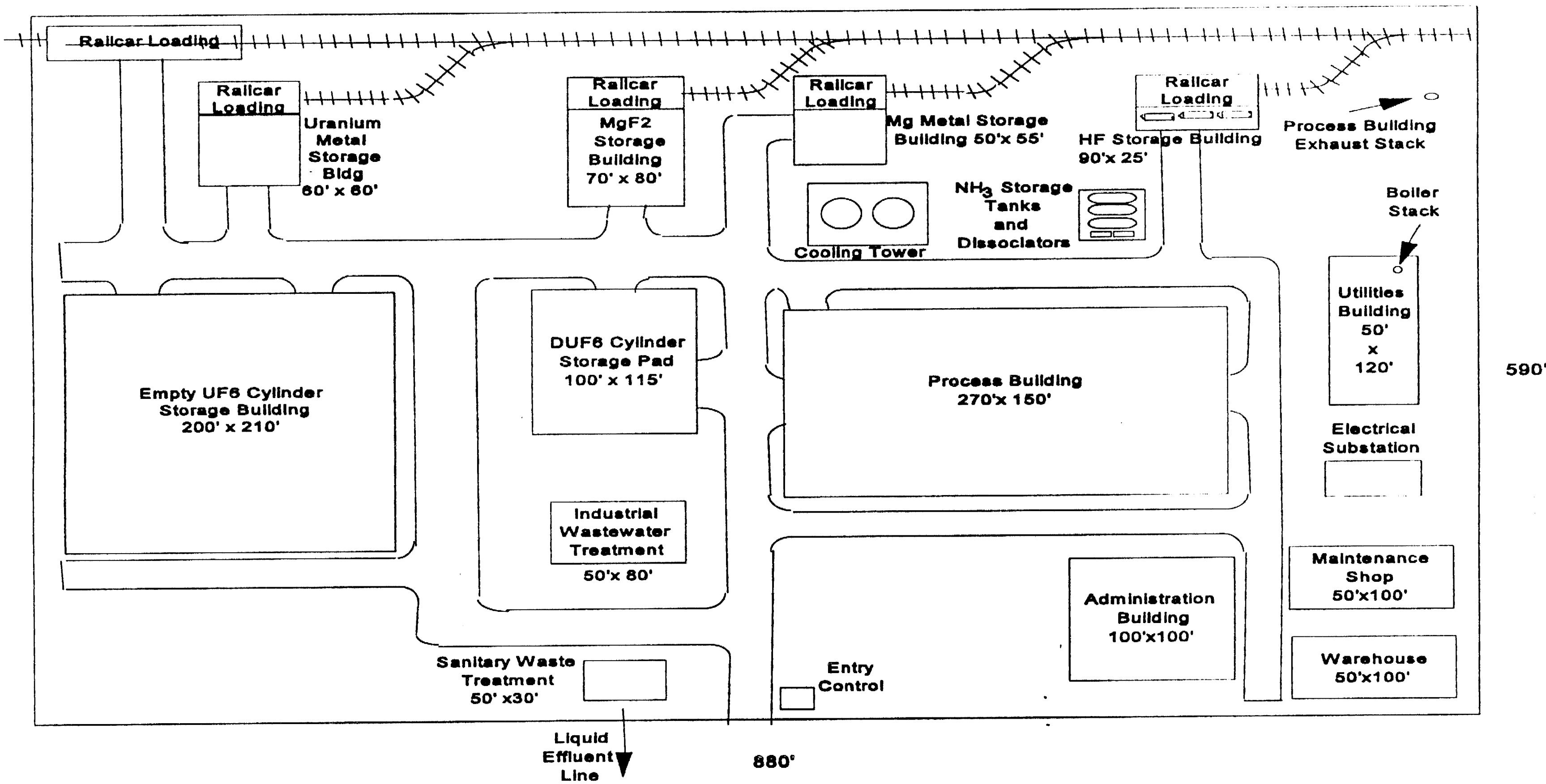


Figure 4-4: Site Map for Continuous Reduction to Uranium Metal Facility Construction - 100% Capacity

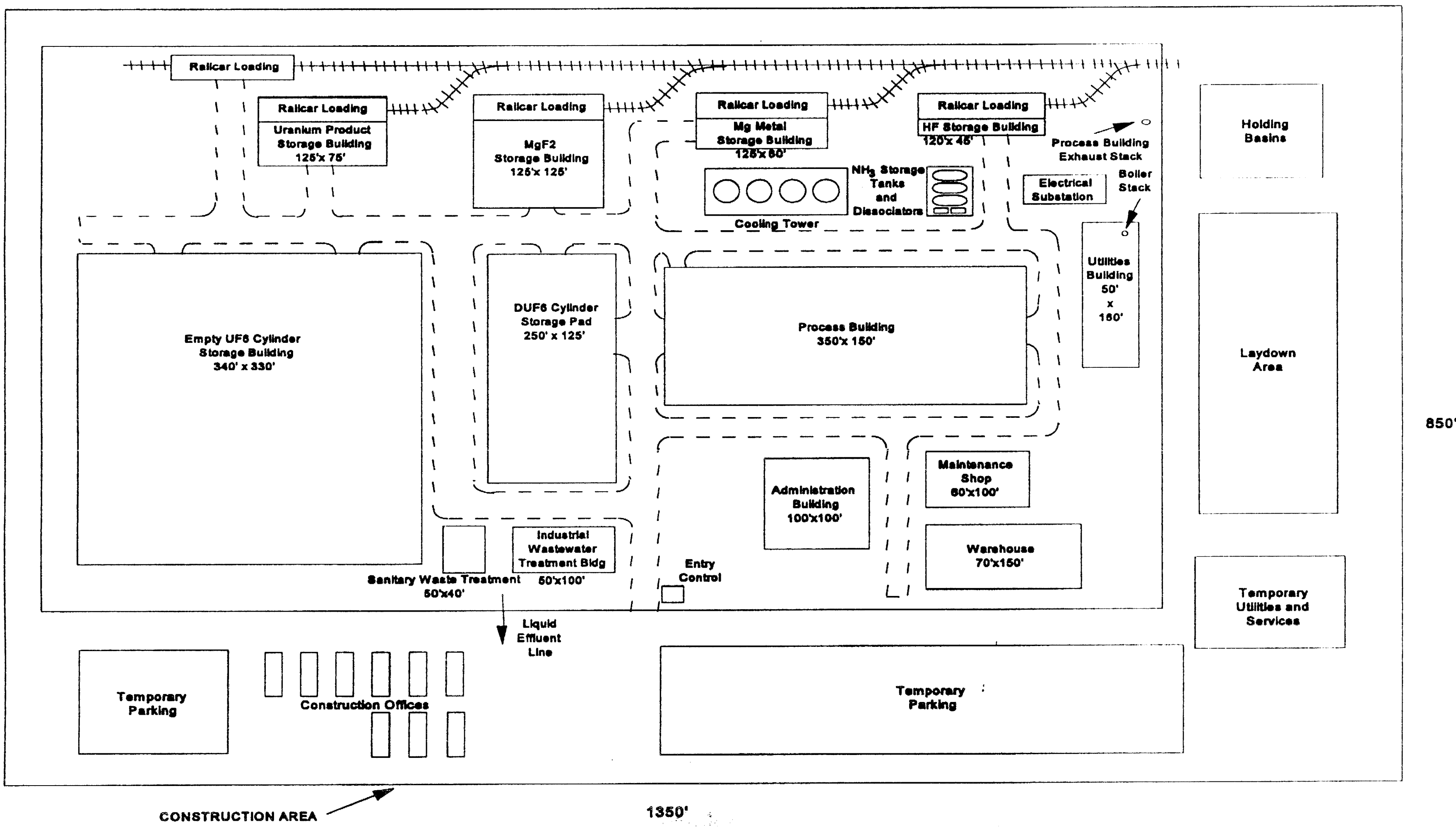


Figure 4-5: Site Map for Continuous Reduction to Uranium Metal Facility Construction - 50% Capacity

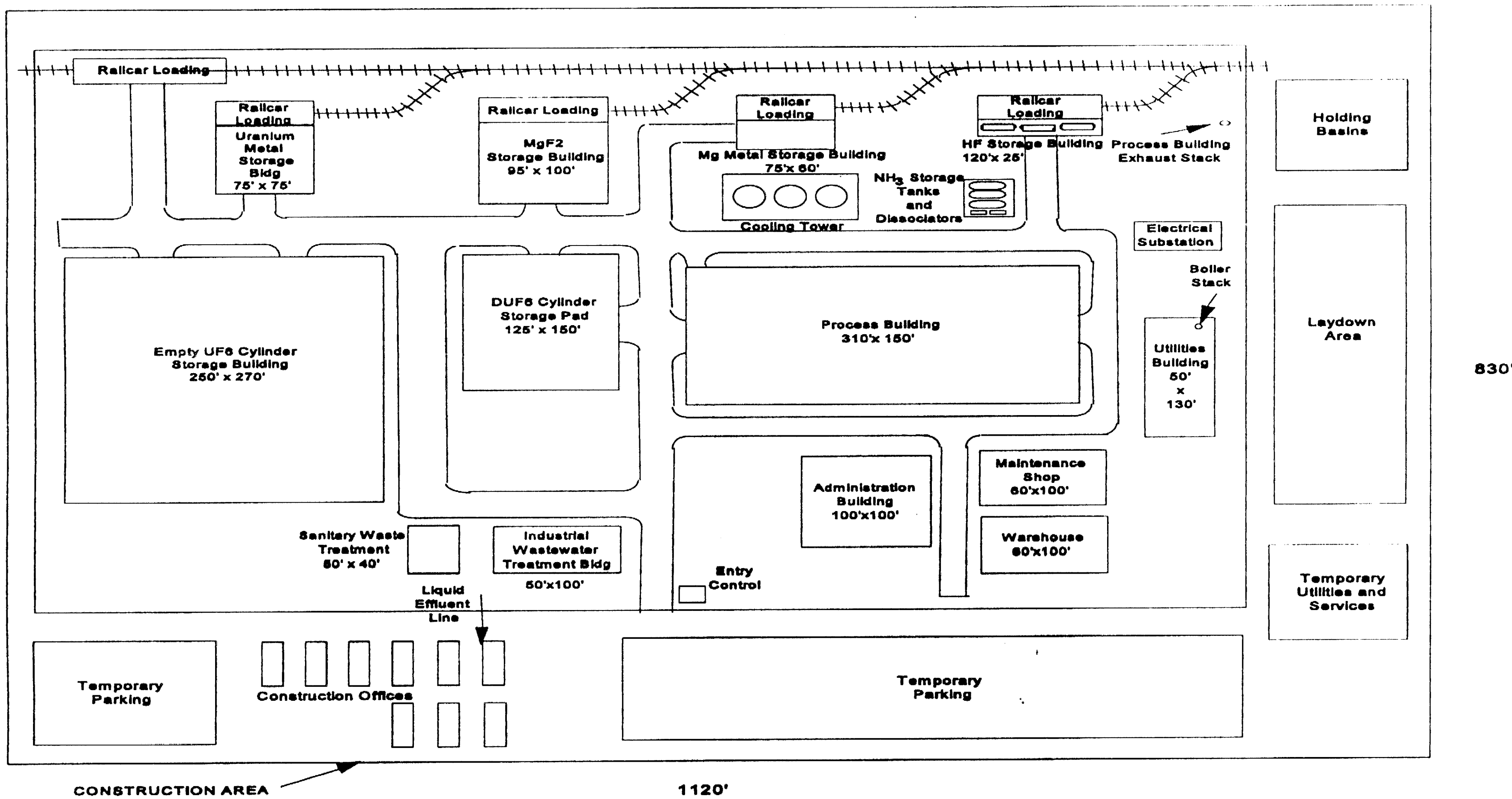
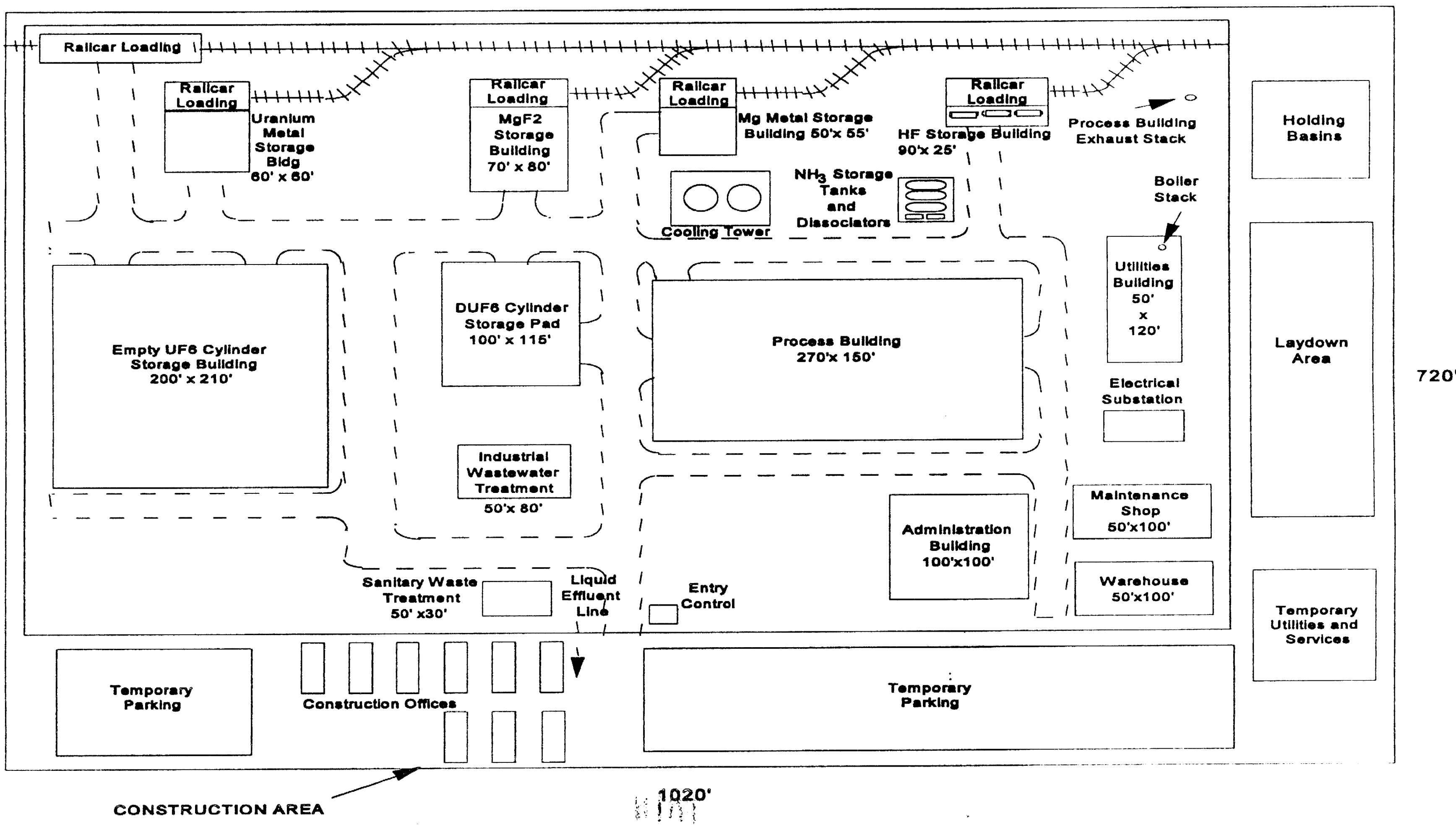


Figure 4-6: Site Map for Continuous Reduction to Uranium Metal Facility Construction - 25% Capacity



4.3 Accident Analysis

Most of the accidents associated with the facility remain unchanged. However some accidents have changed because their source term was dependent on the facility throughput. These accidents are shown in Tables 4-5 and 4-6. The narrative for these accidents, with revisions underlined, follows. Note that accidents associated with transfer of HF from the Process Building to the HF Storage Building do not change because the transfer is a batch operation at the same flow rate.

Table 4-5: Bounding Postulated Accident Summary
Continuous Reduction to Uranium Metal Facility

Accident	Frequency	Respirable Airborne Material Released to Environment [1]
Earthquake	Extremely Unlikely	.058/.029/.015 lb U_3O_8
HF System Leak	Anticipated	3.6/1.8/0.9 lb HF
Loss of Cooling Water	Anticipated	17/8.5/4.3 lb HF
Hydrogen Explosion	Extremely Unlikely	.05/.025/.013 lb UF_4 2/1/0.5 lb HF
Uranium Metal Fire	Unlikely	.058/.029/.015 lb U_3O_8
Reactor Rupture	Extremely Unlikely	2.6×10^{-3}/1.2×10^{-3}/ 8.9×10^{-4} lb U_3O_8

[1] Quantities correspond to 100%/50%/25% capacity cases.

**Table 4-6: Accident Source Terms and Parameters
Continuous Reduction to Uranium Metal Facility**

Accident	Effective Material at Risk [1]	Respirable Airborne Fraction	Fraction of Respirable Airborne Material Released to Environment	Release Duration
Earthquake	49,000/24,500/12,250 lbU (58,000/29,000/14,500 lbU_3O_8)	1×10^{-3}	1×10^{-3}	30 min
HF System Leak	9/4.5/2.3 lb HF	1	.4	15 min
Loss of Cooling Water	17/8.5/4.3 lb HF	1	1	2 min
Hydrogen Explosion	1,000/500/250 lb UF_4 2/1/0.5 lb HF	.05 1	1×10^{-3} 1	30 min
Uranium Metal Fire	49,000/24,500/12,250 lb U (58,000/29,000/14,500 lbU_3O_8)	1×10^{-3}	1×10^{-3}	30 min
Reactor Rupture	2,200/1,000/750 lb U (2,600/1,200/890 lb U_3O_8)	1×10^{-3}	1×10^{-3}	15 min

[1] Quantities correspond to 100%/50%/25% capacity cases.

4.3.1 Earthquake

Structures in high hazard areas of the Process Building and HF Storage Building (i.e., in areas with high inventories of HF or UF_6 at elevated temperatures) are designed for the performance category PC-4 DBE. Therefore, failure of these structures in the event of the DBE is incredible. In the extremely unlikely event that an earthquake exceeding the PC-3 DBE or failure of PC-3 SSCs in the Process Building occurs, it is postulated that a fire occurs in the metal storage area. The resulting consequences would be bounded by the fire scenario described in Section 3.5.5.

4.3.2 HF System Leak

Gaseous HF is produced from the reactions in the UF_6 reduction process. The HF is condensed and collected. Possible accidents include leakage from a vessel, pump, or pipe.

It is postulated that the off-gas line from a reactor to the condenser leaks 5% of its flowing contents for 10 minutes, thus releasing 9/4.5/2.3 lb (100%/50%/25% cases) of HF into the process building. After the leak is detected by air monitoring instruments, the reactor feed is halted to stop the leak. It is assumed that about 40% of the HF vapor (3.6/1.8/0.9 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

4.3.3 Loss of Cooling Water

Pressure relief valves are provided to protect the reactors, vessels, and equipment. Loss of cooling water to the UF_6 reactor HF cooler or condenser would cause the reactor pressure to rise and the relief valve to open. It is postulated that cooling water is lost and all of the hot off-gas flows through the relief valve for one minute, releasing 17/8.5/4.3 lb of HF. High temperature and pressure alarms and interlocks would shut down the feed input to the reactor to stop the release. The HF scrubber would also condense some of the HF to prevent overpressure. About 17/8.5/4.3 lb of HF would be discharged through the relief valve and released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

4.3.4 Hydrogen Explosion

Hydrogen is fed to the reduction reactors as a reagent to react with UF_6. There are two reactors in parallel, and each reactor receives about 30/15/7.5 lb/hr of hydrogen. Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. The reactor vapor space normally contains excess unreacted hydrogen, HF, and nitrogen. There is normally no air in the reactor. Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the reactor, air to leak into the reactor, and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

Assuming the reactor normally contains a 15 minute holdup of material, the reactor contains about 2,000/1,000/500 lb of UF_4. It is assumed that 50% of the uranium is released into the room, and that 100% of that material becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the uranium. Thus, .05/.025/.013 lb of UF_4 would be discharged through the Process Building exhaust stack. Also, assuming the reactor contains 2/1/0.5 lb of HF, this would also be released in this accident. This accident is judged to be extremely unlikely.

4.3.5 Uranium Metal Fire

Most of the areas where uranium and other hazardous materials are handled do not contain combustible materials that would support a fire of any significant magnitude. In the uranium product loading area; however, the uranium billets are packaged in wooden boxes. In the unlikely event that a fire occurs in this area, it is postulated that up to one shift's production of uranium billets may accumulate in the area (654/327/164 billets each weighing 75 lb). A fraction of 0.1% is assumed to be released as respirable airborne particles in this event, with 99.9% filtration efficiency in the building HVAC system, resulting in about .049/.025/.013 lb of uranium (.058/.029/.015 lb U_3O_8) being released to the atmosphere through the Process Building exhaust stack.

4.3.6 Reactor Rupture

There are three UF_4 continuous reduction reactors in the 100% case, each with a 3 ft diameter molten pool. There are three reactors in the 50% case, each with a 24 inch diameter pool, and two reactors in the 25% case, each with a 21 inch diameter pool. Assuming a 3 ft deep pool and the bottom 10% of the pool is molten uranium (corresponding to a 1 hour uranium holdup time), there is about 2,200/1,000/750 lb of molten uranium in each reactor. In the extremely unlikely event of a reactor rupture, the molten metal could become exposed to air, oxidize, and be released as airborne particles. A fraction of 0.1% is assumed to be released as respirable airborne particles in this event, with 99.9% filtration efficiency in the building HVAC system, resulting in about 2.2 x 10^{-3}/1.0 x 10^{-3}/7.5 x 10^{-4} lb of uranium (2.6 x 10^{-3}/1.2 x 10^{-3}/8.9 x 10^{-4} lb U_3O_8) being released to the atmosphere through the Process Building exhaust stack.

5.0 Potential Shielding Applications in Metal and Oxide Forms

The shielding facility receives depleted uranium metal or dense UO_2 and fabricates metal or DUCRETE™ shields for spent nuclear fuel. For uranium metal shielding, this section describes the use of 301,000 and 150,500 billet boxes for the 50% and 25% cases, respectively. For uranium dioxide-based shielding (DUCRETE™), this section describes the use of 321,500 and 160,750 drums for the 50% and 25% cases, respectively. The facility description and other data are provided in Section 6.11 of this EAR. General assumptions, design bases, facility description and process descriptions have not changed. Major changes due to the decreased capacity are provided in this section.

5.1 Data Summary

The analysis was influenced by many factors, including the number of storage buildings required for material received and produced, transportation of material, process throughput, and the number of people required to operate the facility. The number of uranium pouring stations for the metal facility (the High Temperature Shielding Manufacture Facility or HTSMF) and of DUCRETE™ mixing stations for the oxide facility (the Low Temperature Shielding Manufacture Facility or LTSMF) were reduced by half for the 50% case, but could not be reduced further for the 25% case. The number of storage buildings was reduced as throughput decreased for both facilities.

Table 5-1 shows the pertinent parametric data for the oxide facility, and Table 5-2 shows the data for the metal facility.

Figures 5-1 through 5-3 display the site layouts for the oxide facility for the three material flow cases. Figures 5-4 through 5-6 display similar data for the metal facility cases. Employment data is tabulated in the pages following the figures.

Table 5-1: DUCRETE™ Shielding Facility (LTSMF)

ITEMS		Material Capacity		
	Units	100%	50%	25%
INPUT/OUTPUT SUMMARY (annual)				
Uranium dioxide	te	21,477	10,739	5,369
Finished casks	#	480	240	120
LAND USE REQUIREMENTS				
Site Land Area	ha	36	34	32
Building Footprint Area	m^2	58,238	46,155	39,892
Total Paved Area	ha	6	6	6
CONSTRUCTION RESOURCES				
Construction Period	yr	4	4	4
Concrete	m^3	45,981	34,273	28,242
Steel	te	10,500	7,826	6,449
Water	ML	132	98	81
Diesel Fuel	ML	2.3	1.7	1.4
Gasoline	ML	0.6	0.5	0.5
Electricity	MW-yrs	4.7	3.5	2.9
OPERATIONS RESOURCES (annual)				
Diesel Fuel	L	7,500	7,000	6,500
Gasoline	L	21,350	18,080	15,260
Natural gas	m^3	5.80E+5	4.60E+05	3.97E+05
Electricity	kWh	3,811	2,824	2,319
Cement	te	2,909	155	727
Water	ML	28	25	21
Waste Drums	#	534	372	273
Stainless Steel	te	9,610	4,805	2,402
Weld Metal	te	240	120	60
Argon	ML	137	69	34
EMPLOYMENT				
Construction (total)	Man yr	2,560	2,335	2,260
Objective (annual)	Man yr	470	398	336
CONSTRUCTION EMISSIONS AND WASTES				
Emissions				
CO	tons	50	41	36
HC	tons	19	15	13
NOx	tons	234	175	144
SOx	tons	15	12	9
PM-10	tons	17	13	11
Waste				
Wastewater	ML	38	34	33

ANNUAL EMISSIONS AND WASTES				
Emissions				
CO	tons	0.91	0.76	0.65
NC	tons	0.21	0.18	0.15
NOx	tons	3.15	2.67	2.39
SOx	tons	0.16	0.14	0.12
PM-10	tons	0.19	0.16	0.14
Uranium	g	8	6	5
Waste				
Empty 30 gallon drums	#	30,542	15,271	7,636
Empty 30 gallon drums (contaminated) (2)	#	1,608	804	402
Compacted Facility Waste (in drums) (2)	L	3,900	1,950	975
Cemented Facility Waste (in drums) (2)	L	39,000	19,500	9,750
Carbon from filters (in drums) (3)	L	2,000	1,600	1,200
DAW - PPEs, swipes, etc. (In drums) (1)	L	53,300	45,135	38,104
Ion Exchange Resins (in drums) (3)	L	2,800	2,240	1,680
HEPA filters (in boxes) (4)	L	25,000	19,400	16,700
Low-level waste - failed mixers (2)	m^3	6	3	2
Uranium (total in LLW)	kg	8,500	6,800	5,100
Used DUCRETE™ - end of life	m^3	3,678	1,839	920
Wastewater	ML	18	16	14
TRANSPORT SUMMARY				
Inputs				
Drums UO_2 per year	#	32,150	16,075	8,038
Drums UO_2 per shipment (truck)	#	24	24	24
Drums UO_2 per shipment (rail)	#	304	304	304
Annual number of shipments (truck)	#	1,340	670	335
Annual number of shipments (rail)	#	106	53	26
Outputs				
Finished Shields	Shipments	480	240	120
Empty UO_2 Containers (all truck)	Shipments	305	153	76
Empty UO_2 Containers (all rail)	Shipments	76	38	19
Contaminated UO_2 Containers (truck)	Shipments	16	8	4
Waste drums (truck)	Shipments	13	9	7

Waste Classifications

(1) Combustible solid (LLW)

(2) Non-combustible, non-compactible solid (LLW)

(3) Organic Solids (LLW)

(4) Non-combustible, compactible solid (LLW)

Table 5-2: Metal Shielding Facility (HTSMF)

ITEMS		Material Capacity		
	Units	100%	50%	25%
INPUT/OUTPUT SUMMARY (Annual)				
Uranium metal (97% U, 3% Fe)	te	19,516	9,758	4,879
Finished casks	#	453	226	13
LAND USE REQUIREMENTS				
Site Land Area	ha	36	34	32
Building Footprint Area	m^2	59,276	46,305	40,486
Total Paved Area	ha	7	7	7
CONSTRUCTION RESOURCES				
Construction Period	yr	4	4	4
Concrete	m^3	47,042	34,624	28,947
Steel	te	11,000	8,096	6,769
Water	ML	163	120	100
Diesel Fuel	ML	2.4	1.8	1.5
Gasoline	ML	0.7	0.7	0.7
Electricity	MW-yrs	4.9	3.6	3.0
OPERATIONS RESOURCES (annual)				
Diesel Fuel	L	7,500	7,000	6,500
Gasoline	L	21,200	18,000	15,200
Natural gas	m^3	8.96E+05	6.17E+05	4.84E+05
Electricity	kWh	4,709	3,251	2,558
Cement	te	39	20	10
Water	ML	28	25	22
Graphite	te	1,000	500	250
Waste Drums	#	3,300	1,800	1,000
Stainless Steel	te	11,414	5,707	2,854
Weld Metal	te	380	190	95
Argon	ML	137	69	34
Nitrogen	ML	20,853	17,203	15,483
EMPLOYMENT				
Construction (total)	Man yr	3,180	2,955	2,880
Operation (annual)	Man yr	466	396	335
CONSTRUCTION EMISSIONS AND WASTES				
Emissions				
CO	tons	53	39	36
HC	tons	21	16	13
NOx	tons	250	184	154
SOx	tons	16	11	10
PM-10	tons	17	12	11
Waste				
Wastewater	ML	47	44	43

ANNUAL EMISSIONS AND WASTES				
Emissions				
CO	tons	1.13	0.88	0.72
HC	tons	0.22	0.17	0.15
NOx	tons	3.59	2.74	2.29
SOx	tons	0.16	0.14	0.12
PM-10	tons	0.21	0.15	0.13
Uranium	g	50	40	30
Waste				
Empty Wooden Containers	#	28,595	14,298	7,149
Empty Wooden Containers (contaminated) (1)	#	1,505	753	376
Compacted Facility Waste (in drums) (2)	L	3,900	1,950	975
Cemented Facility Waste (in drums) (2)	L	39,000	19,500	9,750
Carbon from filters (in drums) (3)	L	2,000	1,600	1,200
DAW - PPEs, swipes, etc. (in drums) (3)	L	52,800	44,900	38,000
DAW - Graphite (in drums) (1)	L	526,200	263,100	131,600
Ion Exchange Resins (in drums) (3)	L	2,800	2,240	1,680
HEPA filters (in boxes) (4)	L	25,000	19,400	16,700
Uranium (total in LLW)	kg	4,000	3,200	2,400
Wastewater	ML	19	16	14
TRANSPORT SUMMARY				
Inputs				
Packages (Billet Boxes) per year	#	30,100	15,050	7,525
Packages per shipment (truck)	#	28	28	28
Packages per shipment (rail)	#	320	320	320
Annual number of shipments (truck)	#	1,075	538	269
Annual number of shipments (rail)	#	94	47	24
Outputs				
Finished Casks	Shipments	226	226	113
Empty Billet Boxes (truck)	Shipments	143	143	71
Empty Billet Boxes (rail)	Shipments	48	48	24
Contaminated Empty Billet Boxes (truck)	Shipments	8	8	4
Waste drums (truck)	Shipments	45	45	25

Waste Classifications
(1) Combustible solid (LLW)
(2) Non-combustible, non-compactible solid (LLW)
(3) Organic Solids (LLW)
(4) Non-combustible, compactible solid (LLW)

Figure 5-1: LTSMF Site Map for 100% Capacity

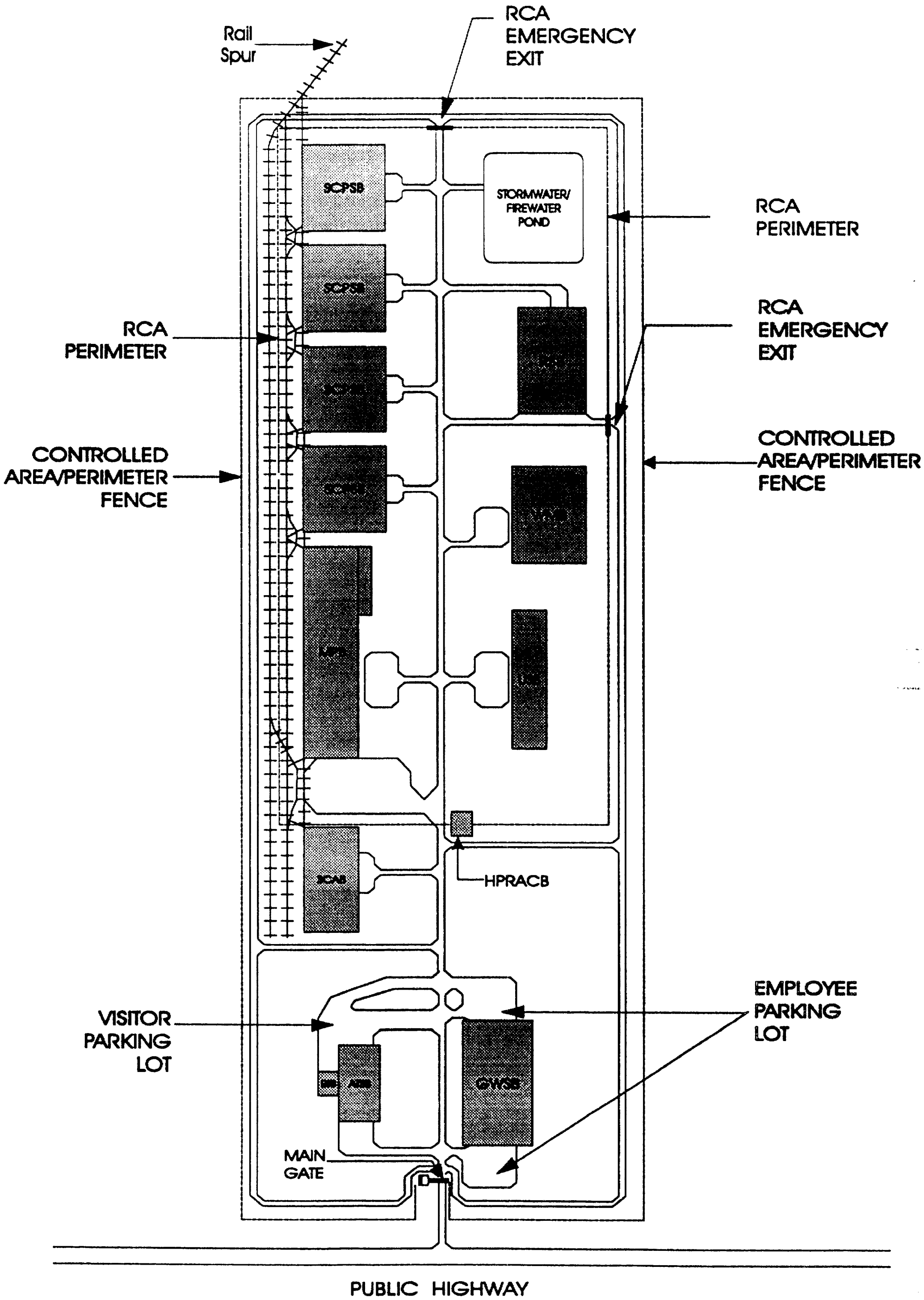


Figure 5-2: LTSMF Site Map for 50% Capacity

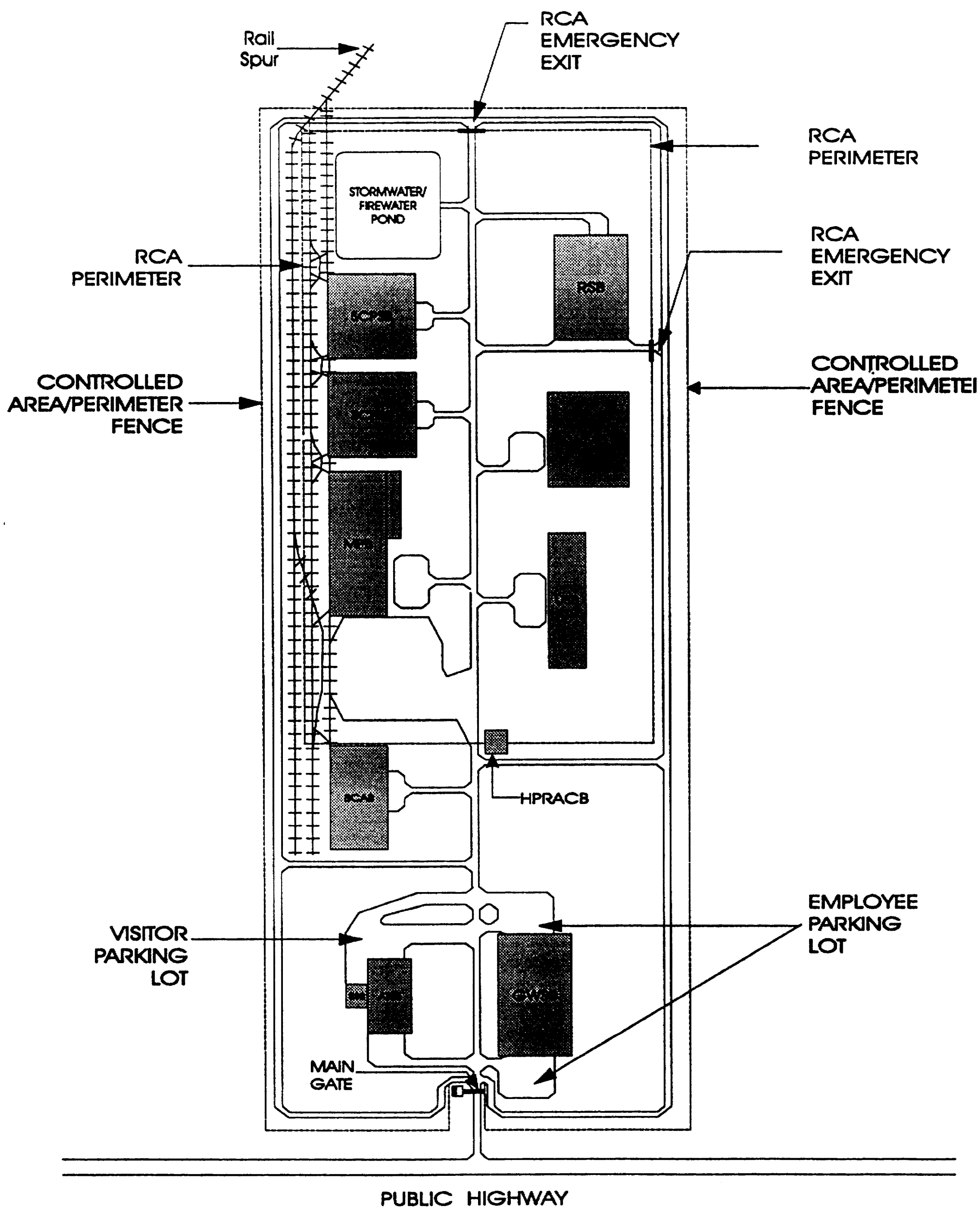


Figure 5-3: LTSMF Site Map for 25% Capacity

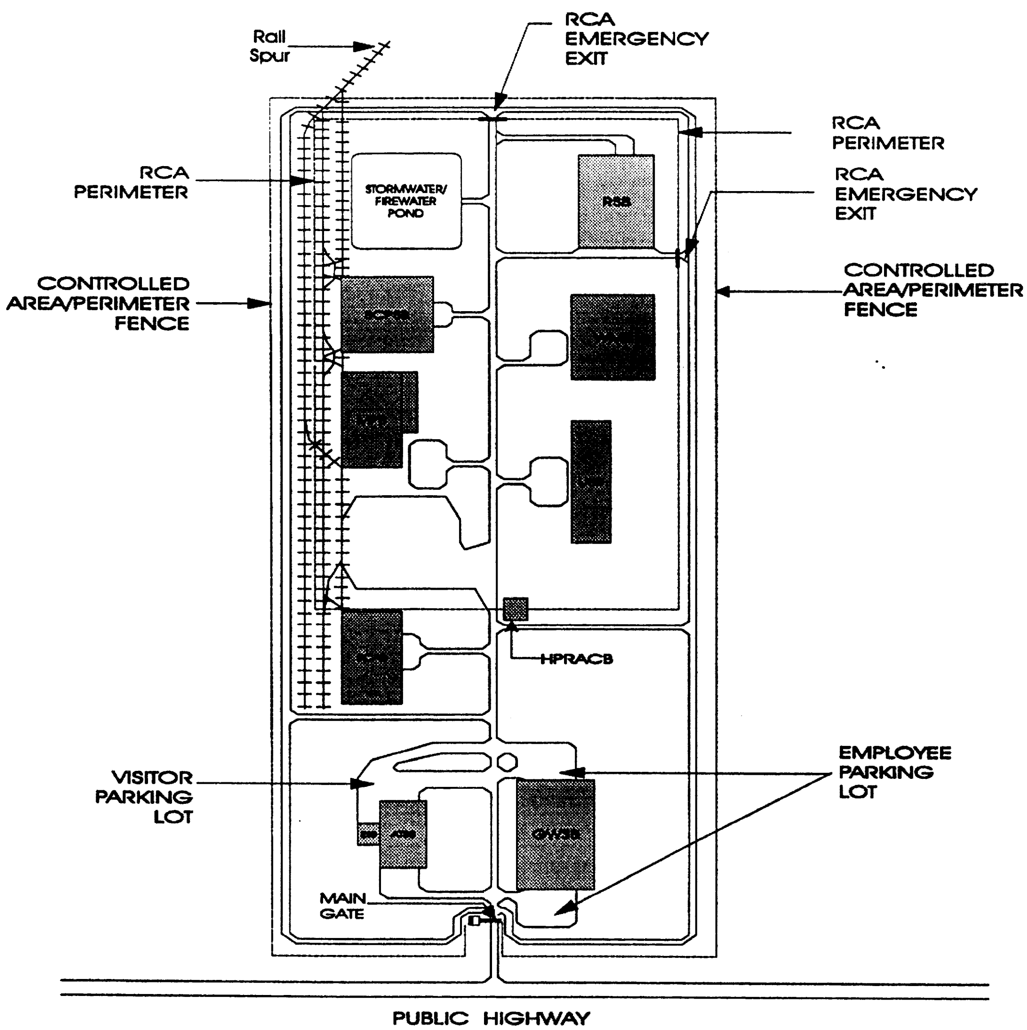


Figure 5-4: HTSMF Site Map for 100% Capacity

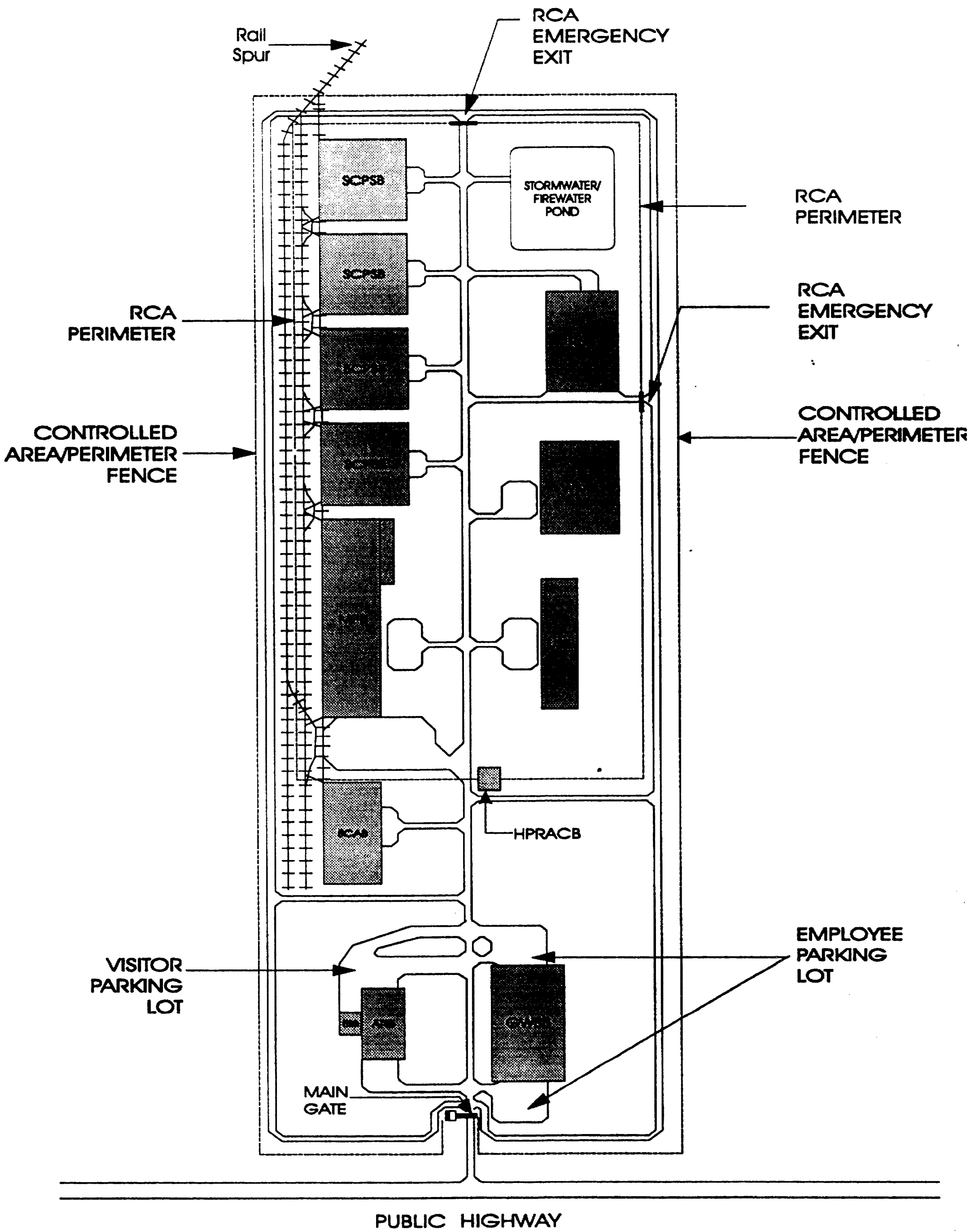


Figure 5-5: HTSMF Site Map for 50% Capacity

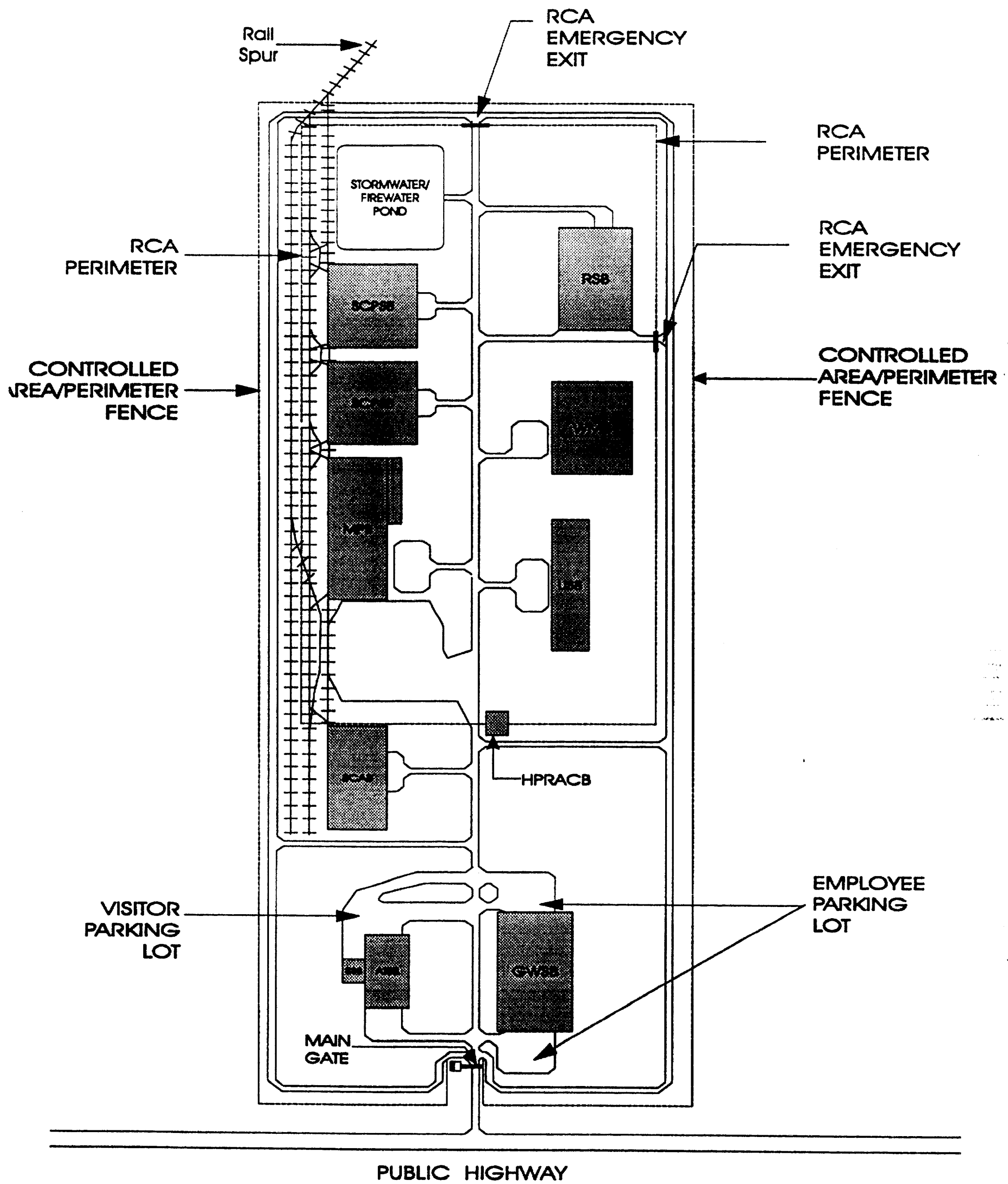
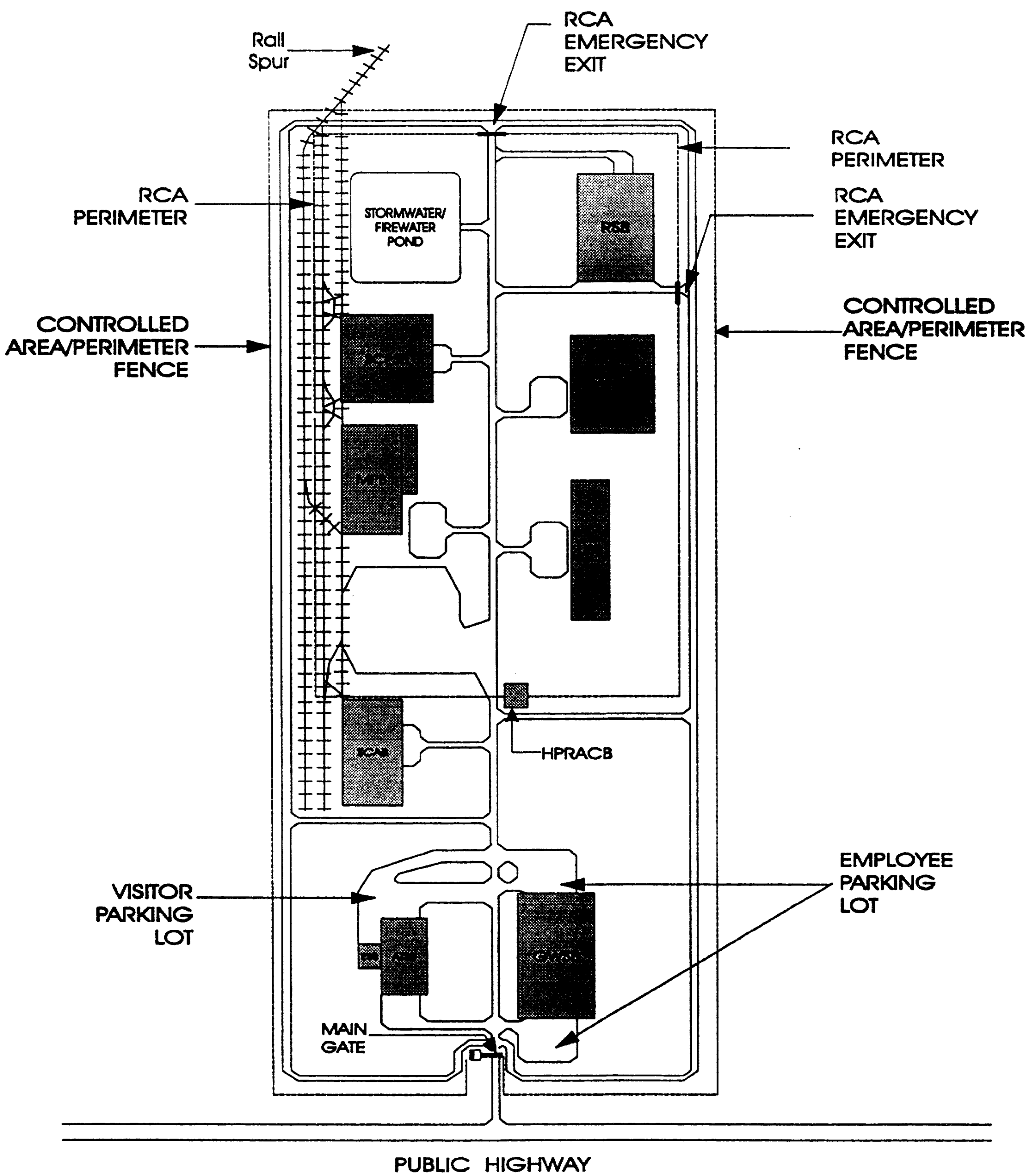


Figure 5-6: HTSMF Site Map for 25% Capacity



5.2 Employment (Oxide and Metal Facilities)

Table 5-3 provides labor category descriptions and estimated minimum numbers of employees required to operate the facility for the three parametric cases of shielding.

Table 5-3: Parametric Employment Data for Oxide and Metal Shielding Manufacture at 100%, 50%, and 25% Material Capacity

Labor category	Number of Employees		
	100%	50%	25%
Oxide shielding			
Managers	31	31	24
Secretary/Records	18	18	14
Engineer/Supervisory Operator	90	80	66
Technicians	283	221	184
Security	24	24	24
Firefighter	16	16	16
Paramedic	8	8	8
Total	470	398	336
Metal Shielding			
Managers	33	31	29
Secretary/Records	18	18	18
Engineer/Supervisory Operator	95	82	71
Technicians	272	217	169
Security	24	24	24
Firefighter	16	16	16
Paramedic	8	8	8
Total	466	396	335

6.0 Storage of UF_6 and UO_2 in Buildings

Storage options for depleted uranium are considered in Section 6.12 of this EAR. The types of storage facilities analyzed are (1) buildings, (2) below ground vaults, and (3) mined cavities. The three chemical forms analyzed are (1) UF_6 (2) U_3O_8, and (3) UO_2. For comparative purposes, the aboveground building storage options for UF_6 and UO_2 have been analyzed to develop engineering data. For UF_6, this equates to the storage of 23,211 and 11,606 cylinders for 50% and 25% cases, respectively. For UO_2, this equates to the storage of 210,000 and 105,000 drums for the 50% and 25% cases, respectively.

6.1 Data Summary

The parameters were influenced by many factors, including the number of storage buildings required for the material received, the total site area required for those buildings, the transportation of the material on the site, and the labor involved in receiving, inspecting, moving, storing, and monitoring the material and the labor to maintain the facility and its equipment. In addition, the Receiving Warehouse and Repackaging Building were redesigned in this evaluation in order to provide facilities more closely tied to the amount of material that must be handled. This results in a significant reduction in the size of this building for both the 50% and 25% cases.

Table 6-1 incorporates all of the pertinent factors and parameters into a set of parametric data for UF_6 storage in a building. Table 6-2 provides the same information for UO_2 storage in a building.

Figures 6-1 through 6-3 display the site layouts for the aboveground storage facility for the three UF_6 cases presented in the tables. Figures 6-4 through 6-6 display the site layouts for the UO_2 cases. The revised designs of the Receiving Warehouse and Repackaging Building are presented in Figures 6-7 through 6-9 for UF_6 storage and in figures 6-10 through 6-12 for UO_2 storage.

Employment data for operations and construction of the aboveground storage facility are included at the end of this report.

TABLE 6-1: PARAMETRIC DATA FOR UF_6 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY

ANNUAL INPUT/OUTPUT SUMMARY				
Item	Units	100%	50%	25%
UF6	Cylinders	2,322	1,161	581
Byproducts				
CaF2	kg	71	40	22
UO2F2	kg	140	79	44
LAND USE REQUIREMENTS				
Item	Units	100%	50%	25%
Total site area	ha	53	29	17
Total disturbed area	ha	25	12	6.5
Total paved area	ha	2.1	1.4	0.84
BUILDING NUMBERS AND DIMENSIONS				
Item	Units	100%	50%	25%
Storage buildings	number	17	8	4
Storage building size	m^2	13,250	13,250	13,250
Receiving warehouse size	m^2	4,422	2,704	1,739
CONSTRUCTION RESOURCES				
Item	Units	100%	50%	25%
Concrete	m3	69,000	33,000	17,000
Cement	tonnes	14,000	6,600	3,400
Sand	tonnes	35,000	17,000	8,500
Gravel	tonnes	68,000	32,000	16,000
Steel	tonnes	29,000	14,000	7,300
Macadam	m3	3,100	2,100	1,300
Water	ML	41	19	10
Diesel fuel	ML	1.1	0.5	0.3
Gasoline	KL	8.6	3.0	1.2
Electricity	MW-yrs	5.4	2.6	1.4
Excavations	m3	120,000	55,000	28,000

TABLE 6-1: PARAMETRIC DATA FOR UF_6 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY (continued)

EMPLACEMENT RESOURCES (annual)				
Item	Units	100%	50%	25%
Diesel	KL	52	23	8.6
Gasoline	KL	10	5.6	3.3
Electricity	MW-hrs	1,600	870	530
Natural gas	MSCM	0.31	0.17	0.10
Water	ML	4.4	3.4	2.6
Containers				
Type 48 cylinders	each	16	9	5
55-gallon drums	each	17	10	7
CaO	kg	54	32	22
SURVEILLANCE AND MONITORING RESOURCES (annual)				
Item	Units	100%	50%	25%
Diesel	KL	0.023	0.010	0.0037
Gasoline	KL	8.0	4.4	2.7
Electricity	MW-hrs	1,600	860	520
Natural gas	MSCM	0.31	0.17	0.10
Water	ML	3.6	2.7	2.1
Containers				
Type 48 cylinders	each	1	1	1
55-gallon drums	each	3	3	3
CaO	kg	3.2	3.2	3.2
EMPLOYMENT				
Item	Units	100%	50%	25%
Construction (total)	man-yrs	1,300	610	320
Operating (annual)	man-yrs	50	38	29
Maint & Monitor (annual)	man-yrs	40	30	24
CONSTRUCTION EMISSIONS AND WASTES				
Item	Units	100%	50%	25%
Emissions				
CO	tons	19.0	9.1	4.9
HC	tons	7.3	3.5	1.9
NOx	tons	89.3	42.3	22.3
SOx	tons	5.9	2.8	1.5
Dust	tons	75	37	19
PM-10	tons	6.3	3.0	1.6
Wastes				
Wastewater	ML	4.0	1.9	0.93

TABLE 6-1: PARAMETRIC DATA FOR UF_6 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY (continued)

ANNUAL EMISSIONS AND WASTES-EMPLACEMENT				
Item	Units	100%	50%	25%
Emissions				
CO	tons	1.3	0.58	0.21
HC	tons	0.42	0.18	0.071
NOx	tons	5.4	2.4	0.90
SOx	tons	0.33	0.14	0.056
PM-10	tons	0.37	0.17	0.062
HF	kg	0.0090	0.0050	0.0028
Wastes				
Wastewater	ML	4.2	3.2	2.5
Low-level waste	m3	3.0	1.6	0.93
UO2F2	kg	140	79	44
CaF2	kg	71	40	22
ANNUAL EMISSIONS AND WASTES-SURVEILLANCE AND MONITORING				
Item	Units	100%	50%	25%
Emissions				
CO	tons	0.36	0.15	0.059
HC	tons	0.06	0.025	0.010
NOx	tons	1.1	0.47	0.18
SOx	tons	0.050	0.021	0.0083
PM-10	tons	0.060	0.026	0.0099
HF	kg	0.00060	0.00060	0.00060
Wastes				
Wastewater	ML	3.4	2.5	2.0
Low-level waste	m3	0.20	0.20	0.20
UO2F2	kg	8.8	8.8	8.8
CaF2	kg	4.4	4.4	4.4
TRANSPORT SUMMARY				
Item	Units	100%	50%	25%
UF6				
Packages per year	cylinders	2,322	1,161	581
Packages/shipment (rail)	number	48	48	48
Packages/shipment (truck)	number	1	1	1
Shipments/yr (truck)	number	2,322	1,161	581

TABLE 6-2: PARAMETRIC DATA FOR UO_2 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY

ANNUAL INPUT/OUTPUT SUMMARY				
Item	Units	100%	50%	25%
UO_2	55-gal drums	21,000	10,500	5,250
LAND USE REQUIREMENTS				
Item	Units	100%	50%	25%
Total Site area	ha	32	20	15
Total disturbed area	ha	14	8.1	5.1
Total paved area	ha	1.4	1.1	0.81
BUILDING NUMBERS AND DIMENSIONS				
Item	Units	100%	50%	25%
Storage buildings	number	9	5	3
Storage building size	m2	13,250	13,250	13,250
Receiving warehouse size	m2	4,422	2,592	1,628
CONSTRUCTION RESOURCES				
Item	Units	100%	50%	25%
Concrete	m3	37,000	21,000	13,000
Cement	tonnes	7,500	4,200	2,500
Sand	tonnes	19,000	10,000	6,400
Gravel	tonnes	36,000	20,000	12,000
Steel	tonnes	16,000	9,400	6,000
Macadam	m3	2,200	1,700	1,200
Water	ML	22	12	7.5
Diesel fuel	ML	0.6	0.3	0.2
Gasoline	KL	3.5	1.6	0.86
Electricity	MW-yrs	3.0	1.7	1.1
Excavations	m3	62,000	35,000	21,000
EMPLACEMENT RESOURCES				
Item	Units	100%	50%	25%
Diesel	KL	39	22	7.5
Gasoline	KL	8.0	4.3	2.7
Electricity	MW-hrs	1,200	700	460
Natural Gas	MSCM	0.21	0.13	0.089
Water	ML	4.2	3.1	2.2
30-gallon drums	each	140	71	36
55-gallon drums	each	4	2	1

Table 6-2: PARAMETRIC DATA FOR UO_2 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY (continued)

SURVEILLANCE AND MONITORING RESOURCES (annual)				
Item	Units	100%	50%	25%
Diesel	KL	0.013	0.0073	0.0025
Gasoline	KL	5.7	3.3	2.3
Electricity	MW-hrs	1,200	700	460
Natural gas	MSCM	0.21	0.13	0.089
Water	ML	3.3	2.4	1.9
55-gallon drums	each	1	1	1
30-gallon drums	each	7	4	2
EMPLOYMENT				
Item	Units	100%	50%	25%
Construction (total)	man-yrs	680	390	240
Operating (annual)	man-yrs	47	35	25
Maint & Monitor (annual)	man-yrs	37	27	21
CONSTRUCTION EMISSIONS AND WASTES				
Item	Units	100%	50%	25%
Emissions				
CO	tons	10.4	6.0	3.7
HC	tons	4.0	2.2	1.4
NOx	tons	48.6	27.3	16.6
SOx	tons	3.2	1.8	1.1
Dust	tons	4.4	2.6	1.6
PM-10	tons	1.2	0.71	0.42
Waste				
Wastewater	ML	2.1	1.2	0.70
ANNUAL EMISSIONS AND WASTES-EMPLACEMENT				
Items	Units	100%	50%	25%
Emissions				
CO	tons	0.96	0.54	0.19
HC	tons	0.32	0.18	0.062
NOx	tons	4.1	2.2	0.79
SOx	tons	0.25	0.14	0.049
PM-10	tons	0.28	0.15	0.054
Waste				
Wastewater	ML	4.0	3.0	2.1
Low-level waste	m3	0.75	0.38	0.20

TABLE 6-2: PARAMETRIC DATA FOR UO_2 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY (continued)

ANNUAL EMISSIONS AND WASTES-SURVEILLANCE AND MONITORING				
Item	Units	100%	50%	25%
Emissions				
CO	tons	0.25	0.081	0.048
HC	tons	0.040	0.022	0.0076
NOx	tons	0.76	0.43	0.15
SOx	tons	0.030	0.016	0.0057
PM-10	tons	0.040	0.022	0.0076
Wastes				
Wastewater	ML	3.1	2.3	1.8
Low-level waste	m3	0.040	0.023	0.011
TRANSPORT SUMMARY				
Item	Units	100%	50%	25%
UO2				
Packages per year	drums	21,000	10,500	5,250
Packages/shipment (rail)	number	576	576	576
Packages/shipment (truck)	number	16	16	16
Shipments/yr (rail)	number	37	19	10
Shipments/yr (truck)	number	1,313	657	329

Figure 6-1: Plan View of Receiving Warehouse and Repacking Building
UF_6 Storage in a Building - 100% Capacity

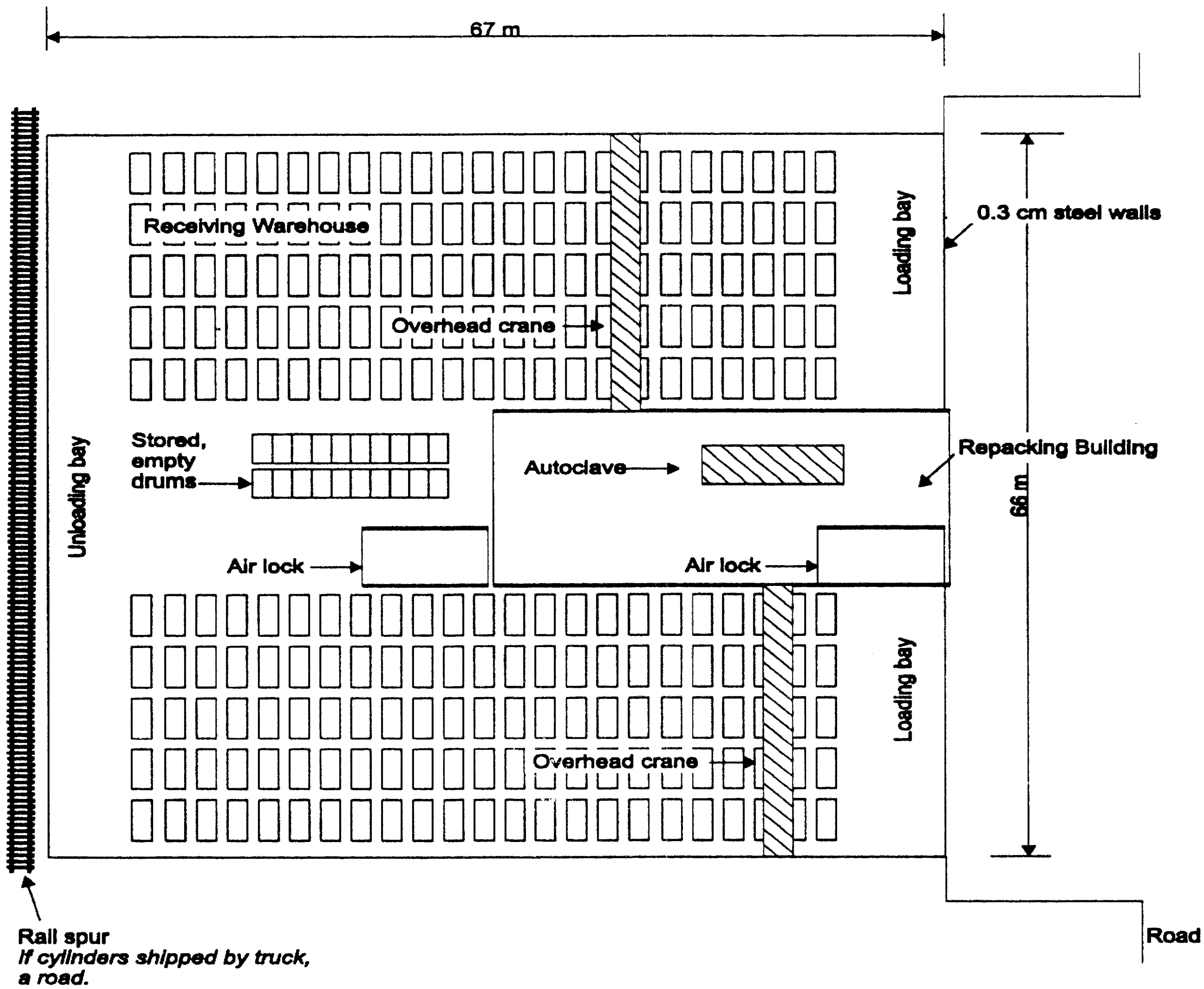


**Figure 6-2: Plan View of Receiving Warehouse and Repackaging Building
UF_6 Storage in a Building - 50% Capacity**

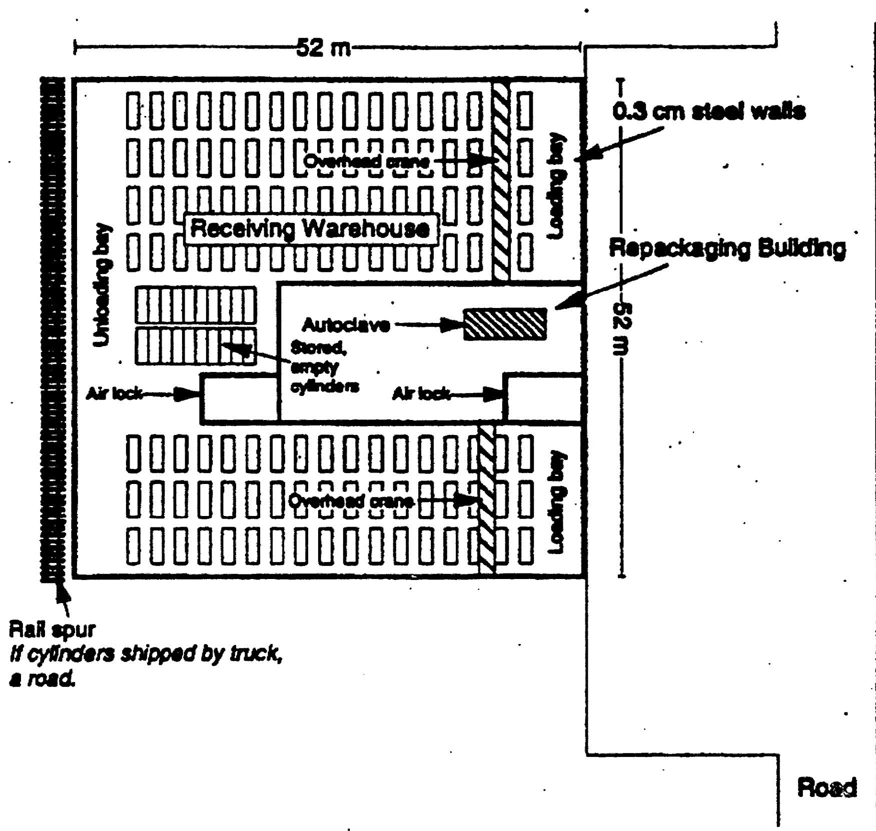


Figure 6-3: Plan View of Receiving Warehouse and Repacking Building UF_6 Storage in a Building - 25% Capacity

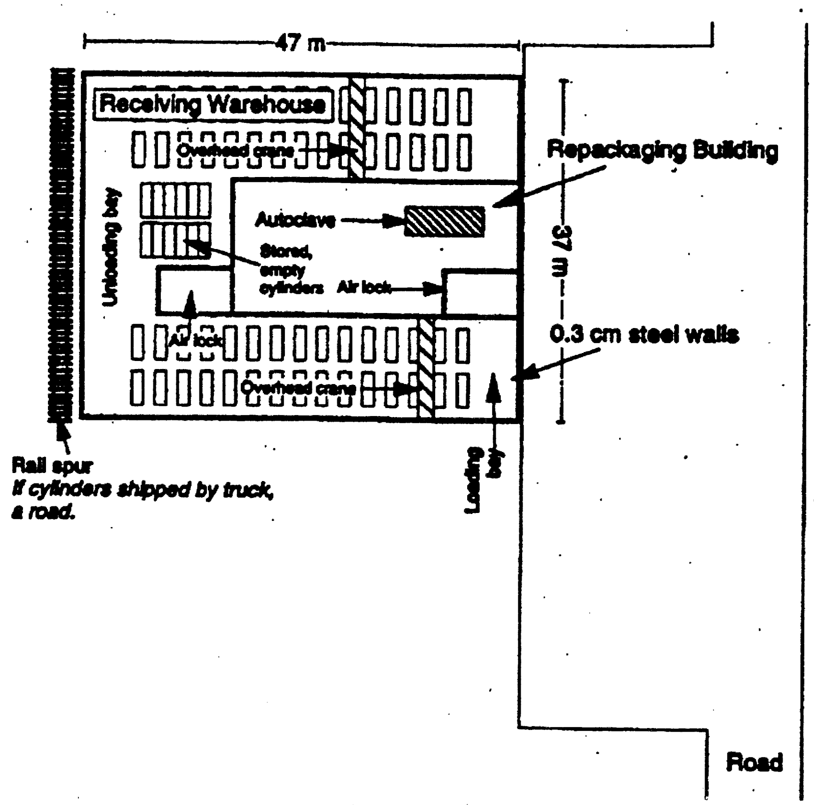


Figure 6-4: Plan View of Receiving Warehouse and Repackaging Building UO_2 Storage in a Building - 100% Capacity

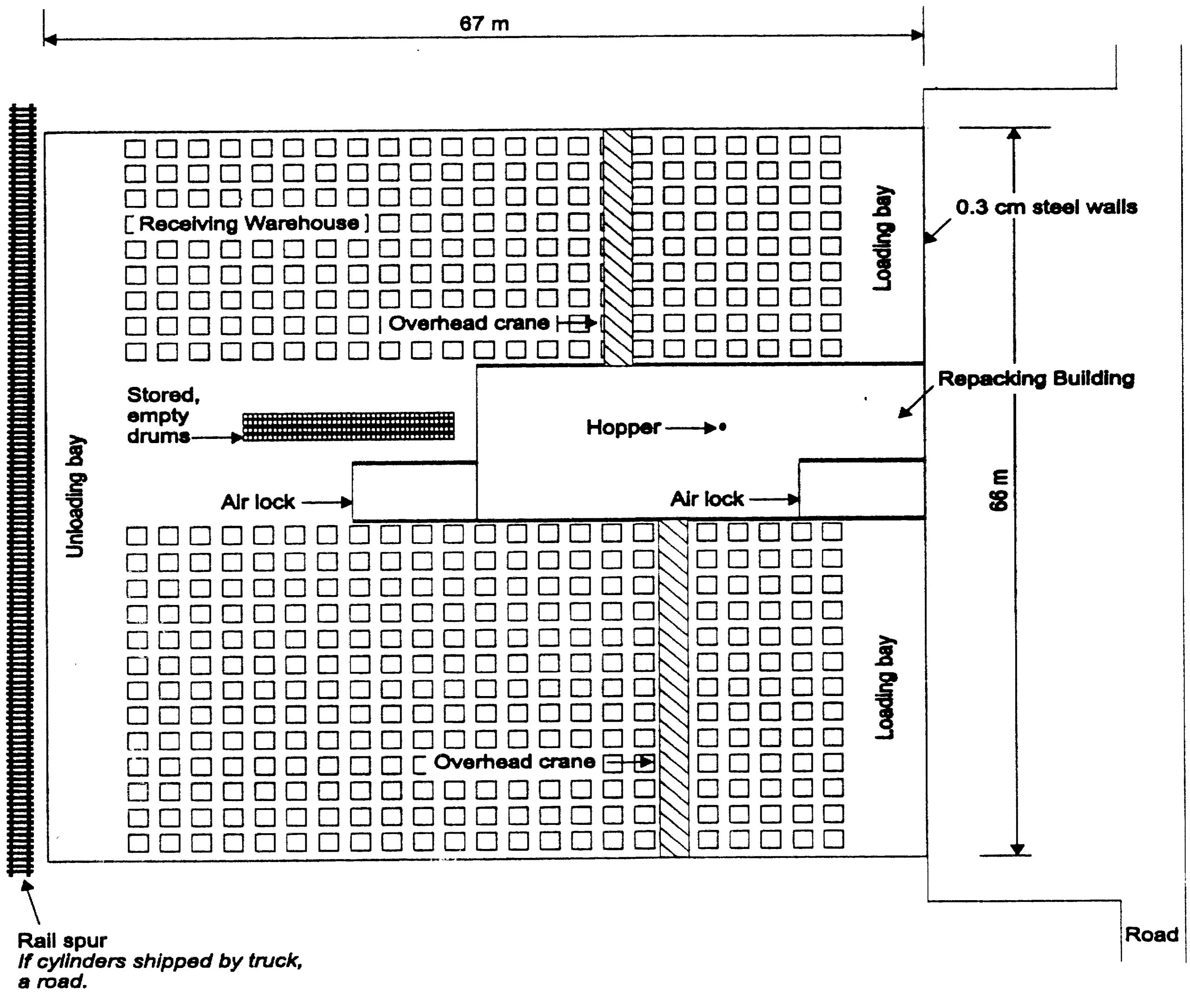


Figure 6-5: Plan View of Receiving Warehouse and Repackaging Building UO_2 Storage in a Building - 50% Capacity

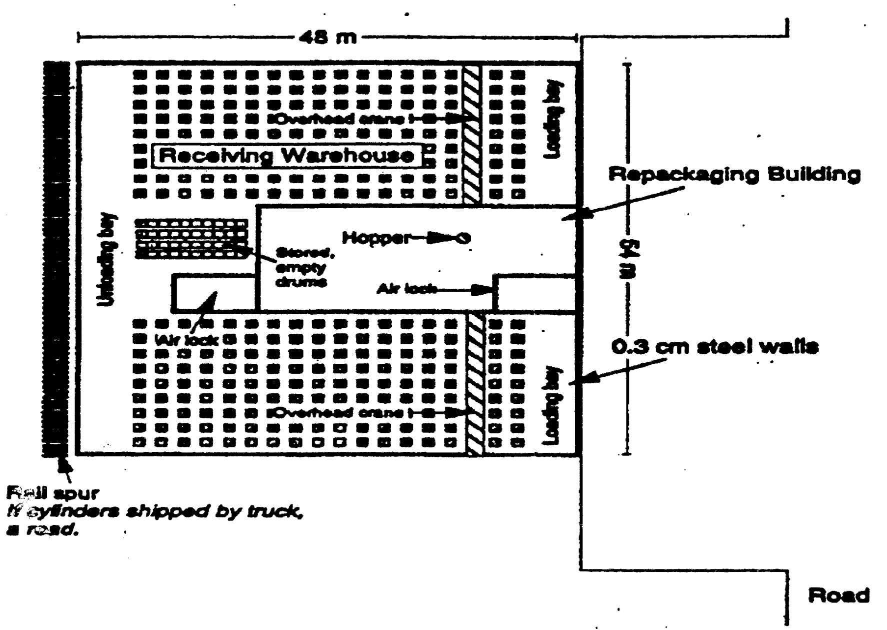


Figure 6-6: Plan View of Receiving Warehouse and Repackaging Building UO_2 Storage in a Building - 25% Capacity

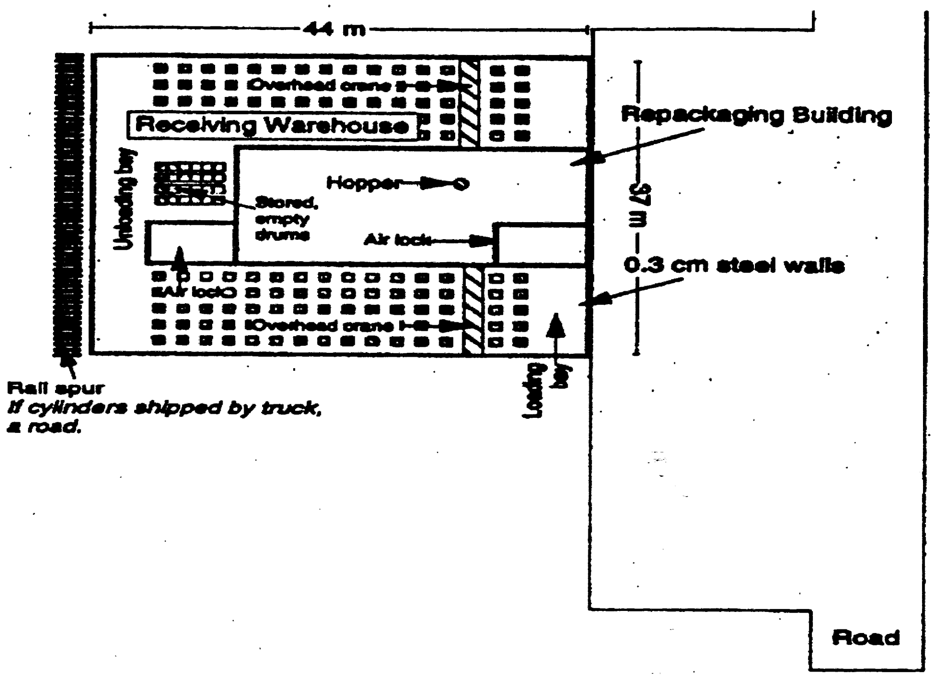
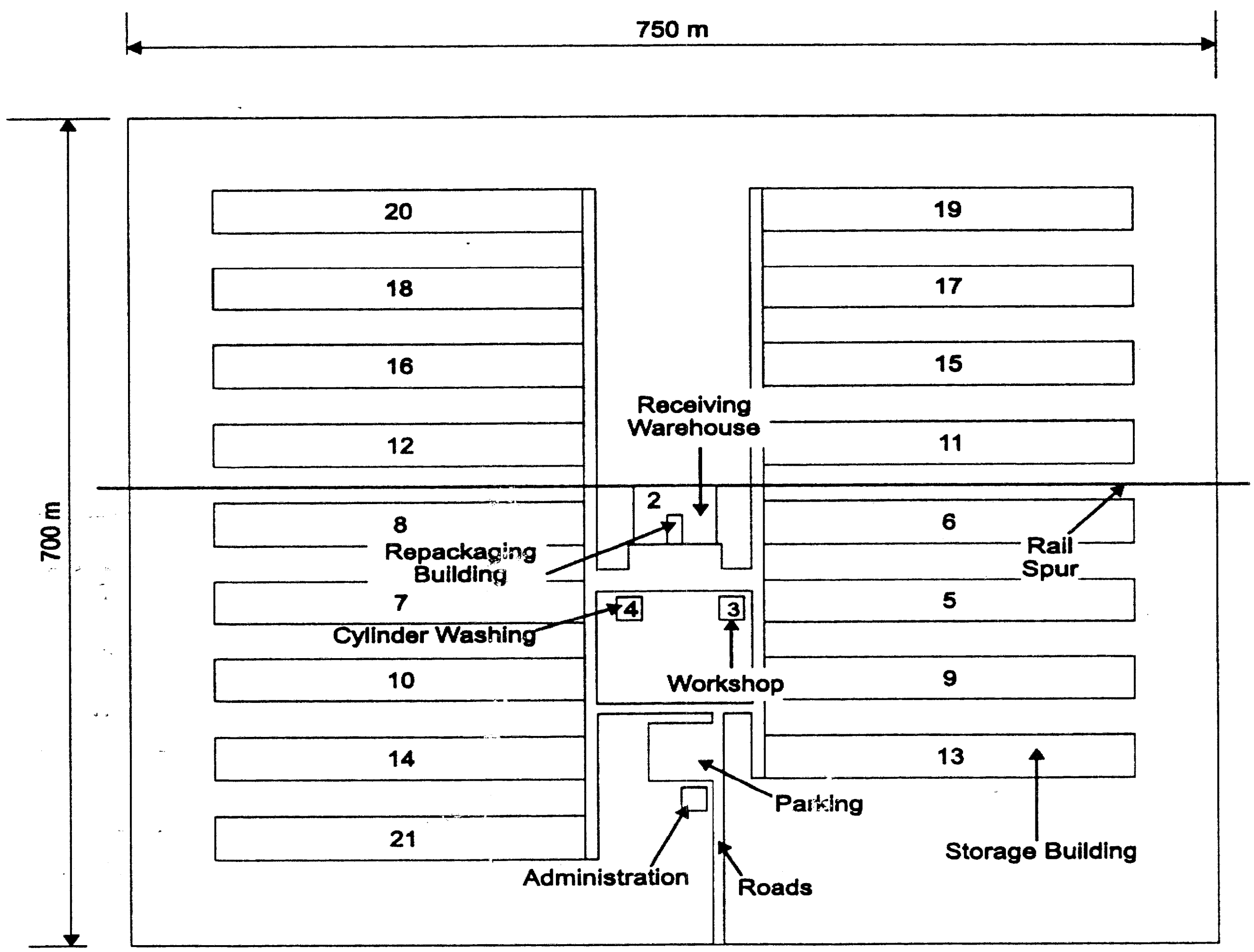
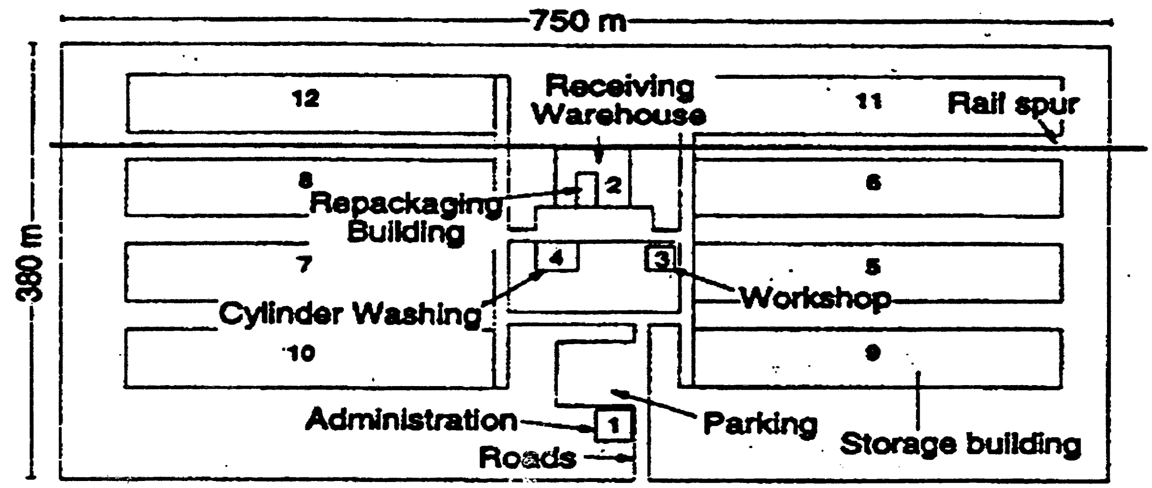


Figure 6-7: Site Layout UF_6 Building Storage Facility - 100% Capacity



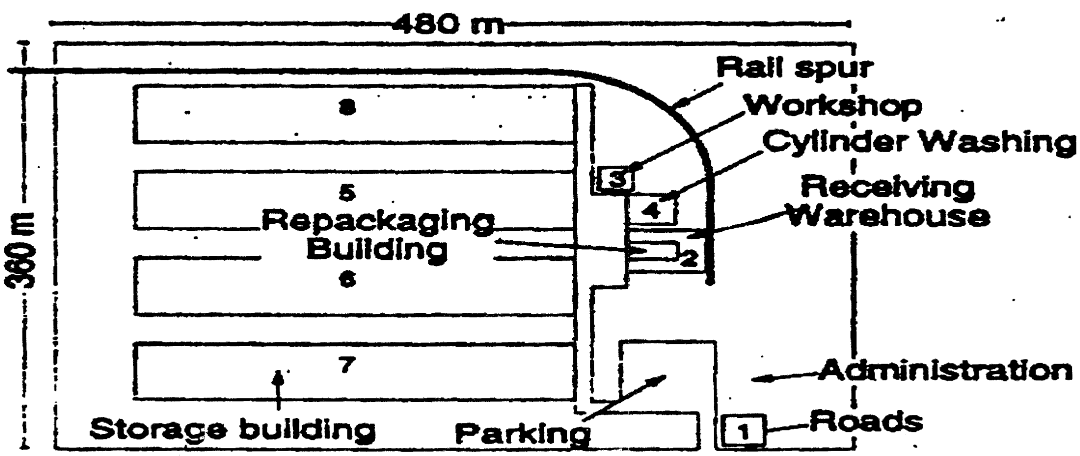
Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is 12 indicating 9 storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 6-8: Site Layout UF_6 Building Storage Facility - 50% Capacity



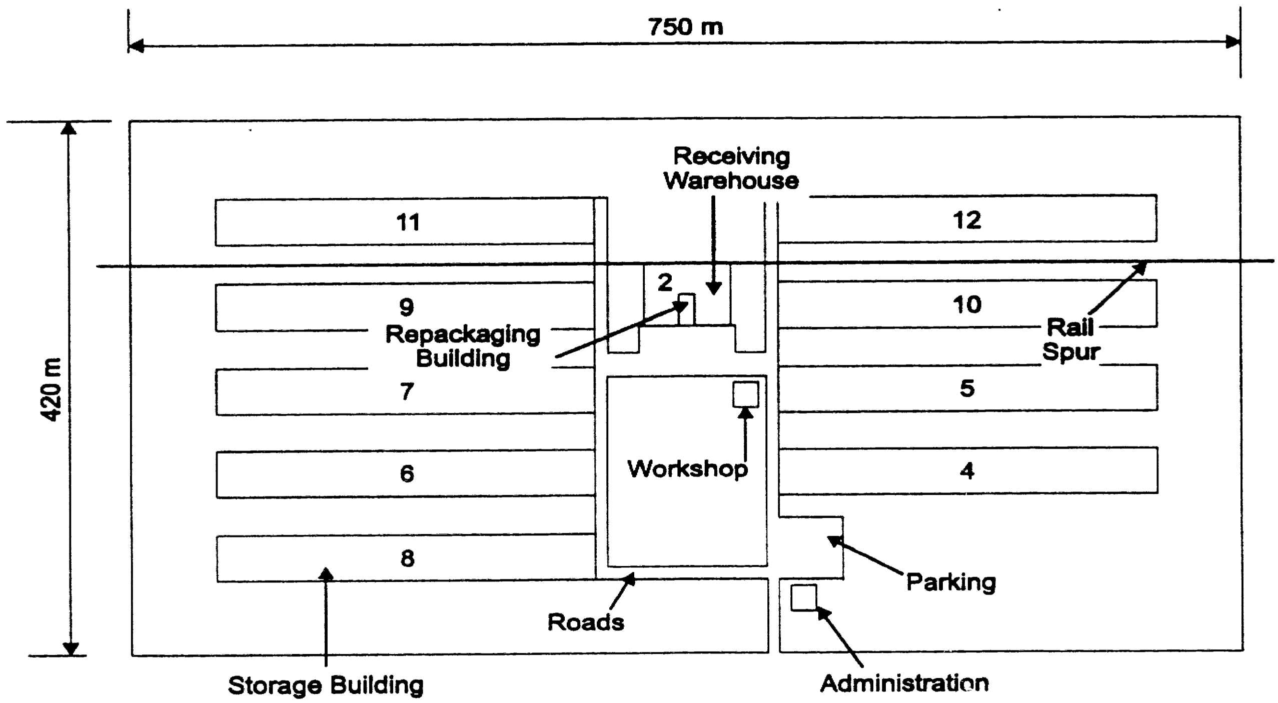
Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is 12 indicating 8 storage buildings and four support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 6-9: Site Layout UF_6 Building Storage Facility - 25% Capacity



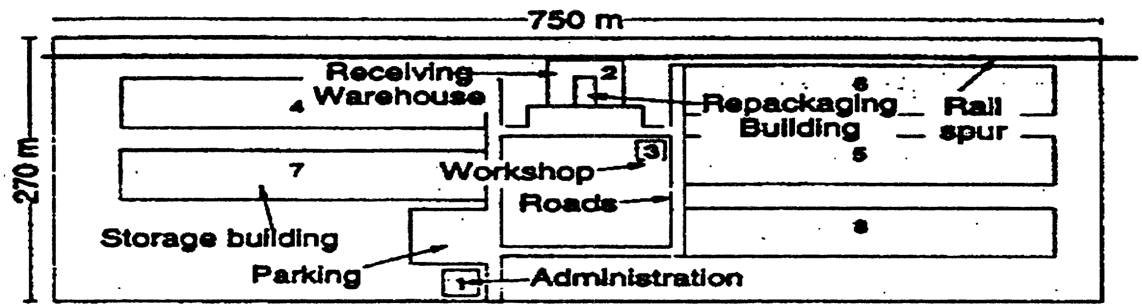
Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is eight indicating four storage buildings and four support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 6-10: Site Layout UO_2 Building Storage - 100% Capacity



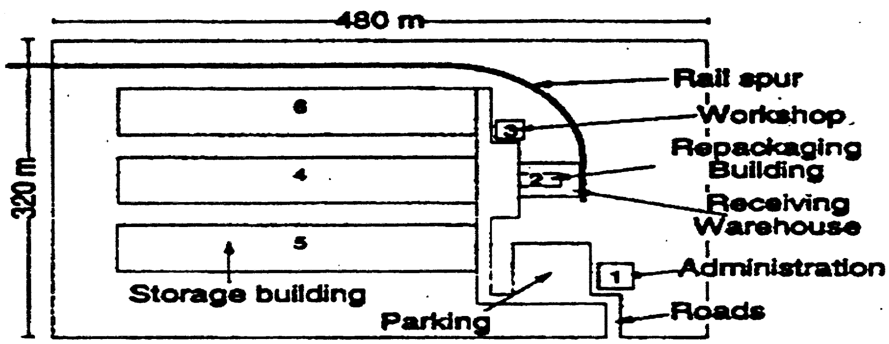
Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is 12 indicating 9 storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 6-11: Site Layout UO_2 Building Storage Facility - 50% Capacity



Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is eight indicating five storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

Figure 6-12: Site Layout UO_2 Building Storage Facility - 25% Capacity



Note 1: Numbers refer to construction order of buildings. The highest numbered storage building is six indicating three storage buildings and three support buildings.
Note 2: If shipments are received by truck, the rail spur would be a road.

6.2 Employment (Building Storage for UF_6 and UO_2)

This section of the report provides preliminary estimates of employment for the aboveground building storage of UF_6 and UO_2 during emplacement.

Table 6-3 provides labor category descriptions and estimated minimum numbers of employees required to operate the facility for the three parametric cases for UF_6 storage. Table 6-4 presents the same data for UO_2 storage. Tables 6-5 and 6-6 present information on relative levels of exposure to radiation for the three parametric cases for UF_6 and UO_2 respectively.

TABLE 6-3: PARAMETRIC EMPLOYMENT DATA FOR UF_6 BUILDING STORAGE OF 100%, 50% AND 25% MATERIAL CAPACITY

EMPLOYMENT, UF6, EMPLACEMENT			
	Number of Employees		
Labor category	100%	50%	25%
Managers	3	3	2
Professional	1	1	0
Line Supervisors	6	6	6
Operators	5	4	3
Technicians	17	10	7
Security	10	8	6
Craft Workers (Maintenance)	3	3	3
Office and Clerical	5	3	2
Total	50	38	29
EMPLOYMENT, UF6, SURVEILLANCE AND MONITORING			
	Number of Employees		
Labor category	100%	50%	25%
Managers	2	2	2
Professionals	1	0	0
Line Supervisors	5	5	5
Operators	3	2	1
Technicians	13	8	5
Security	10	8	6
Craft Workers (Maintenance)	3	3	3
Office and Clerical	3	2	2
Total	40	30	24

TABLE 6-4: PARAMETRIC EMPLOYMENT DATA FOR UO_2 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY

EMPLOYMENT, UO2, EMPLACEMENT			
Labor category	Number of Employees		
	100%	50%	25%
Managers	3	2	2
Professionals	1	1	0
Line Supervisors	5	5	5
Operators	5	4	3
Technicians	15	9	6
Security	10	7	4
Craft Workers (Maintenance)	3	3	3
Office and Clerical	5	4	2
Total	47	35	25
EMPLOYMENT, UO2, SURVEILLANCE AND MONITORING			
Labor category	Number of Employees		
	100%	50%	25%
Managers	2	2	2
Professionals	1	1	0
Line Supervisors	4	4	4
Operators	3	2	2
Technicians	11	6	4
Security	10	7	4
Craft Workers (Maintenance)	3	3	3
Office and Clerical	3	2	2
Total	37	27	21

TABLE 6-5: PARAMETRIC RADIATION EXPOSURE DATA FOR UF_6 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY

EMPLACEMENT			
Exposure category	Number of Employees		
	100%	50%	25%
Exposed to containers full time	21	14	11
Exposed to containers 25% time	9	8	6
Exposed to containers 10% time	20	16	12
Total	50	38	29
SURVEILLANCE AND MONITORING			
Exposure category	Number of Employees		
	100%	50%	25%
Exposed to containers full time	15	9	6
Exposed to containers 25% time	7	6	6
Exposed to containers 10% time	18	15	12
Total	40	30	24

TABLE 6-6: PARAMETRIC RADIATION EXPOSURE DATA FOR UO_2 BUILDING STORAGE OF 100%, 50%, AND 25% MATERIAL CAPACITY

EMPLACEMENT			
Exposure category	Number of Employees		
	100%	50%	25%
Exposed to containers full time	19	14	9
Exposed to containers 25% time	9	7	6
Exposed to containers 10% time	19	14	10
Total	47	35	25
SURVEILLANCE AND MONITORING			
Exposure category	Number of Employees		
	100%	50%	25%
Exposed to containers full time	12	7	5
Exposed to containers 25% time	7	7	6
Exposed to containers 10% time	18	13	10
Total	37	27	24

7.0 Disposal of Ungrouted U_3O_8 in a Mined Cavity

Three disposal facility options, (1) engineered trench, (2) below ground vault, and (3) mined cavity, are considered in Section 6.13 of this EAR. Each option was evaluated for the same four waste form suboptions: (1) grouted (cemented) U_3O_8 (2) grouted UO_2, (3) bulk (i.e., not grouted) U_3O_8, and (4) bulk UO_2. For comparative purposes, the mined cavity disposal option for ungrouted-U_3O_8 has been analyzed to develop engineering data in support of the parametric analysis. The parametrics that were analyzed were for 50% and 25% material capacity, which equates from the 100% material capacity of 35,750 drums per year of ungrouted-U_3O_8 to 17,875 drums and 8,938 drums for 50% and 25% respectively.

7.1 Data Summary

The parameters were influenced by many factors, including the volume reduction of the underground area, the surface area reduction of constructed facilities, the labor force and equipment required to perform specific functions. For example, air emissions calculations are a direct function of the amount of diesel fuel used during the construction and operation of the disposal facility. Other factors remained constant, such as the mine cavity depth, mine ramp dimensions, and the administrative building footprint.

Table 7-1 incorporates all of the pertinent factors and parameters into a set of parametric data for incorporation into the engineering report. Figures 7-1 and 7-2 display the relative waste form facility and mined cavity underground for each parametric case, respectively. Figures 7-3, 7-4, and 7-5, display the disposal facility footprint for the 100%, 50%, and 25% capacity cases, respectively. Each figure includes the aboveground facilities (waste form facility, service facility area, tuff pile, and access roads) and the below-ground areas (entrance ramps and mine underground).

Employment data for operations and construction of the mined cavity disposal facility are included at the end of this section.

Table 7-1: Parametric Data for Ungrouted-U_3O_8 Mined Cavity Disposal of 100%, 50%, and 25% Material Capacity

PARAMETRIC DATA	100%	50%	25%
ANNUAL INPUT/OUTPUT SUMMARY			
Received Drums of U3O8 per year	35,750	17,875	8,938
Type of Drum	55-gallon	55-gallon	55-gallon
Number of Drums per Pallet	4	4	4
Width of Pallet, m	1.22	1.22	1.22
Required 3-month storage footprint - double tiered pallets, m^2	1664	832	417
Drum U3O8 Content, te (lbs)	0.625 (1380)	0.625 (1380)	0.625 (1380)
Uranium, te (lbs)	0.530 (1170)	0.530 (1170)	0.530 (1170)
Weight of Empty Drum, kg (lbs)	34.0 (75)	34.0 (75)	34.0 (75)
LAND USE REQUIREMENTS (Waste form Facility)			
Construction Area, ha	1.25 *	0.912	0.692
Length, m	125 *	106	91
Width, m	100 *	86	76
Plant Site Area, ha	1.25 *	0.912	0.692
Length, m	125 *	106	91
Width, m	100 *	86	76
Total Paved Area, ha	0.295 *	0.222	0.174
Total Fenced Area, ha	1.00 *	0.740	0.578

PARAMETRIC DATA	100%	50%	25%
Administrative Building Footprint Area, m^2	675	675	675
Product Receiving & Shipping Warehouse Footprint Area, m^2	3000	1656	936
Total Excavated Material, m^3	7350	4660	3220
LAND USE REQUIREMENTS (Mined Cavity Disposal Area)			
Construction Area Above-Ground, ha (including Waste form Facility)	118 *	65.7	39.1
Above-Ground Plant Site Area, ha (including Waste form Facility)	118 *	65.7	39.1
Paved Area Above-Ground, ha	9.9 *	8.7	7.8
Waste Ramp Area, ha	1.24 *	1.24	1.24
Length, m	2065 *	2065	2065
Diameter, m	7 *	7	7
Height, m	5 **	5	5
Tuff Ramp Area, ha	1.24 *	1.24	1.24
Length, m	2065 *	2065	2065
Diameter, m	7 *	7	7
Height, m	5 **	5	5
Perimeter Tunnel Area, ha	2.29 *	1.64	1.19
Length, m	3812 *	2734	1980
Diameter, m	7 *	7	7
Height, m	5 **	5	5
Depth of Shafts, m^3	180	180	180
Man & Material Shaft Diameter, m	6 **	6	6

PARAMETRIC DATA	100%	50%	25%
Exhaust Shaft #1 Diameter, m	6 **	6	6
Exhaust Shaft #2 Diameter, m	3 **	3	3
Exhaust Shaft #3 Diameter, m	2 **	2	2
Mined Cavity Underground Area, ha	92.2	47.7	25.2
Length, m	970 *	701	508
Width, m	950 *	680	496
Central Service Tunnel Area, ha	0.485 *	0.351	0.254
Length, m	970 *	701	508
Diameter, m	6 *	6	6
Height, m	5 **	5	5
Number of Mine Drifts	48 *	34	24
Total Emplacement Drift Length, m	21,888	10,914	5,496
Single Drift Area, ha	0.296 *	0.209	0.149
Length, m	456 *	321	229
Width, m	6.5	6.5	6.5
Height, m	3.5	3.5	3.5
Spacing Between Drift Tunnels, m	32	32	32
Total Paved Area Underground, ha	20.8 ***	12.5	8.2
Total Excavated Material, m^3	883,000***	569,000	401,000

PARAMETRIC DATA	100%	50%	25%
CONSTRUCTION RESOURCES (Waste form Facility)			
Diesel Fuel, L	67,200	41,300	27,100
Electricity, kW-hr	403,000	308,000	257,000
Concrete Redi-mix, m^3	4133	2515	1623
Reinforcing Steel, te	260	157	103
Water, ML	2.6	1.9	1.5
Excavated Material, m^3	7350	4660	3220
Waste Water, ML	0.55	0.55	0.55
Masonry Brick, m^2	573	573	573
CONSTRUCTION RESOURCES (Mined Cavity Disposal Area)			
Diesel Fuel, L	519,000	335,000	236,000
Electricity, Giga-Watt-hour [GWh]	4300	3040	2150
Concrete Redi-mix, m^3	74,100	49,500	36,000
Reinforcing Steel, te	2908	1943	1413
Water, ML	13	9.2	6.5
Excavated Material, m^3	883,000	569,000	401,000
OPERATIONS RESOURCES (Waste form Facility)			
Natural Gas, therms/yr	109	69	48
Electricity, MW-hr/yr	572	422	341
Water, ML/yr	0.52	0.38	0.28
Waste Water, ML/yr	0.52	0.38	0.28
Diesel Fuel, L/yr	500	400	350

PARAMETRIC DATA	100%	50%	25%
OPERATIONS RESOURCES (Mined Cavity Disposal Area)			
Diesel Fuel, L/yr	6150	3690	2460
Electricity, MW-hr/yr	6000	4243	3000
Water, ML/yr	2.3	1.6	1.2
Waste Water, ML/yr	0.4	0.3	0.2
EMPLOYMENT (Waste form Facility)			
Construction (total man-years)	195	190	185
Operating (annual)	35	26	19
EMPLOYMENT (Mined Cavity Disposal Area)			
Construction (total man-years)	3000 ****	2400	2100
Operating (annual)	26	17	12
FACILITY AIR RELEASE POINTS: [N/A]			
CONSTRUCTION EMISSIONS AND WASTES (Waste form Facility)			
Criteria Pollutants (Total Construction Emissions/2-Years of Facility Construction)			
SO_2, lb/yr	357	219	144
NO_x, lb/yr	5429	3337	2189
NMHC's, lb/yr	410	252	165
Carbon Monoxide (CO), lb/yr	1170	719	472
Particulate Matter (PM-10), lb/yr	382	235	154
NO_2, lb/yr	5	3	2
CH_4, lb/yr	33	20	13

PARAMETRIC DATA	100%	50%	25%
CO2, lb/yr	203,136	124,844	81,919
Wastes: Total Generated During 2 Years of Construction			
hazardous solids, kg	76	54	38
hazardous liquids, L	3520	2490	1760
nonhazardous solids, ML	24	17	12
CONSTRUCTION EMISSIONS AND WASTES (Mined Cavity Disposal Area)			
Criteria Pollutants (Total Construction Emissions/7.5-Years of Mine Construction)			
SO2, lb/yr	735	475	334
NOx, lb/yr	11,182	7217	5085
NMHC's, lb/yr	844	545	384
Carbon Monoxide (CO), lb/yr	2409	1555	1095
Particulate Matter (PM-10), lb/yr	786	507	357
NO2, lb/yr	11	7	5
CH4, lb/yr	69	44	31
CO2, lb/yr	418,363	270,042	190,238
Wastes: Total Generated During 7.5 Years of Construction)			
hazardous solids, kg	417	324	258
hazardous liquids, L	5280	3734	2640
nonhazardous solids, ML	0.64	0.45	0.32

PARAMETRIC DATA	100%	50%	25%
OPERATIONAL EMISSIONS (Waste form Facility)			
Criteria Pollutants			
SO2, lb/yr	5	4	4
NOx, lb/yr	81	65	57
NMHC's, lb/yr	6	5	4
Carbon Monoxide (CO), lb/yr	17	14	12
Particulate Matter (PM-10), lb/yr	6	5	4
NO2, lb/yr	<1	<1	<1
CH4, lb/yr	<1	<1	<1
CO2, lb/yr	3023	2418	2116
OPERATIONAL EMISSIONS (Mined Cavity Disposal Area)			
Criteria Pollutants			
SO2, lb/yr	65	39	26
NOx, lb/yr	994	596	397
NMHC's, lb/yr	75	45	30
Carbon Monoxide (CO), lb/yr	214	128	86
Particulate Matter (PM-10), lb/yr	70	42	28
NO2, lb/yr	1	1	<1
CH4, lb/yr	6	4	2
CO2, lb/yr	37,181	22,309	14,872

PARAMETRIC DATA	100%	50%	25%
RADIOLOGICAL EMISSION (Operations): negligible			
LLW WASTES (Operations)			
Solid LLW Wastes, m^3	47.4	33.5	23.7
HAZARDOUS WASTES (Operations): negligible			
MIXED LLW WASTES (Operations)			
Liquid Mixed LLW Wastes, m^3	0.18	0.13	0.09
NONHAZARDOUS WASTES (Operations): negligible			
TRANSPORTATION SUMMARY (Waste form Facility U3O8 received in 4-drum pallets)			
Pallets/yr	8938	4469	2235
Pallets/shipment (rail)	80	80	80
Pallets/shipment (truck)	7	7	7
Shipments/yr (rail)	112	56	28
Shipments/yr (truck)	1277	639	320
TRANSPORTATION SUMMARY (internal site shipment to disposal area)			
Pallets/yr	8938	4469	2235
Pallets/shipment (truck)	7	7	7
Shipments/yr (truck)	1277	639	320

* Parametric value was generated from Figures 7-1, 7-2, 7-3, 7-4, and/or 7-5; and not from the Section 6.13 of the EAR, since only base case parameters were included in the EAR for most of the noted parameters.

** Parametric value was derived from Yucca Mountain data which was not included in Section 6.13 of the EAR.

*** The total paved underground value is calculated to be the total surface area of the mined cavity; the excavated volume is the total volume of the mined cavity accessible areas, including tunnels, drifts, ramps, and shafts. These values are not included in Section 6.13 of the EAR.

**** Employment construction man-years derived from Table 7-7; no equivalent variation data is included in Section 6.13 of the EAR.

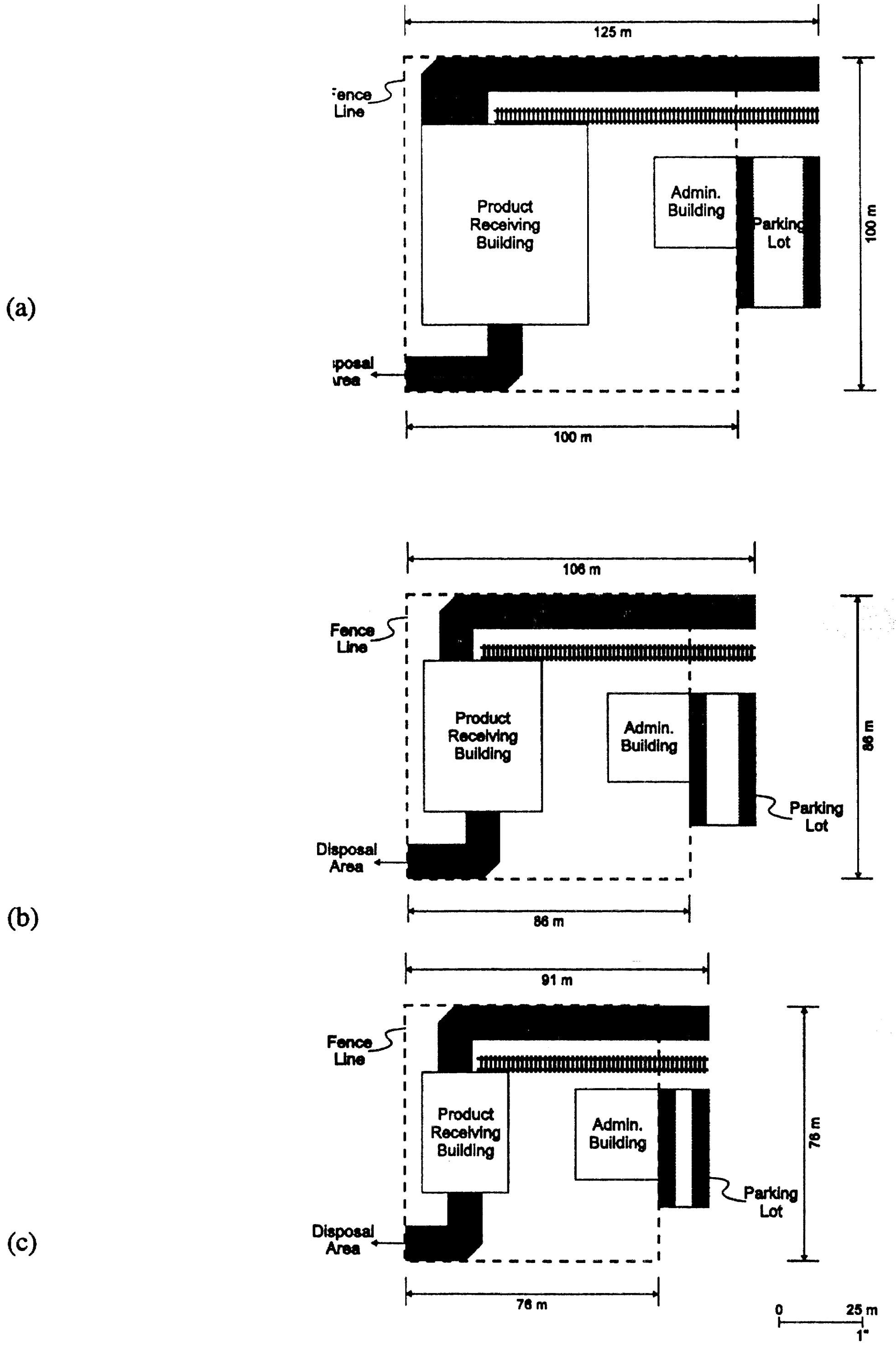


Figure 7-1: Waste form Facility Footprint for (a) Ungrouted U_3O_8 Disposal - 100% Capacity, (b) 50% Capacity, and (c) 25% Capacity

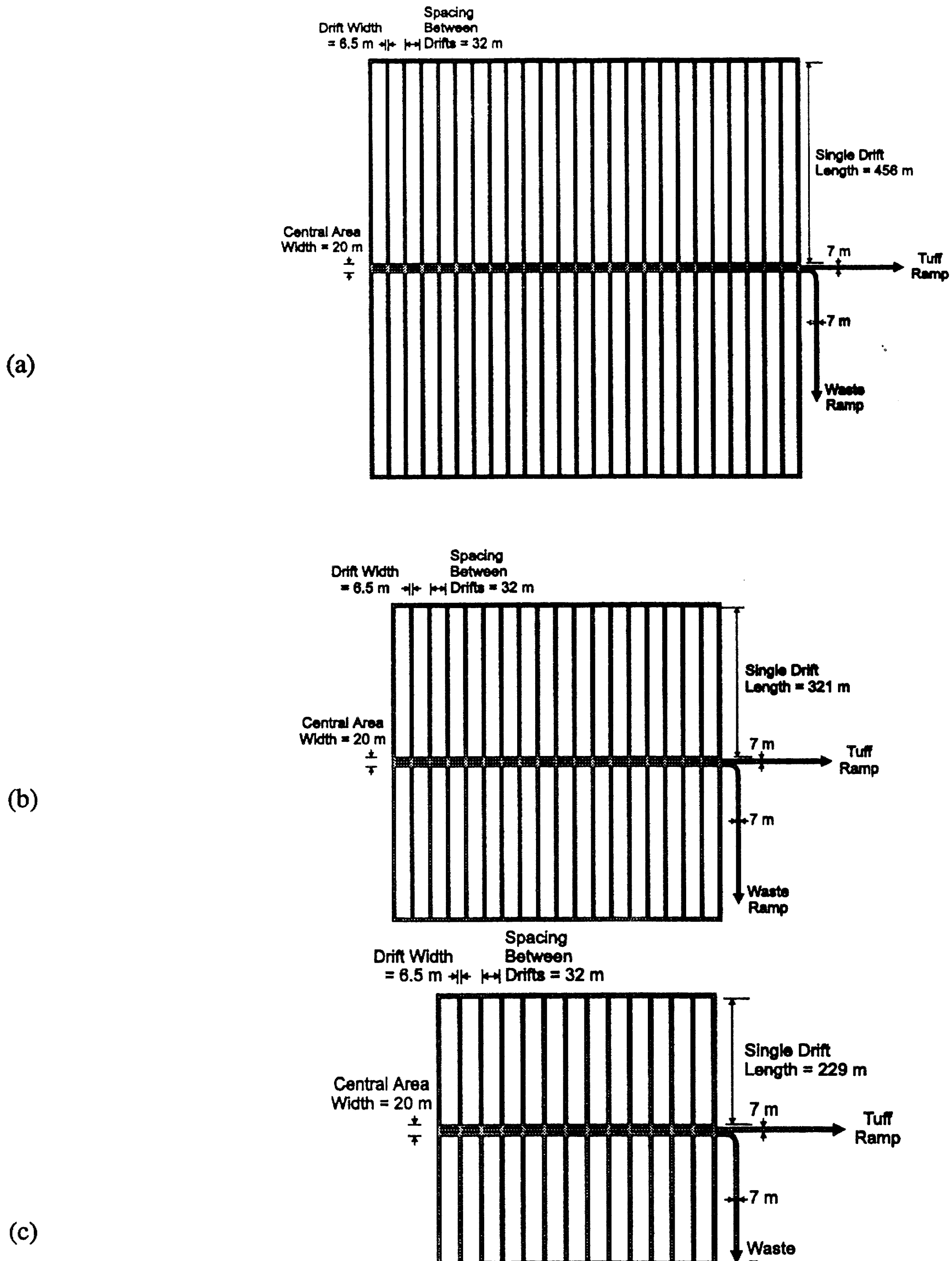


Figure 7-2: Mined Cavity Underground Footprint for Ungrouted U_3O_8 Disposal - (a) 100% Capacity, (b) 50% Capacity, and (c) 25% Capacity

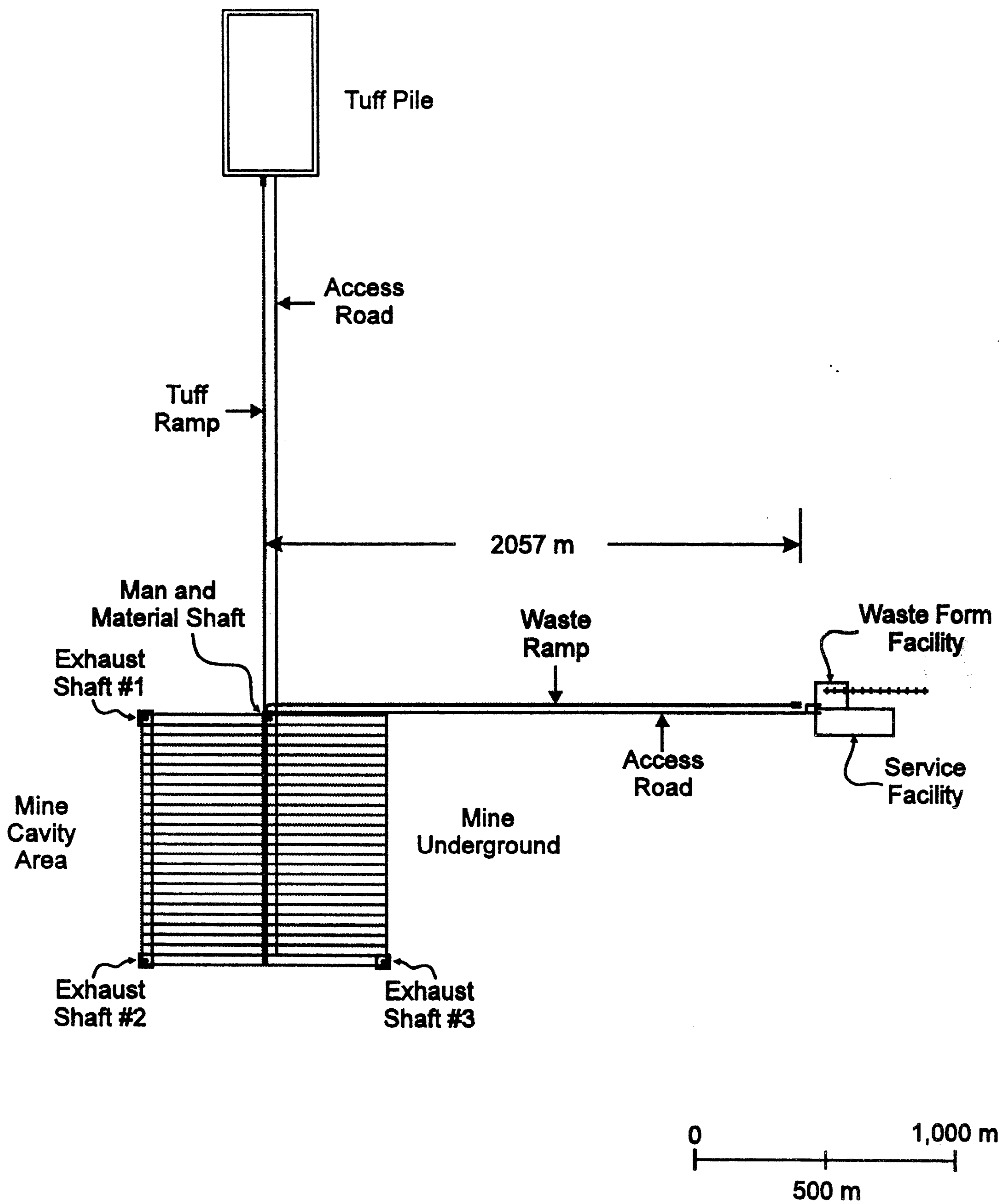


Figure 7-3: Ungrouted U_3O_8 Mined Cavity Disposal Facility Footprint at 100% Capacity

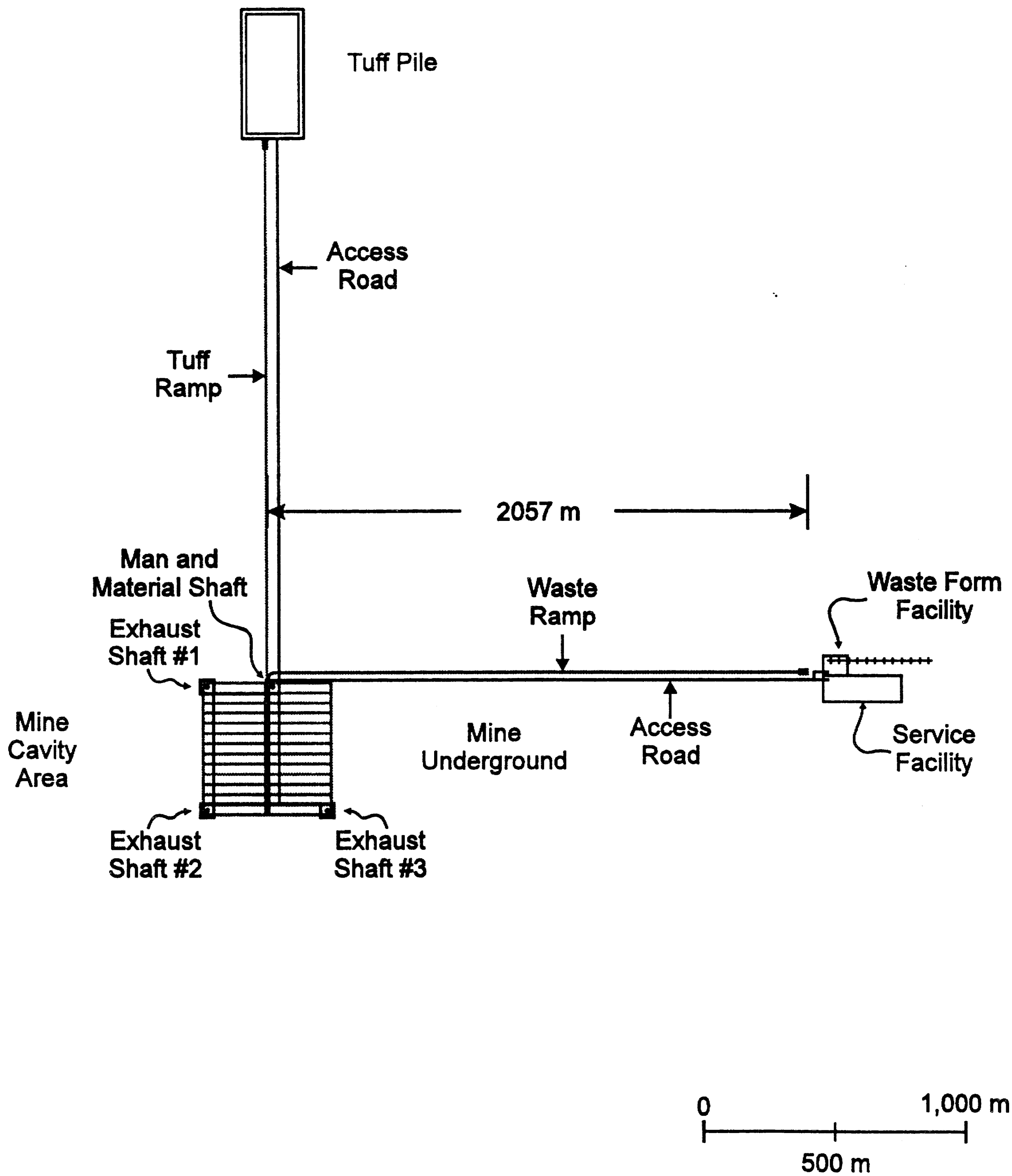


Figure 7-4: Ungrouted U_3O_8 Mined Cavity Disposal Facility Footprint at 50% Capacity

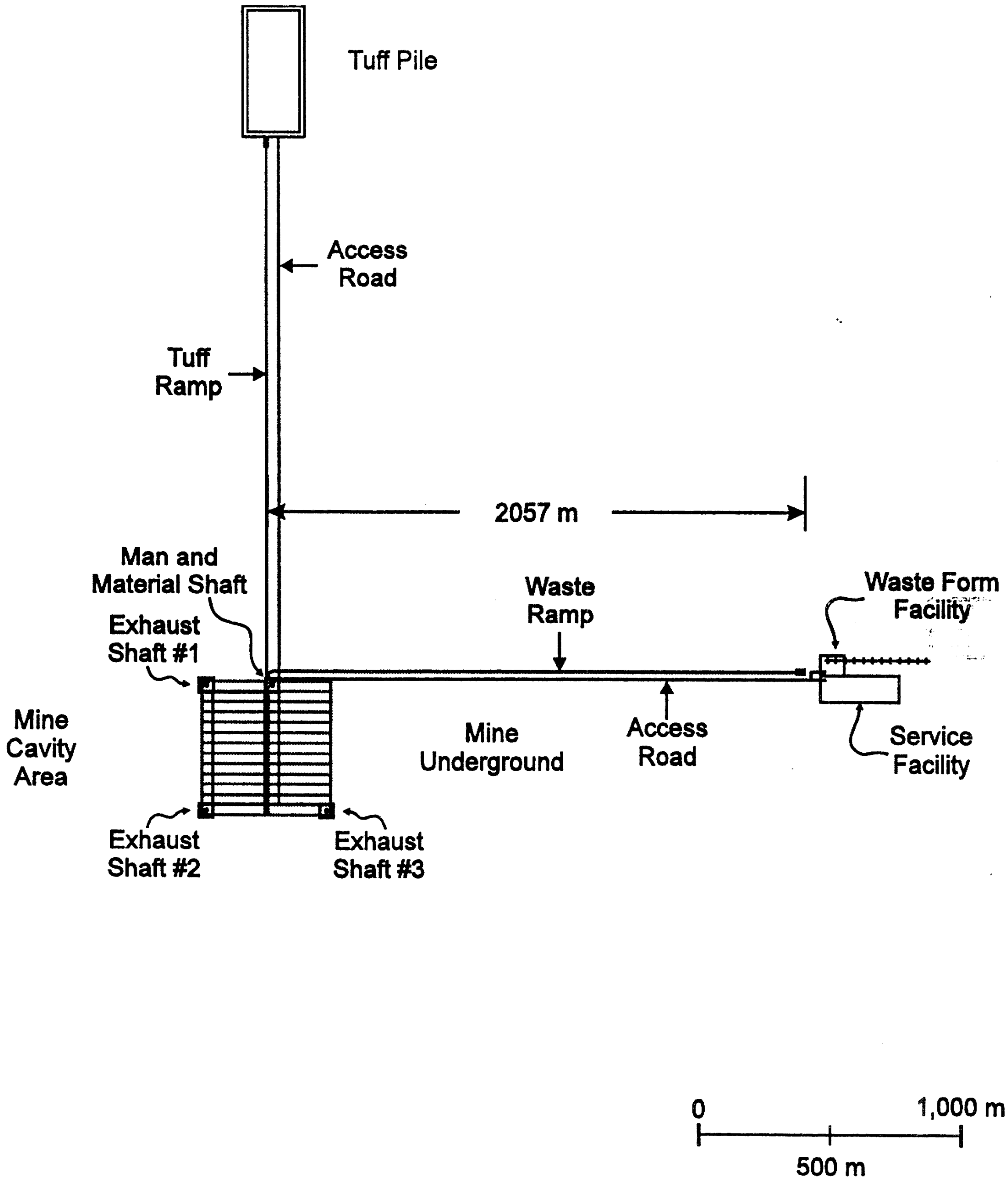


Figure 7-5: Ungrouted U_3O_8 Mined Cavity Disposal Facility Footprint at 25% Capacity

7.2 Employment (Ungrouted-U_3O_8 Mined Cavity Disposal)

This section of the report provides preliminary estimates of employment needs of the mined cavity ungrouted-U_3O_8 disposal facility during both operation and construction.

Table 7-2 provides labor category descriptions and the estimated minimum numbers of employees required to operate the facility for each of the parametric cases for ungrouted-U_3O_8 disposal in a mined cavity.

Tables 7-3, 7-4, and 7-5 give the estimated location of facility employees during normal operation for each of the parametric cases. Many of the numbers are fragments due to staff movement from one area to another.

Table 7-2: On-Site Employment During Operation
Ungrouted-U_3O_8 Mined Cavity Disposal Facility

LABOR CATEGORY	Number of Employees		
	(100%)	(50%)	(25%)
Officials and Managers	2	1	1
Professionals	2	2	1
Technicians	3	3	1
Office and Clerical	11	6	3
Craft Workers (Maintenance)	10	8	7
Operators / Supervision	18 / 3	9 / 2	5 / 2
Security	12	12	11
TOTAL EMPLOYEES (for all on-site facilities)	61	43	31

**Table 7-3: Number and Location of Employees During Operation (100%)
Ungrouted U_3O_8 Mined Cavity Disposal Facility**

Facility	Shift 1	Shift 2	Shift 3	Shift 4
Admin Building	12	4	2 ½	2
Receiving Building	7 3/4	5 3/4	3/4	1/4
Mined Cavity Area	9 3/4	8 3/4	1/4	1/4
Support Area	2 ½	2 ½	1 ½	½
TOTAL EMPLOYEES	32	21	5	3

**Table 7-4: Number and Location of Employees During Operation (50%)
Ungrouted U_3O_8 Mined Cavity Disposal Facility**

Facility	Shift 1	Shift 2	Shift 3	Shift 4
Admin Building	11	2 ½	2	2
Receiving Building	7 1/4	3/4	1/4	1/4
Mined Cavity Area	9 1/4	3/4	1/4	1/4
Support Area	2 ½	3	½	½
TOTAL EMPLOYEES	30	7	3	3

**Table 7-5: Number and Location of Employees During Operation (25%)
Ungrouted U_3O_8 Mined Cavity Disposal Facility**

Facility	Shift 1	Shift 2	Shift 3	Shift 4
Admin Building	7	2 ½	2	2
Receiving Building	4 1/4	3/4	1/4	1/4
Mined Cavity Area	5 1/4	3/4	1/4	1/4
Support Area	2 ½	2	½	½
TOTAL EMPLOYEES	19	6	3	3

Tables 7-6 and 7-7 provide an estimate of the employment buildup by year during construction of the waste form/receiving facility and the mined cavity for the 100% parametric case. Tables 7-8, 7-9, 7-10, and 7-11 provide the same information for the 50% and 25% cases. The estimates for the mined cavity construction assume a gradual ramp-up of employees over 5 years and a close out over the last two years.

Table 7-6: Number of Construction Employees Needed by Year for the Waste form Facility Site (100% case) - Ungrouted U_3O_8 Mined Cavity Disposal Facility

EMPLOYEES	Year 1	Year 2	Year 3
Total Craft Workers	45	60	60
Construction Management and Support Staff	5	10	15
TOTAL EMPLOYEES	50	70	75

Table 7-7: Number of Construction Employees Needed by Year for the Mined Cavity (100% case) - Ungrouted U_3O_8 Mined Cavity Disposal Facility

EMPLOYEES	Year							
	1	2	3	4	5	6	7	8
Total Craft Workers	90	225	360	460	550	550	375	140
Construction Management and Support Staff	10	25	40	40	50	50	25	10
TOTAL EMPLOYEES	100	250	400	500	600	600	400	150

Table 7-8: Number of Construction Employees Needed by Year for the Waste form Facility Site (50% case) - Ungrouted U_3O_8 Mined Cavity Disposal Facility

EMPLOYEES	Year 1	Year 2	Year 3
Total Craft Workers	40	60	60
Construction Management and Support Staff	5	10	15
TOTAL EMPLOYEES	45	70	75

Table 7-9: Number of Construction Employees Needed by Year for the Mined Cavity (50% case) - Ungrouted U_3O_8 Mined Cavity Disposal Facility

EMPLOYEES	Year							
	1	2	3	4	5	6	7	8
Total Craft Workers	70	180	290	370	440	440	300	110
Construction Management and Support Staff	10	20	30	30	40	40	20	10
TOTAL EMPLOYEES	80	200	320	400	480	480	320	120

Table 7-10: Number of Construction Employees Needed by Year for the Waste form Facility Site (25% case) - Ungrouted U_3O_8 Mined Cavity Disposal Facility

EMPLOYEES	Year 1	Year 2	Year 3
Total Craft Workers	36	60	60
Construction Management and Support Staff	4	10	15
TOTAL EMPLOYEES	40	70	75

Table 7-11: Number of Construction Employees Needed by Year for the Mined Cavity (25% case) - Ungrouted U_3O_8 Mined Cavity Disposal Facility

EMPLOYEES	Year							
	1	2	3	4	5	6	7	8
Total Craft Workers	60	160	250	320	385	385	260	90
Construction Management and Support Staff	10	20	30	30	35	35	20	10
TOTAL EMPLOYEES	70	180	280	350	420	420	280	100