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Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride: Storage of Depleted Uranium Metal

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CONTENTS

CONTENTS (Cont.)

FIGURES

FIGURES (Cont.)

TABLES

TABLES (Cont.)

TABLES (Cont.)

TABLES (Cont.)

TABLES (Cont.)

TABLES (Cont.)

TABLES (Cont.)

NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this report.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
CAA	Clean Air Act
CFR	Code of Federal Regulations
CRD	Contractor Requirements Documents
CWA	Clean Water Act
DF	damage fraction
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FTE	full-time equivalent
H_2	hydrogen
HEPA	high-efficiency particulate air
hp	horsepower
HVAC	heating, ventilation, and air conditioning
INEEL	Idaho National Engineering and Environmental Laboratory
LAN	local access network
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
LPF	leak path factor
MAR	material at risk
MC&A	material control and accountability
MPFL	maximum possible fire loss
MSA	major system acquisition
MSCM	million standard cubic meters
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NPH	natural phenomena hazard

NRC	U.S. Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PEIS	Programmatic Environmental Impact Statement
RARF	respirable airborne release fraction
RG	Regulatory Guide
RH	relative humidity
ROD	Record of Decision
SSC	structures, systems, and components
SWDA	Safe Drinking Water Act
TEDE	total effective dose equivalent
U^{235}	uranium-235
U^{238}	uranium-238
U_3O_8	triuranium octaoxide
UF_6	uranium hexaflouride
UH_3	uranium hydride
UO_2	uranium dioxide
UPHF	Uranium Processing and Handling Facility
USEC	United States Enrichment Corporation

UNITS OF MEASURE

°C	degree Celsius	Lb	pound
Ci	curie	M	meter
cm	centimeter	m^2	square meter
cm^2	square centimeter	m^3	cubic meter
cm^3	cubic centimeter	MeV	million electronvolt
ft	foot	Mg	milligram
ft^2	square foot	ML	megaliter
ft^3	cubic foot	Mol	mole
g	gram	MW	megawatt
gal	gallon	MW-h	megawatt hour
h	hour	MW-yr	megawatt year
ha	hectare	Pa	pascal
in.	inch	Rem	rem
kg	kilogram	Sv	sievert
kL	kiloliter	Te	metric ton
kW	kilowatt	W	watt
L	liter	Yr	year

ENGINEERING ANALYSIS REPORT FOR THE LONG-TERM MANAGEMENT OF DEPLETED URANIUM HEXAFLUORIDE: STORAGE OF DEPLETED URANIUM METAL

by

S.M. Folga, P.H. Kier, and P.R. Thimmapuram

ABSTRACT

This report contains an engineering analysis of long-term storage of uranium metal in boxes as an option for long-term management of depleted uranium hexafluoride (UF_6). Three storage facilities are considered: buildings, vaults, and mined cavities. Three cases are considered: either all, half, or a quarter of the depleted uranium metal that would be produced from the conversion of depleted UF_6 is stored at the facility. The analysis of these alternatives is based on a box design used in the *Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride*, report DOE/EIS-0269, published in 1999 by the U.S. Department of Energy. This box design does not appear to effectively use space within the box. Hence, an alternative box design that allows for a reduced storage area is addressed in the appendices for long-term storage in buildings.

1 INTRODUCTION

A number of options for the long-term management of depleted uranium hexafluoride (UF_6) were assessed by the U.S. Department of Energy (DOE) in *Depleted Uranium Hexafluoride Management Program: The Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride* prepared by Lawrence Livermore National Laboratory (LLNL 1997) and the *Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride* (DOE 1999). These options included several choices for the chemical form of depleted uranium to be stored and three types of storage facilities. The chemical forms analyzed were uranium hexafluoride (UF_6), uranium dioxide (UO_2), and triuranium octaoxide (U_3O_8). The types of storage facilities considered were buildings, vaults, and mined cavities.

This report addresses long-term storage of an additional chemical form — uranium metal. The engineering analysis for storage of the other three chemical forms (LLNL 1997) is referred to in this report as the Engineering Analysis Report. Section 6.12 of the Engineering Analysis Report addresses the storage options for the other chemical forms. To help ensure fair treatment of all options, the assumptions used in this report are the same as those used in the Engineering Analysis Report to the extent possible. When different assumptions are made, they are discussed.

Also, to assist the reader with comparisons of the options presented in Section 6.12 and the option for storage of depleted uranium metal analyzed in this report, the table of contents, figures, and tables in this report are comparable to those in the Engineering Analysis Report, Section 6.12.

Three cases for storage of depleted uranium metal are considered. The first is that all of the depleted uranium metal that would be produced from the conversion of depleted UF_6 generated by DOE prior to July 1993 would be stored at the storage facility (100% Case). In the second case, half of this depleted uranium metal would be stored at the storage facility (50% Case). In the third case, one-quarter of this depleted uranium metal would be stored at the storage facility (25% Case). The 50% Case and the 25% Case give DOE additional flexibility in considering storage at more than one storage facility and using more than one chemical form.

The estimated values in the main text of this report are based on the storage box design developed in the Engineering Analysis Report for the continuous metallothermic reduction process to convert depleted UF_6 to depleted uranium metal. This box design was used in the Engineering Analysis Report and the Programmatic Environmental Impact Statement (PEIS) (DOE 1999) for interim storage and transport of metal billets from the conversion site to the manufacturing site, where the billets were melted and used in making casks. This design does not appear to effectively use the space available for uranium metal storage and, as a consequence, results in a larger storage area than may be needed. A description of this box design, as well as another box design that would reduce the amount of void space and thereby the total area required for storage, is given in Appendix E. Appendix D provides information on building layout, site layout, staffing requirements, and resource requirements for long-term storage of depleted uranium metal in aboveground buildings and serves as a sensitivity analysis to the main text.

1.1 CURRENT STATUS

Commercial nuclear power reactors in the United States and the nuclear weapons program require the use of enriched uranium; that is, uranium enriched in the fissile isotope uranium-235 (U^{235}). A gaseous diffusion process that separated uranium-235 from uranium-238 (U^{238}) was used to produce enriched uranium. A by-product of this enriched process was UF_6 containing uranium depleted in uranium-235, or depleted UF_6. Approximately 560,000 metric tons (tonnes, or te) of depleted UF_6 were produced by DOE at the gaseous diffusion sites (Paducah, Kentucky; Portsmouth, Ohio; and the K-25 Site at Oak Ridge, Tennessee) prior to July 1993. This material is stored in 46,422 steel cylinders. In July 1993, the United States Enrichment Corporation (USEC) took over operation of the diffusion plants in Paducah and Portsmouth (K-25 was shut down in 1985). Because of two memoranda of agreement recently signed between USEC and DOE, some of the depleted UF_6 generated by USEC is also being transferred to DOE for management. However, to maintain consistency and compatibility with the Engineering Analysis Report, this report considers only the inventory of depleted UF_6 that DOE generated prior to July 1993.

1.2 BACKGROUND ON STORAGE OF DEPLETED URANIUM

Because depleted uranium has several potential uses and is not highly radioactive, DOE's long-term management options include storage options. Storage, as opposed to disposal, permits the future use of depleted uranium. If depleted uranium were stored as uranium metal, depleted UF_6 would be processed to produce billets of uranium metal. These uranium metal billets would be placed in wood boxes and transported by rail or truck to the long-term storage facility. (The long-term storage facility is also referred to as the "storage facility" in this report.)

1.2.1 Storage Area Required

The area required to store depleted uranium depends on four factors: the weight percent of uranium in the stored compound, the bulk density of the stored compound, the type of storage containers used, and the storage configuration. Table 9.1 in Section 6.10 of the Engineering Analysis Report presents depleted uranium stored as a metal alloy consisting of 97 wt% uranium and 3 wt% iron. The metal would be in the form of billets that are 2 in. × 3 in. × 20 in. The uranium billets would be stored in wood boxes that are 2 ft × 2 ft × 1 ft, with 19 billets per box. The 0.75-in.-thick wood boxes would weigh 50 lb. Each billet would weigh 75 lb, so the contents of the box would weigh 1,425 lb. Thus, the bulk density would be 5.71 g/cm^3, which is less than one-third the density of uranium metal (18.7 g/cm^3). Each year, 30,100 boxes would be shipped to the long-term storage facility for the 100% Case; thus, 602,000 boxes would be shipped to the disposal facility during the course of 20 years.

The storage configuration for these boxes is based on long-term storage of up to 40 years. A standard storage configuration was developed for each type of storage enclosure (buildings, vaults, and mined cavities). In this configuration, the boxes would be stored on pallets, four boxes per pallet, in rows. The pallets (and boxes) would be stacked four high. Figure 1.1[1] shows this storage configuration.

1.2.2 Other Considerations

A primary concern for storage of depleted uranium is the integrity of the container in which it resides. Because storage implies that the depleted uranium would be used later, it is important that the integrity of the storage container, which for uranium metal is a wood box with 0.75-in.-thick walls, would take into account its characteristics. Wood would deteriorate if exposed to the elements; consequently, storage in structures such as buildings, vaults, or mined cavities would be appropriate. As will be discussed below, the boxes should be treated to limit their combustibility because uranium metal is pyrophoric and reactive.

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[1] The figures and tables referenced in this report are placed at the end of each chapter.

Some relevant characteristics are discussed in the report on uranium-238 in the radionuclide report series published by the National Low-Level Waste Management Program (Adams 1995). Uranium is chemically reactive and combines directly with most elements. If it is finely divided, such as in a powder, it is pyrophoric and can be ignited and sustain combustion. Because uranium metal is very reactive when heated in air, processes that require melting of uranium metal are done either in an inert atmosphere or in a vacuum. Also, uranium and its alloys are difficult to machine, partly because all machining of uranium results in some burning or sparking because of its pyrophoricity.

Uranium-238 has a very long radiological half-life of approximately 4.5 billion years, with a specific activity of 3.4×10^{-7} Ci/g. Its radioactive decay results in the emission of energetic alpha particles with energies above 4 MeV. The International Atomic Energy Agency has rated uranium-238 to have high radiotoxicity. Uranium is also very hazardous chemically when either inhaled or ingested, causing toxicity to the kidneys.

Uranium metal billets would not be machined or intentionally heated in the long-term storage facility. Rather, they would be handled, moved, and stored. Under normal conditions, uranium metal stored in boxes presents few problems. However, should an initiating event cause a fire or explosion, heat could cause the uranium to burn and release finely divided particles of U_3O_8 that would be hazardous both chemically and radiologically if inhaled or ingested. An overview of issues in the long-term storage of uranium metal is found in Appendix C.

1.2.3 Control and Accountability of Depleted Uranium at the Storage Facility

The basic compliance documents for material accountability and security requirements for facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE Orders. DOE Order M 474.1-1, *Manual for Control And Accountability of Nuclear Materials*, prescribes DOE's requirements and procedures for nuclear material control and accountability. DOE Order 5633.3B, *Control and Accountability of Nuclear Materials*, addresses the material control requirements for depleted uranium at the storage facility. Although DOE Order 5633.3B describes depleted uranium as a material of limited strategic and monetary values, its requirements apply because the storage facility would contain more than 10 te of depleted uranium. Depleted uranium is treated as Category IV, Attractiveness Level E, material — the lowest category and attractiveness level of nuclear material subject to this order.

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3) and for protection of the plant radiological and hazardous materials from unauthorized access and removal. The materials accountability system at the storage facility is required to track nuclear materials inventories, document nuclear material transactions, issue periodic reports, and assist with the detection of unauthorized system access, data falsification, and materials gains or losses. As identified primarily in Appendix A, the materials accountability system includes the following elements. In the unloading bay of the receiving warehouse, incoming boxes would be weighed and assigned a bar code. Hand-held bar coding equipment with a computer link would be used, so that the weight and bar code of a box would be recorded in a database. When boxes would be loaded for transport to a storage building, the bar codes of the boxes would be read with the bar coding equipment. In the repackaging area, the bar coding equipment would be used to record the code of damaged boxes and to make codes for new boxes to account for the billets transferred from damaged boxes to new boxes.

Upon receipt in a storage building, the boxes would be weighed and their bar codes read for accountability purposes. Similarly, the codes of damaged boxes transported to the repackaging area would be read. Each storage enclosure, the receiving warehouse, the repackaging area, and the administration building would contain a computer attached to a local access network (LAN) so that inventory movements would be recorded. In the administration building, the computer would be used to audit the inventory of boxes and depleted uranium, track inventory movements, and issue periodic reports.

1.2.4 Safeguards and Security Considerations

DOE Order O 470.1 requires that certain facilities have a safeguards and security program. Such facilities include “those that have a radiological/toxicological sabotage threat that would cause a unacceptable impact on the national security, the health and safety of employees, the public or the environment.” Persons entering the storage facility with sabotage or other malevolent intent could cause boxes to be damaged or set fires or explosions. Hence, because the health and safety of employees, the public, or the environment could be threatened, a safeguards and security program would be needed. As the storage facility will not contain special nuclear material or classified matter, DOE intends that a graded approach be used so that the “magnitude of the resources expended are commensurate with the security interest’s importance and the impact of the loss, destruction, misuse.”

It is beyond the scope of an engineering analysis to address details of a safeguards and security plan, except to indicate how it would affect the equipment required (Appendix A) and the data used to estimate radiation exposure and staffing (Appendix B). It was assumed that security personnel would be assigned to each major building and key areas of the site (e.g., entry point); all persons on-site would be issued security badges; these badges would have location indicators that would be monitored by security personnel; and the receiving warehouse and repackaging building, as well as storage enclosures, would have an automated security station to control access. Security surveillance and alarm systems (e.g., closed circuit television and remote operated locked barriers) would be included, as appropriate. Site security fencing would consist of galvanized steel fabric fencing with barbed wire or barbed wire coil topping, per DOE Order 6430.1A, Section 0283. The fence would limit access into the site to a single road, where a guard station would be located at the boundary of the site. Perimeter fence lighting particulars would be determined by security and safeguards requirements.

Material surveillance refers to the monitoring of enriched uranium to detect unauthorized activities. Protective force personnel and operators would be present in most areas of the storage facility around the clock. They would be further supported by full-time security and emergency staff who could provide immediate aid in the event of any security breach or environmental incident.

1.2.5 Fire Protection

The requirements for facility fire protection are contained in DOE Standard DOE-STD-1066-97, *Fire Protection Design Criteria* (DOE 1997), and the *DOE Fire Protection Handbook*, DOE-HDBK-1062-96 (DOE 1996). These requirements replace certain mandatory fire protection requirements that were formerly in DOE Order 5480.7A, *Fire Protection*, and DOE Order 6430.1A, *General Design Criteria*. Supplemental fire protection guidance applicable to the design and construction of DOE facilities and site features (such as water distribution systems) is provided. This guidance is intended to be used in conjunction with the application building code, National Fire Protection Association (NFPA) codes and standards, and any other applicable construction criteria.

DOE Standard DOE-STD-1066-97, Section 5.2, states that new permanent structures in excess of 5,000-ft^2 (465-m^2) floor area should be of noncombustible or fire-resistive construction if no local building code is enforced. The three long-term storage options for depleted uranium metal (i.e., building, vault, and mined cavity) would meet this structural requirement.

In addition, DOE Standard DOE-STD-1066-97, Section 5.3, states that all facilities of significance, including facilities where a fire could cause unacceptable off-site consequences to health and safety, should be protected by an automatic fire suppression system (usually a wet pipe sprinkler system). DOE has historically considered a facility with a maximum possible fire loss (MPFL) in excess of $1 million as being significant from a property protection standpoint. In accordance with these requirements, the following fire protection systems and features would be provided:

- Fire detection and alarm systems would be provided in all buildings.

- Automatic fire sprinkler systems would be used throughout the facilities, including the receiving warehouse and repackaging building and the actual storage locations (whether building, vault, or mined cavity).

- The administration building, receiving warehouse and repackaging building, and the workshop (where the majority of the workforce would be located) would be 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.

It was assumed during building design that water for fire fighting would be obtained from the domestic system. Necessary equipment would include water pumps and area distribution loops.

Depleted uranium is a combustible metal. Metal-water reactions can occur at room temperature and slowly release hydrogen. Thus, events such as the inadvertent operation of the water-based fire suppression system could release hydrogen. Hydrogen could collect and be ignited through combustion of the wooden boxes holding the depleted uranium metal billets. To avoid this, provisions have been made to construct the wooden boxes out of fire-retardant materials to minimize the potential for inadvertent combustion.

A sprinkler system would be provided within the storage areas to reduce the potential for the uranium metal to ignite and burn because of inadvertent ignition of other combustible materials. However, inadvertent actuation of the sprinkler system is to be avoided. As such, the sprinkler system would be of the pre-action type, in which automatic sprinklers are attached to a piping system containing air that may or may not be under pressure. A supplemental heat-responsive system with more sensitive characteristics than the automatic sprinklers would be provided. Actuation of the heat-responsive system (e.g., from a fire) would open a valve that would permit water to flow into the sprinkler piping system and be discharged from those sprinklers that were opened by heat from the fire.

Once uranium starts to burn, it is extremely difficult to extinguish. Typical extinguishing methods, such as carbon dioxide or halon, are not effective in fighting uranium fires; in fact, halon may be explosive and produce toxic fumes if used directly on the fire. Normally, small fires may be extinguished by using MET-L-X powder, which is a mixture of sodium chloride (table salt) and potassium carbonate (baking powder). When spread over the burning metal in significant quantities, MET-L-X starves the fire of oxygen (DOE 1998).

Large fires, such as those involving storage drums or pallets, are more difficult to extinguish. Submersion in water will eventually work once the metal cools down. However, continuous water addition, such as from a sprinkler system, is necessary to make up for losses due to boiling and evaporation (DOE 1998).

1.3 OVERVIEW OF STORAGE FACILITIES

A storage facility is a single-purpose facility with enclosures for storing depleted uranium boxes and with support buildings. It is designed for receiving, inspecting, and repackaging (when necessary) boxes of depleted uranium metal and storing them in a series of enclosures. Figure 1.2 shows the overall process flow within a storage facility. A storage facility for depleted uranium metal has the following support facilities: an administrative building, a receiving warehouse, a repackaging area, and a workshop. The repackaging area shares a building with the receiving warehouse.

The process flow within a storage facility would be as follows. Boxes of depleted uranium would be received at the facility by rail or road and unloaded by davit crane at an unloading dock attached to the receiving warehouse and repackaging building. The boxes would be placed in the receiving warehouse, where the boxes would be visually inspected for damage and external smearable contamination. Undamaged boxes would be transported to a temporary storage area in the receiving warehouse by a bridge crane with a capacity of 10 to 15 te (22,000 to 33,000 lb). Damaged boxes would be transported by bridge crane to the repackaging area, where billet packaging equipment would be used to repackage the uranium billets into a clean, undamaged box. The next box would then be transported by bridge crane to the temporary storage area. Empty damaged boxes would be broken up, packed in drums, and shipped to a low-level radioactive waste (LLW) disposal facility.

Boxes containing uranium billets would be transported on pallets by truck from the temporary storage area in the receiving warehouse to a storage enclosure. They would be unloaded by davit crane from the truck and moved by straddle carrier to their long-term storage location.

The operations at the storage facility would require little energy and few materials. The major consumable item would be the diesel fuel used in the on-site movement of the boxes. Minor amounts of wastes would be generated, the most notable being air emissions from on-site diesel transport and minimal space heating and waste from damaged boxes, which are assumed to be LLW. The material and energy flows for a storage facility would be dominated by the material and energy used in their construction.

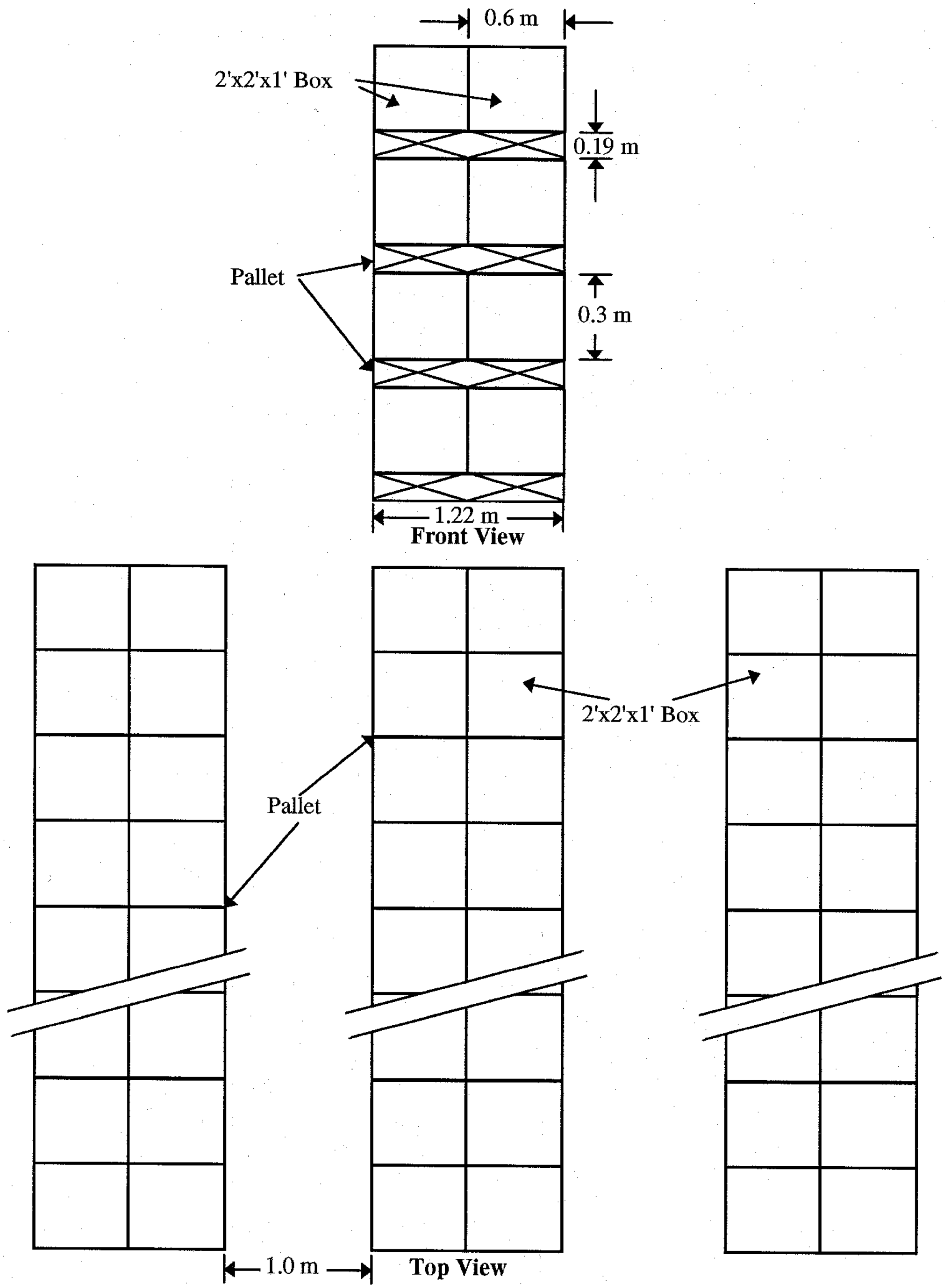

FIGURE 1.1 Storage Configuration for Uranium Metal

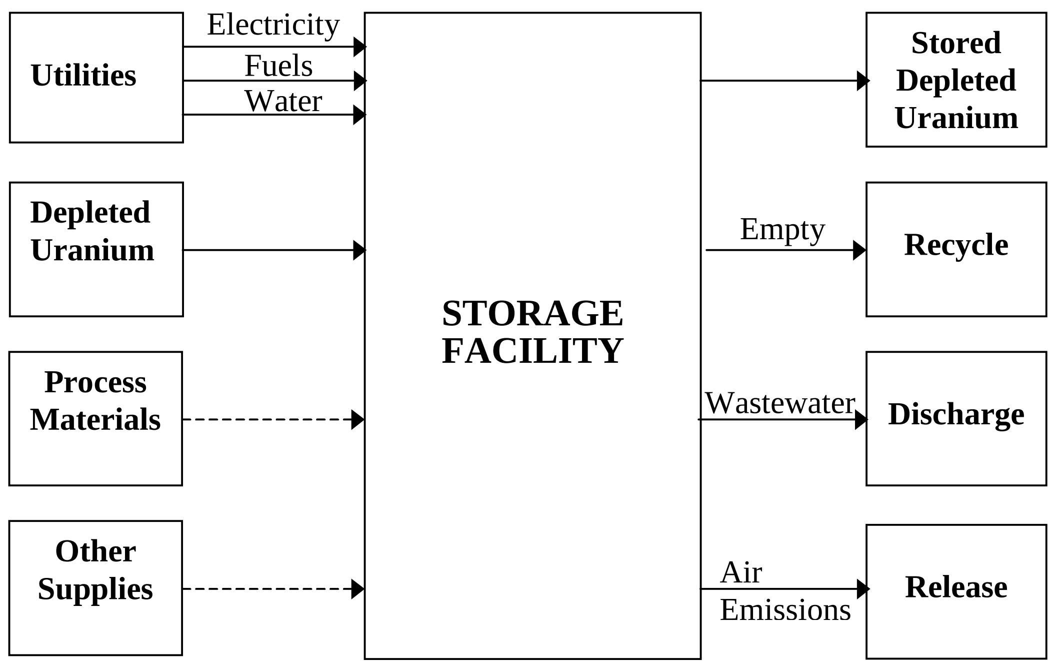

FIGURE 1.2 Overall Process Flow Diagram for the Storage Facility during Operations

2 DESCRIPTION OF THE FACILITY

A long-term storage facility for depleted uranium metal would have three major types of buildings in addition to storage enclosures. These buildings are:

- A receiving warehouse and repackaging building in which containers shipped to the storage facility are temporarily stored before inspection and transport to a storage enclosure. If the inspection shows that a box is defective, then its uranium metal billets are repackaged (i.e., transferred to another box) prior to being transported to a storage enclosure.

- A workshop used for maintaining equipment necessary for the receipt and repair of failed inspection and repackaging equipment. Maintenance machinery and tools, including a jib crane for material handling, are provided.

- An administration building that incorporates all technical and administrative support functions needed to manage the operation of the storage facility. These functions include security duties, facility access control, health physics administration and radiation badge control, sanitary facilities operation, work control and personnel support, internal and external (public relations) communications, spill or emergency response provisions, analytical laboratory activities, environmental regulatory reporting, and records management for materials control and accountability (MC&A).

2.1 GENERAL DESIGN CRITERIA

The following criteria are used in the engineering design of the storage facility:

- The storage facility must provide for the receipt of materials over a 20-year period and for storage for 20 years after receipt of the last container. Means of ingress and egress for depleted uranium for transportation by rail or truck should be provided.

- The storage system must provide systems or methods for (a) inspection of the integrity of the boxes, (b) monitoring of air within a storage building for indications of failed boxes, (c) removal and management of any failed box, and (d) inventory of material for MC&A reporting.

- The facility will be designed, constructed, and operated to comply with the requirements of DOE Order 5480.28, *Natural Phenomena Hazards Mitigation*. The general requirements of this order state that structures,

> systems, and components (SSCs) shall be designed to withstand the effects of natural phenomena hazards (NPHs) to prevent loss of structural integrity that could endanger life safety. The order provides that an additional objective for selecting SSCs or site activities is to prevent loss of capability to perform functions consistent with (1) importance to safety for workers and the public, (2) impact on the environment, (3) repair/replacement costs, or (4) programmatic mission.

Design criteria are contained in DOE-STD-1024-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (DOE 1994a). The NPH standards in DOE-STD-1024-94 have five performance categories for selecting SSCs. The design and evaluation criterion in Performance Categories 0, 1, and 2 are similar to those in model building codes. For SSCs assigned to Performance Category 0, consideration of NPHs may not be needed. For SSCs assigned to Performance Category 1, provisions in model building codes that protect against NPHs are adequate. SSCs assigned to Performance Category 2, which are slightly more demanding that the design criteria for hospitals and fire or police stations, should maintain functionality even when a natural phenomena event occurs.

Performance Categories 3 and 4 are appropriate when an SSC failure would result in a potential significant threat to the public safety and the environment. The SSCs assigned to these categories are designed to control and confine hazardous material so that damage is contained within confinement barriers. A qualitative assessment of the hazard ranking and performance category for the proposed storage facility has been performed. Table 2.1 summarizes the results of this assessment.

The administration building would be an office building that does not contain any uranium. Therefore, it is given the lowest hazard and performance category ranking. The workshop would be used for maintenance of equipment necessary for the repair of inspection and repackaging equipment. Since the workshop would not contain depleted uranium or be involved with energetic processes, it would have a low hazard ranking. Because the primary concern is to prevent major structural damage or collapse that could endanger personnel, Performance Category 1 SSCs would be appropriate.

No energetic processes would be performed in the receiving warehouse and repackaging building, where only movement of boxes and pallets and repackaging activities would occur. However, this building would hold a substantial inventory of uranium. Performance Category 2 SSCs and a low hazard ranking appear to be appropriate for this building, as well as for the storage enclosures.

2.2 SUPPORT BUILDINGS

The receiving warehouse and repackaging building, the workshop, and the administration building are assumed to be the same, regardless of whether the storage enclosures are buildings, vaults, or mined cavities. The size of the receiving warehouse and repackaging building would depend, however, on the number of boxes of depleted uranium metal received per unit time at the storage facility.

2.2.1 Receiving Warehouse and Repackaging Building

The storage facility would have a building for temporary storage and inspection of boxes containing uranium metal received at the storage facility. The building would also house a facility for repackaging uranium billets in damaged boxes. This building will be referred to as the receiving warehouse and repackaging building. The entire building would be high-efficiency-particulate-air (HEPA) filtered and served by two overhead cranes. The receiving warehouse is designed to store pallets that would be delivered in 5.8 weeks, when approximately 145 pallets would be delivered each week for the 100% Case, 73 for the 50% Case, and 37 for the 25% Case. Boxes would be stored on pallets, four boxes per pallet, one high. Each pallet is assumed to be 4 ft wide by 4 ft long. Each pallet would have a 1-m clearance to allow detailed inspection of all sides. Table 2.2 shows the dimensions, storage configuration, and capacity of the receiving warehouse when the storage facility receives 100%, 50%, and 25% of the depleted uranium needed to be stored. Figures 2.1a through 2.1c contain plan views for the receiving warehouse for these three cases. Undamaged boxes would be moved to a loading bay for removal to a storage enclosure. Damaged boxes would be moved to the repackaging facility for transfer of their contents to new boxes.

The repackaging facility would be an enclosure within the receiving warehouse building that is kept at a slightly lower pressure than the receiving warehouse. Therefore, ingress and egress would be through air locks. The repackaging facility would contain a billet packaging station for transferring billets from damaged boxes to new boxes. A storage area with empty new boxes and 55-gal drums would hold damaged boxes that are assumed to be LLW, pending shipment to an off-site disposal facility. Boxes would be moved in the receiving warehouse by bridge crane and to or from trucks or railcars by davit crane. A forklift would be used to transfer damaged boxes from the receiving warehouse to the repackaging facility.

The receiving warehouse and repackaging building would be a standard warehouse-type building with sheet steel used for exterior walls, spread footings, and a 30-cm (1 ft) concrete floor. The exterior walls would have steel pillars, as needed, to provide additional support for crane rails. There would be no interior pillars. Steel trestles would support a standard flat roof. Heating, ventilation, and air conditioning (HVAC) would control temperature and humidity to comfortable working levels. Once-through air flow and single filtration of exhaust air through HEPA filters would also be provided.

2.2.2 Workshop

The long-term storage facility would also have a workshop for maintaining equipment necessary for the repair of inspection and repackaging equipment. It would be a standard warehouse-type building with sheet steel used for exterior walls, spread footings, and a 30-cm (1-ft) concrete floor. There would be no interior pillars. Steel trestles would support a standard flat roof. HVAC would control temperature and humidity to comfortable working levels. The area of the workshop would be approximately 25 m × 25 m (82 ft × 82 ft).

2.2.3 Administration Building

The storage facility would also have an administration building to house management and office staff and to provide showers and a changing area for personnel working with depleted uranium boxes. The area of this building would be approximately 25 m × 27 m (82 ft × 88 ft).

2.3 STORAGE BUILDINGS

To provide a fair comparison with other chemical forms considered for storage of depleted uranium, the storage buildings are assumed to be similar in size to the storage buildings used for the UF_6, UO_2, and U_3O_8 options (refer to 2.2 of Section 6.12 of the Engineering Analysis Report). The storage buildings studied for those chemical forms were 265 m (870 ft) in length, 50 m (164 ft) in width, and 5 m (16 ft) in height. These dimensions would allow 22 rows of pallets, stacked four high, with each row containing 209 stacks when the same assumptions are made with regard to the width of aisles between rows (1 m), the distance between the outer rows and the side of the buildings (1 m), and the distance between the end of a row and the end of the storage building (5 m). Buildings of this area would accommodate 73,568 boxes. With buildings of this size, nine storage buildings would be needed for the 100% Case. If eight buildings were fully utilized, the ninth building would use only 18% of its space. It would be uneconomical and not cost-effective to build a building and use less than 20% of its capacity. Therefore, it was assumed in this report that the length of the storage buildings would be increased to 271 m (890 ft) — an increase in building capacity of only 2.4%. This building length would allow a capacity of 75,328 boxes (22 rows, 214 stacks per row, 16 boxes per stack). With this size storage building, eight buildings would be needed for the 100% Case, four for the 50% Case, and two for the 25% Case.

Stacking pallets and boxes four high conforms with the Occupational Safety and Health Administration (OSHA) requirement that containers stored in tiers shall be stacked, blocked, interlocked, and limited in height so that they are stable and secure against sliding or collapse (29 CFR 1910.176(b)). The height of a stack of 4 pallets and 16 boxes, with a pallet having a height of 0.19 m, is 1.98 m. Assuming that a pallet weighs 25 kg, the corresponding loading is

7,268 kg/m^2. These heights and loadings are within the envelopes defined by the other chemical forms, as shown in Table 2.3.

Boxes of depleted uranium would be brought to a storage building, one pallet at a time, and subsequently be moved to its storage location, one pallet (four boxes) at a time. When a storage building is filled with its complement of 75,328 boxes, it would be difficult for a handling machine to maneuver because the building would be tightly packed. All boxes must be readily removable in the event that a box might fail and it is necessary to repackage its contents. As discussed in the Engineering Analysis Report, a forklift would not have room to maneuver, and an overhead crane could cause damage to the stored boxes should the roof collapse in the event of natural phenomenon disaster. Therefore, a straddle carrier was chosen to be the best machine for handling pallets of boxes in a storage building. A straddle carrier is a mini-crane on wheels, capable of lifting a loaded pallet and moving it around.

A storage building would be a standard warehouse-type (“Butler”) building. It would have spread footings and a 30-cm- (1-ft)-thick floor. Its exterior walls would be 0.3-cm-thick sheet steel. There would be no interior pillars; rather, steel trestles would support a truss-supported flat roof. The HVAC would avoid temperature and humidity extremes that could cause deterioration of wood boxes and enhance corrosion of the depleted uranium billets. The ventilation system would utilize once-through flow of air to prevent recirculation of contaminants, accommodate single filtration of exhaust through HEPA filters, and control pressure to assure air flow from areas of low hazard to areas of high hazard. Each building would have a bay for shipping or receiving boxes at each end. Figure 2.2a shows a plan view of a storage building with storage configuration, and Figure 2.2b shows an elevation view of a storage building with storage configuration.

2.4 STORAGE VAULTS

The storage vaults in the Engineering Analysis Report (Section 6.13) are modeled on low-level radioactive waste disposal vaults. The storage vaults are partly subsurface reinforced concrete structures with 0.3-m-thick walls. They are 5 m in height, of which 4.6 m are below the surface. While the disposal vaults have a concrete slab roof to prevent access and interior concrete walls that divide a vault into cells to support the concrete roof, the storage vaults have a lighter steel roof supported by trusses, which eliminates the need for interior support. In the Engineering Analysis Report, access to the interior of a vault is attained by removing part of the roof and using a mobile crane to move boxes or pallets. Because access to a vault is needed when boxes are emplaced and removed at the end of the lifetime of the facility, as well as when damaged boxes are discovered and new boxes substituted, it might be burdensome to ensure that the roof is airtight every time it is repositioned. Therefore, in this report, it is assumed that a ramp with a low grade is used to move boxes to a vault, that a vault has a door in a concrete wall, and that a straddle carrier is used to transport boxes within a vault. A vault has a 0.3-m-thick concrete pad that sits on 0.3 m of gravel.

A storage vault in the Engineering Analysis Report is 81 m (266 ft) long and 40 m (131 ft) wide. If pallets are stored side-by-side in rows, with a 1 m distance between rows, then between the outer row and the sides of the vault (and with some clearance between the ends of the rows and the ends of the vault) a vault could accommodate 17,952 boxes (17 rows, 66 stacks per row, 16 boxes per stack). Thirty four vaults would be needed, with the last vault half empty. For the 50% Case, 17 vaults would be needed. For the 25% Case, 9 vaults would be needed, with the last vault more than half empty. Because it would be uneconomical and not cost-effective to have vaults with empty space, it was decided in this analysis to decrease the length of a vault to 79 m (259 ft), which results in a decrease in capacity of 15%. With this length and a width of 40 m, a vault could hold 15,232 boxes (17 rows, 56 stacks per row, 16 boxes per stack), and 40 vaults would be needed for the 100% Case. For the 50% Case and 25% Case, 20 vaults and 10 vaults would be needed, respectively.

The HVAC system would be provided to all vaults at all times. This is a change from the Engineering Analysis Report, in which only forced ventilation would be provided only when workers were present in a vault. Air conditioning the vaults would enhance safety by preventing hydrogen buildup to reduce the risk of explosion and by hindering deterioration of boxes and corrosion of uranium metal caused by moisture. Because the wooden boxes are not seal-tight, hydride formation due to the entrapment of hydrogen would be minimal. Power would also be needed for internal lighting and HEPA filtration. 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 rainwater. Figures 2.3a and 2.3b present a plan view and an elevation view, respectively, of a vault with storage configuration.

2.5 MINED-CAVITY STORAGE

Storage of depleted uranium in mined cavities would be in drifts, which are lateral extensions of belowground tunnels that would act as aisleways. A mined-cavity storage facility would be more complex to build than a building storage facility or a vault storage facility because forced ventilation would be needed throughout shafts, tunnels, and drifts to enable workers to function without breathing tanks. While this is technically possible, the maintenance and energy requirements for ventilation would be very high compared with the other enclosure options.

As discussed in the Engineering Analysis Report, the size of a drift is dependent on the geological structure in which it is cut. Strong non-plastic strata can support larger drifts than softer, fractured, or plastic strata. There are thick surface strata of shale near the locations where depleted uranium is currently stored; however, these shale strata are generally fractured, and mines in these shale strata usually have small drifts of the order of 2 m wide by 2 m high. Drifts of this size would be inefficient for storing pallets of depleted uranium because they would accommodate only one row of pallets per drift. Other parts of the country have deep strata of basalt, tuff, or salt in which tall wide drifts can be constructed. It is assumed that mined-cavity storage would be situated where geologic materials are suitable for tunneling. It is also assumed that a mined-cavity facility would not be located in a groundwater region, major aquifer, or interbed containing perched water.

In the Engineering Analysis Report, the drifts were assumed to be rectangular in cross section, 12 m (39 ft) wide, 5 m (16 ft) high, and 100 m (328 ft) long. In this report, a slight change was made in the width of a drift, from 12 m to 12.1 m. With this change, the drifts would be wide enough to accommodate five rows of pallets, with four boxes of depleted uranium per pallet stacked four high to maintain standard clearances. The drifts would be long enough for 82 stacks per row. The drifts do not need a concrete foundation, but would have 0.3-m-thick reinforced concrete walls for linings.

A drift would have a capacity of 6,560 boxes, so that 92 drifts would be needed for the 100% Case, 46 drifts for the 50% Case, and 23 drifts for the 25% Case. For each case, the last drift to be filled would be more than 75% filled, so that this size drift would use space efficiently. Figures 2.4a is a plan view of part of a mined-cavity facility, and Figure 2.4b is an elevation view of a drift with storage configurations. The drifts would be parallel in a rectangular array. (Refer to the text and figures in Chapter 3, Section 3.3, for detailed site layout information.) A ventilation shaft, which also could be used as an emergency exit, would be located at each corner of the array. The facility would also have two elevator shafts for transporting workers, boxes of depleted uranium, and mined rock spoil either to the mined cavity or to the surface. Electric-driven straddle carriers would be used to transport pallets of boxes along aisleways and drifts.

Table 2.4 summarizes the requirements for each type of enclose for each case.

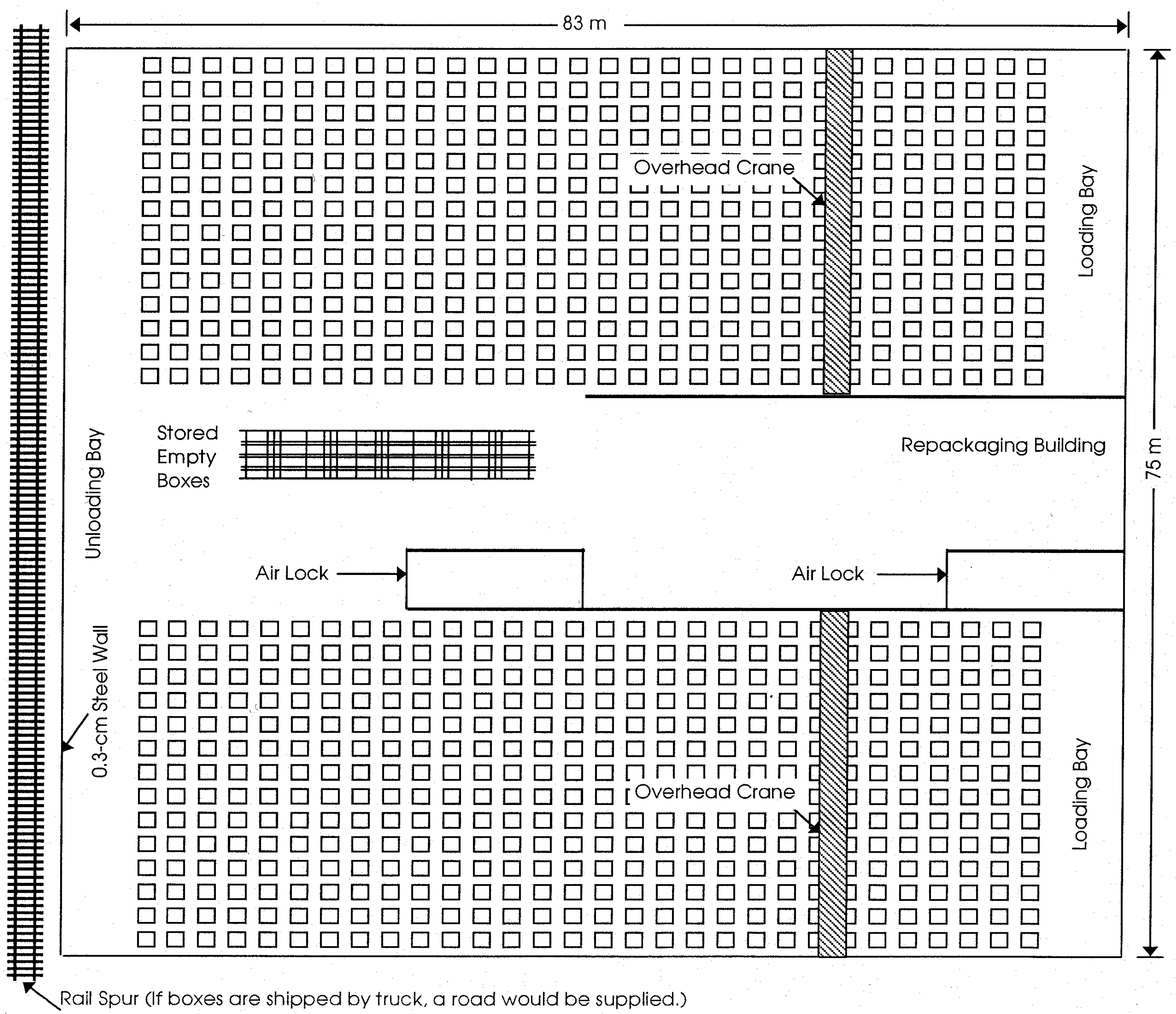

FIGURE 2.1a Plan View of the Receiving Warehouse and Repackaging Building — Uranium Metal, 100% Case

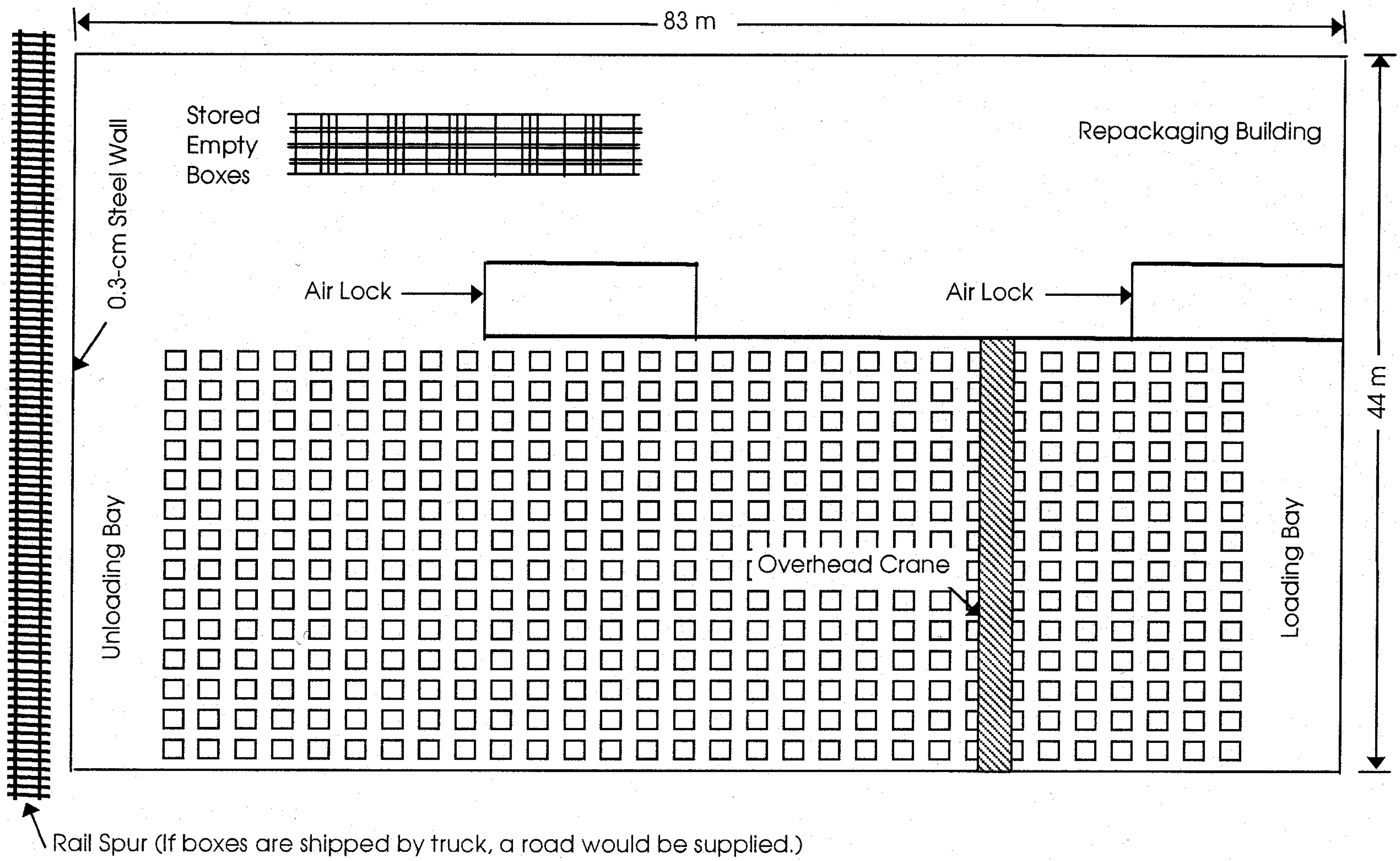

FIGURE 2.1b Plan View of the Receiving Warehouse and Repackaging Building — Uranium Metal, 50% Case

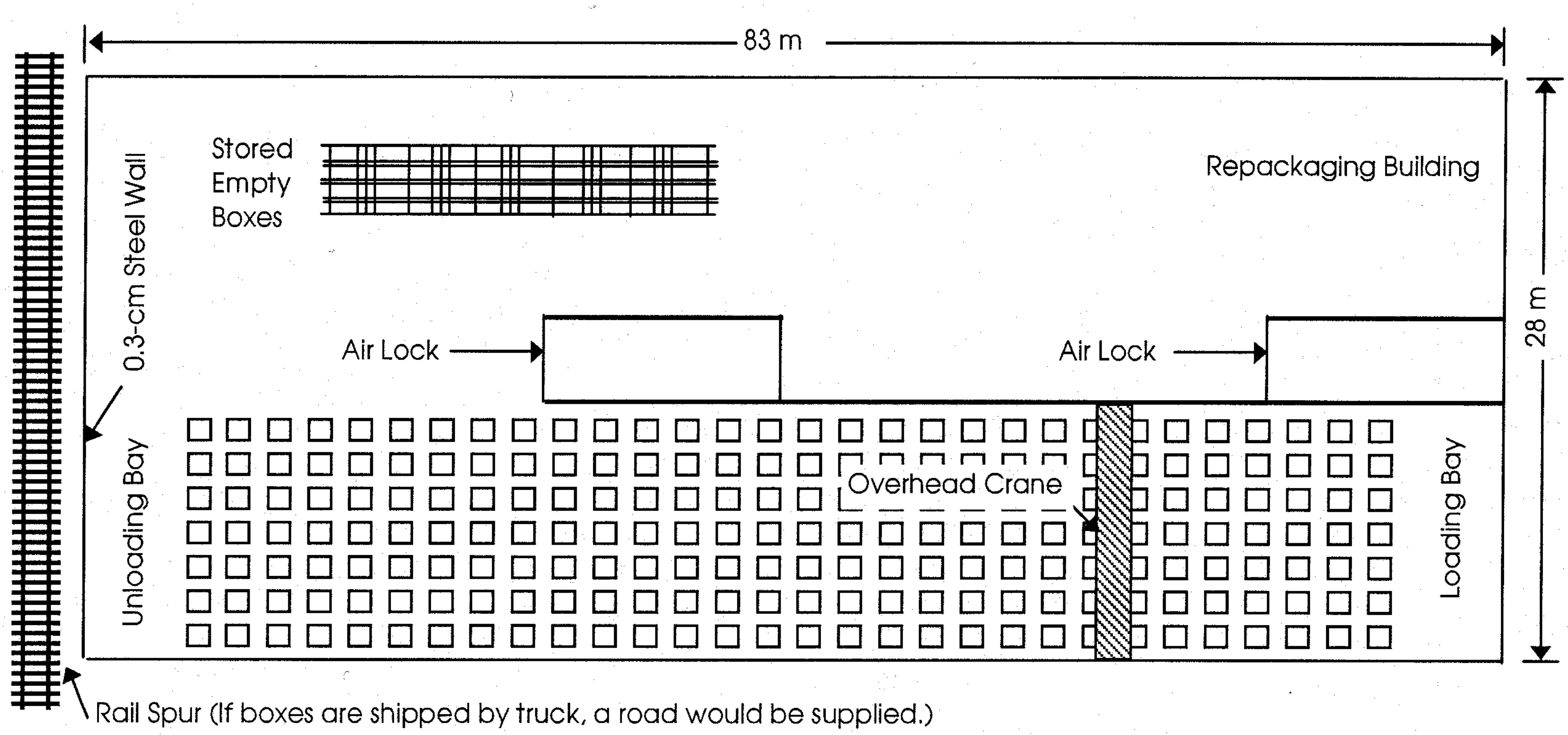

FIGURE 2.1c Plan View of the Receiving Warehouse and Repackaging Building — Uranium Metal, 25% Case

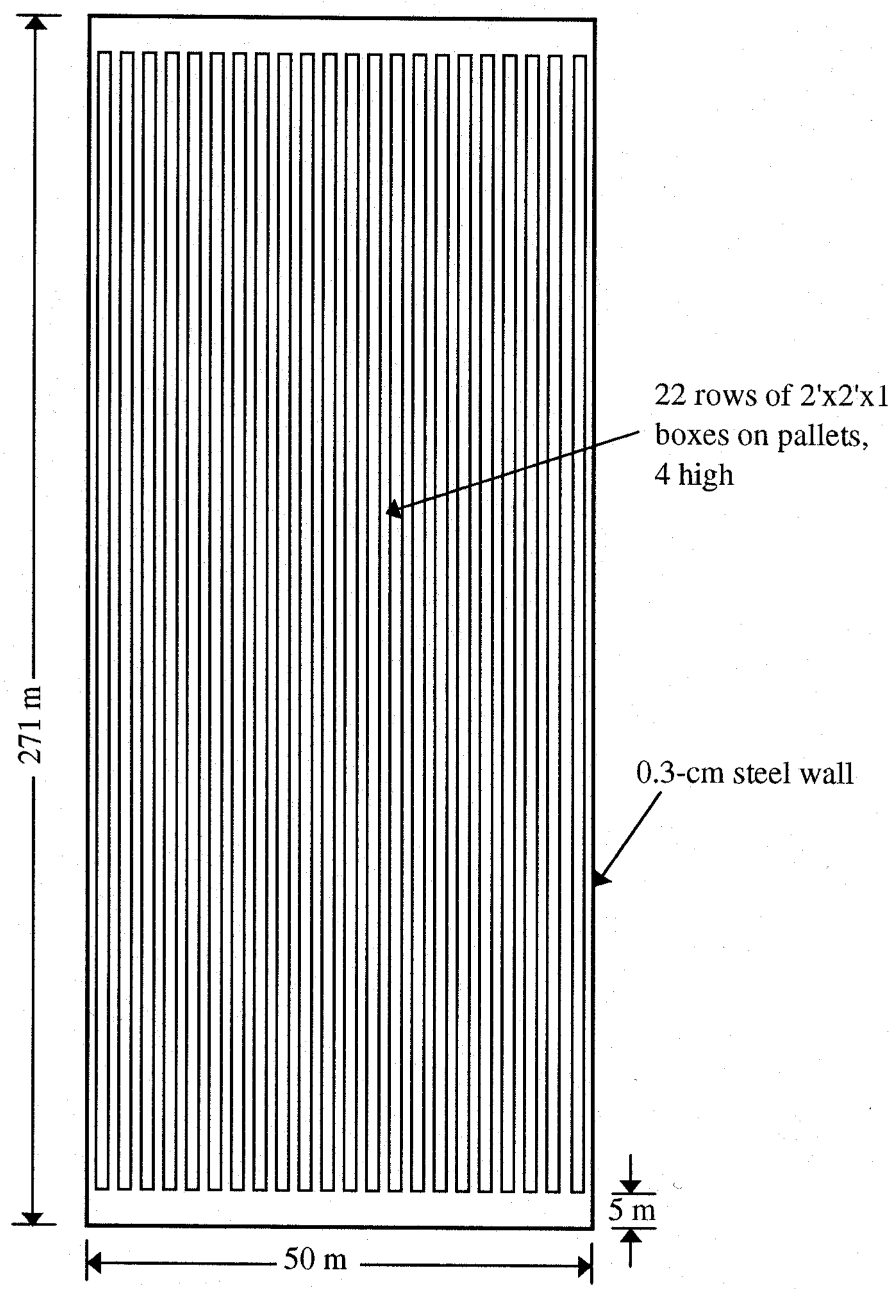

FIGURE 2.2a Plan View of a Storage Building with Storage Configuration

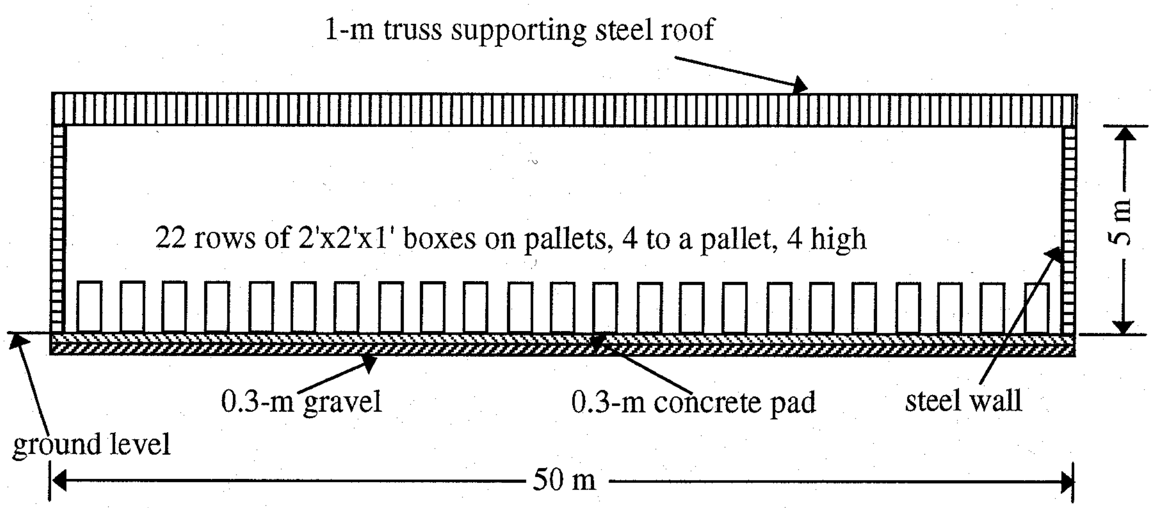

FIGURE 2.2b Elevation View of a Storage Building with Storage Configuration

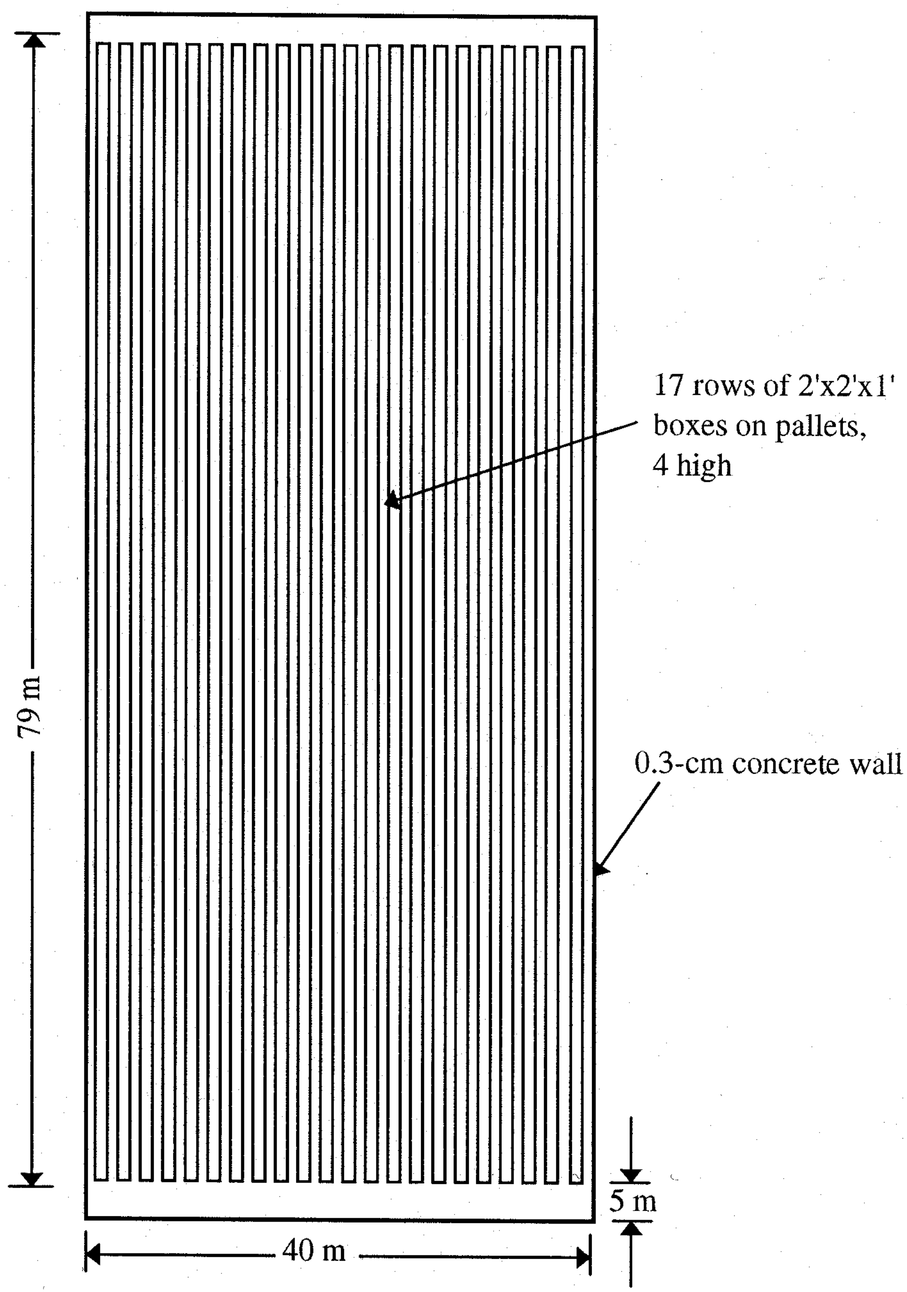

FIGURE 2.3a Plan View of a Storage Vault with Storage Configuration

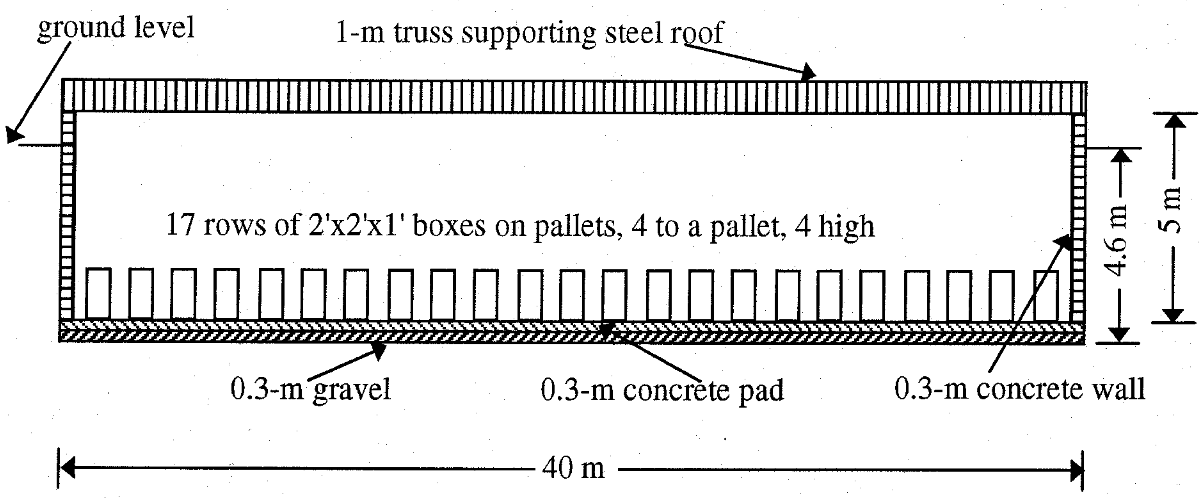

FIGURE 2.3b Elevation View of a Storage Vault with Storage Configuration

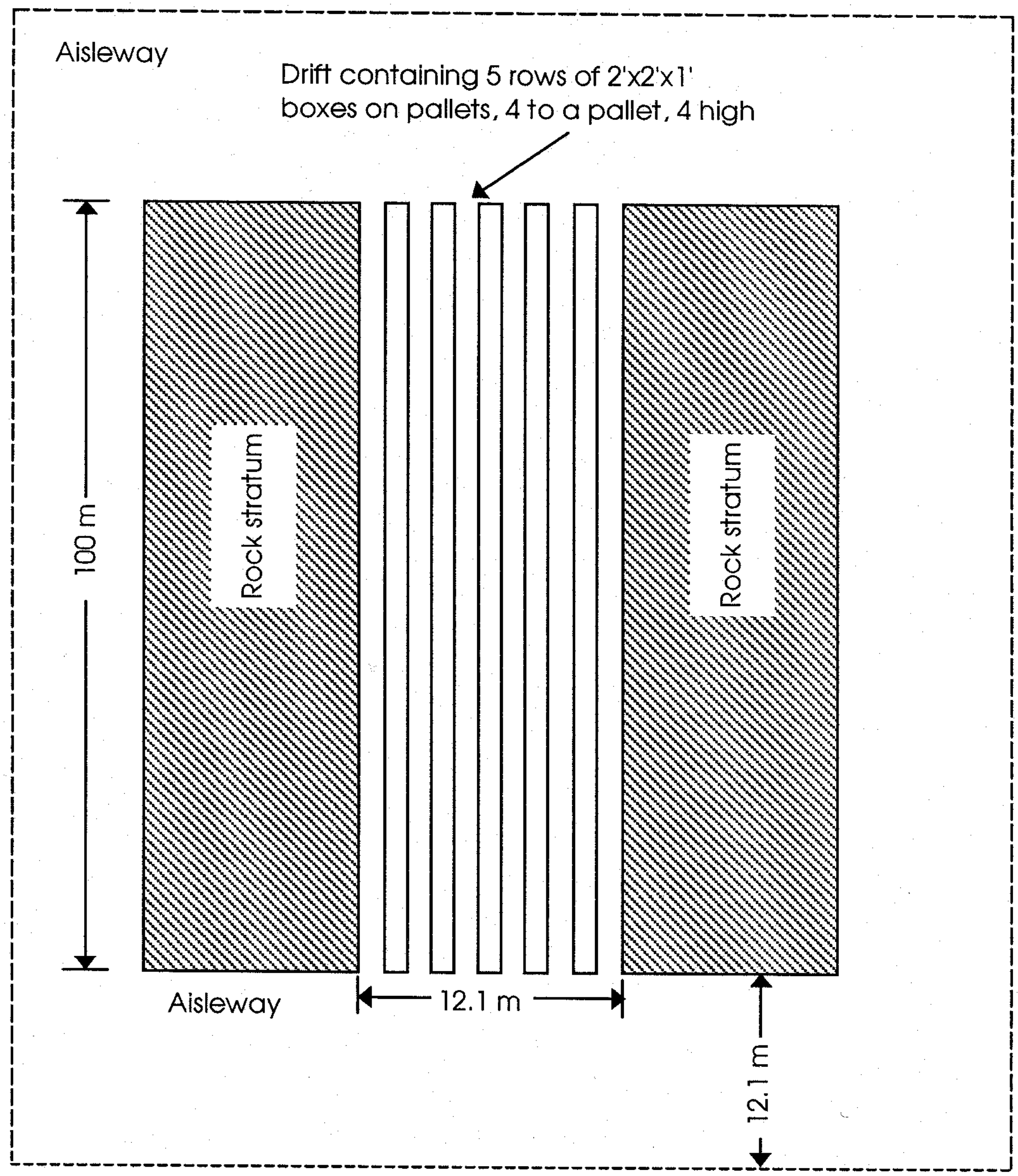

FIGURE 2.4a Plan View of a Drift with Storage Configuration

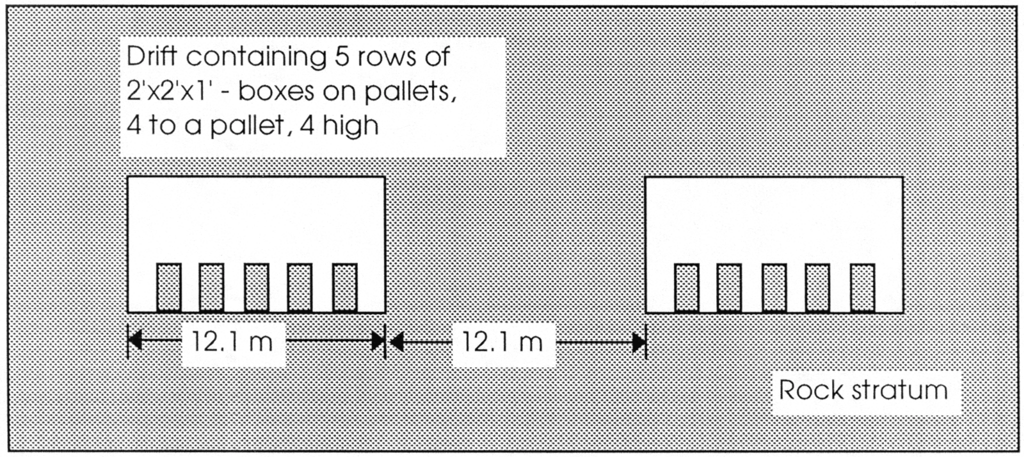

FIGURE 2.4b Elevation View of a Mined Cavity with Storage Configuration

TABLE 2.1 Qualitative Assessment of Hazard Ranking for Storage Facility Buildings

Building/Area	Hazard Ranking/Category	Qualitative Rationale
Administration	None/Performance Category 0	No hazards
Receiving warehouse and repackaging area	Low/Performance Category 2	Minimal off-site and on-site releases
Workshop	Low/Performance Category 1	No off-site releases; minimal on-site releases from radioactive materials; no consequences
Storage building	Low/Performance Category 2	Minimal off-site and on-site releases
Vault	Low/Performance Category 2	Minimal off-site and on-site releases
Mined-cavity	Low/Performance Category 2	Minimal off-site and on-site releases

TABLE 2.2 Dimensions, Storage Configuration, and Capacity of the Receiving Warehouse

Percent received	Length (m)	Width (m)	Number of rows	Containers per row	Containers, bldg. capacity	Storage capacity (weeks)
100%	83	75	28	120	3,360	5.8
50%	83	44	14	120	1,680	5.8
25%	83	28	7	120	840	5.8

TABLE 2.3 Comparison of Containers in Storage Configuration

Chemical form	Description	Height (m)	Loading (kg/m^2)
Uranium metal	2' × 2' × 1' boxes , 4-box pallet, 4 layers	1.98	7,268
UF_6	Type 48 cylinder, on supports	2.52	4,425
UO_2	30-gal drum, 4-drum pallet, 2 layers	1.86	8,565
U_3O_8	55-gal drum, 4-drum pallet, 2 layers	2.15	4,121

TABLE 2.4 Enclosure Requirements for Each Type of Facility

Enclosure type/ dimensions[a]	Rows	Stacks/row	Number of Enclosures[b] 100% Case	50% Case	25% Case
Building (271 × 50 × 5 m)	22	214	8	4	2
Vault (79 × 40 × 5 m)	17	56	40	20	10
Drift (mined-cavity) (100 × 12 .1 × 5 m)	5	82	92	46	23

[a] Length × width × height.

[b] Based on 16 boxes per stack — 4 boxes per pallet, 4 pallets per stack.

3 STORAGE SITE MAP AND USAGE REQUIREMENTS

Storage site maps were developed to be consistent with those shown for the other three chemical forms of depleted uranium presented in Section 6.12.3 of the Engineering Analysis Report. Site maps were developed from consideration of the operations that would take place at the storage facility; that is, unloading containers from rail cars and trucks, storing and inspecting containers in the receiving warehouse, moving inspected boxes to storage enclosures, and repackaging damaged containers. Additional considerations discussed in the Engineering Analysis Report include restricted access to the site by road to promote security and the need for open ground for rainwater infiltration. The advantages of minimizing site area were balanced against the need for storm water control. In general, impervious areas (paving and buildings) were restricted to less than 50% of the site area.

3.1 BUILDING STORAGE FACILITY

Construction sequences for a building storage facility are indicated with reference to Figures 3.1a through 3.1c for the 100% Case, 50% Case, and 25% Case, respectively. Construction would begin with the administration building, proceed with the receiving warehouse and repackaging building, and then continue with the workshop building. Storage buildings would be constructed near the receiving warehouse and 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 and then move away from the centroid as new storage buildings are constructed.

Because boxes containing depleted uranium would be received over a 20-year period, it would not be necessary to build all the storage buildings at once. Clearing and grubbing of the site would be performed for the area where construction would begin in that year. It would not be reasonable to clear and grub the entire site at the beginning of construction because substantial regrowth could occur over 20 years, and it would be necessary to clear and regrub the site for storage buildings constructed in later years.

Between two and eight storage buildings would be needed, depending on the percentage of depleted uranium received at this storage facility. These storage buildings would be laid out in two rows of between two and four buildings, as shown in Figures 3.1a and 3.1b for the 100% Case and the 50% Case. For the 25% Case, there would be one row of two storage buildings, as shown in Figure 3.1c. The area between buildings in a row would be open area for rainwater infiltration.

The complex would have road access from one end of the site and rail access through the center. This configuration should prevent conflicts between road traffic and rail traffic and minimize the travel time and distance required to move boxes from the receiving warehouse and repackaging building to the storage buildings. It should be noted that the estimated construction area is based on a generic site and will require adjustments for the actual site selected. Land area for a building storage facility is given in Table 3.1.

3.2 VAULT STORAGE FACILITY

Construction sequences for a vault storage facility are indicated with reference to Figures 3.2a through 3.2c for the 100% Case, 50% Case, and 25% Case, respectively. Construction would begin with the administration building, proceed with the receiving warehouse and repackaging building, and then continue with the workshop building. Storage vaults would be constructed near the receiving warehouse and 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 and then move away from the centroid as new storage vaults are constructed.

Because boxes containing depleted uranium would be received over a 20-year period, it would not be necessary to build all the storage vaults at once. Clearing and grubbing of the site would be done for the area where construction would begin in that year. It would not be reasonable to clear and grub the entire site at the beginning of construction because substantial regrowth could occur over 20 years, and it would be necessary to clear and regrub the site for storage buildings constructed in later years.

Between 10 and 40 storage vaults would be needed, depending on the percentage of depleted uranium received at this storage facility. These storage vaults would be laid out in rows, as shown in Figures 3.2a through 3.2c. The area between vaults in a row would be mostly open area for rainwater infiltration. However, as discussed in Chapter 2, the vault storage facility in this report has been designed to use a ramp along the length of a vault together with a door in a wall of the vault. A paved ramp would extend 67 m along a side of a vault and descend 4.6 m from the grade level to the foundation of the vault. This would result in a grade of approximately 4 degrees and would leave a horizontal 12-m unloading area adjacent to a door in the vault. Pallets would be unloaded onto straddle carriers from a truck that has backed down the ramp. On the side of the ramp and unloading area, opposite from the side of the vault, would be a 6-in.-thick reinforced concrete retaining wall to prevent soil washout onto the ramp. It should be noted that the retaining wall is not intended to be load-bearing, such as a building foundation, but would serve simply as an erosion barrier.

The complex would have road access from one end of the site and rail access through the center. This configuration should prevent conflicts between road traffic and rail traffic and minimize the travel time and distance required to move boxes from the receiving warehouse and repackaging building to the storage vaults. It should be noted that the estimated construction area is based on a generic site and will require adjustments for the actual site selected. Land area for a vault storage facility is given in Table 3.2.

3.3 MINED-CAVITY STORAGE FACILITY

The site for a mined-cavity storage facility would be developed in two stages. In the first stage, the support buildings would be constructed — the administration building first, then the receiving warehouse and repackaging building, and then the workshop. Ancillary structures necessary for the ventilation of the mined cavity, as well as elevator access and other support functions would be constructed last in the first stage.

The second stage of construction would involve the mining itself. As with building storage and vault storage, boxes would be placed in storage concurrently with preparation of a new storage area during the emplacement phase. First two vertical shafts would be sunk; one would be for the removal of rock spoil and the other for transport of staff and depleted uranium boxes. Two shafts would allow placement of boxes in completed drifts concurrently with tunneling of new drifts. It has been assumed that, because the storage facility would be used for only a 40-year period, the rock spoils would not be removed from the site but rather would be placed in a 10-m-high pile on-site. Then, after operation of the storage facility ends, the rock spoils could readily be returned to fill the mined cavities to prevent subsidence and other safety problems. The aboveground site configurations for the three cases are given in Figures 3.3a through 3.3c.

Mining the major connecting tunnels, the aisleways, would be the first underground activity. Mining of the drifts would follow mining of the aisleways. The drifts farthest from the shaft entrance would be constructed first to facilitate 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 to ensure a safe working environment for straddle carrier operators and container inspectors.

Between 23 and 92 drifts would be needed, depending on the percentage of depleted uranium received at this storage facility. These drifts would be laid out in a grid pattern, as shown in Figures 3.4a through 3.4c. The area between drifts would be a rock wall approximately 12 m thick to give structural support to the drifts. The ceiling of the mined cavities are assumed to be 5 m below the surface. The shafts are assumed to be 30 m by 30 m, and the ventilation shafts are assumed to be 10 m by 10 m.

The complex would have road access from one end of the site and rail access through the other. This configuration should prevent conflicts between road traffic and rail traffic and minimize the travel time and distance required to move boxes from the receiving warehouse and repackaging building to the storage drifts. The administration building would be located near the road access to the site, so the building could also house security staff. The workshop would be located near the repackaging area to allow reasonable access to the receiving warehouse and repackaging building — the building most likely to need extensive ongoing maintenance. Land area for a mined-cavity storage facility is given in Table 3.3.

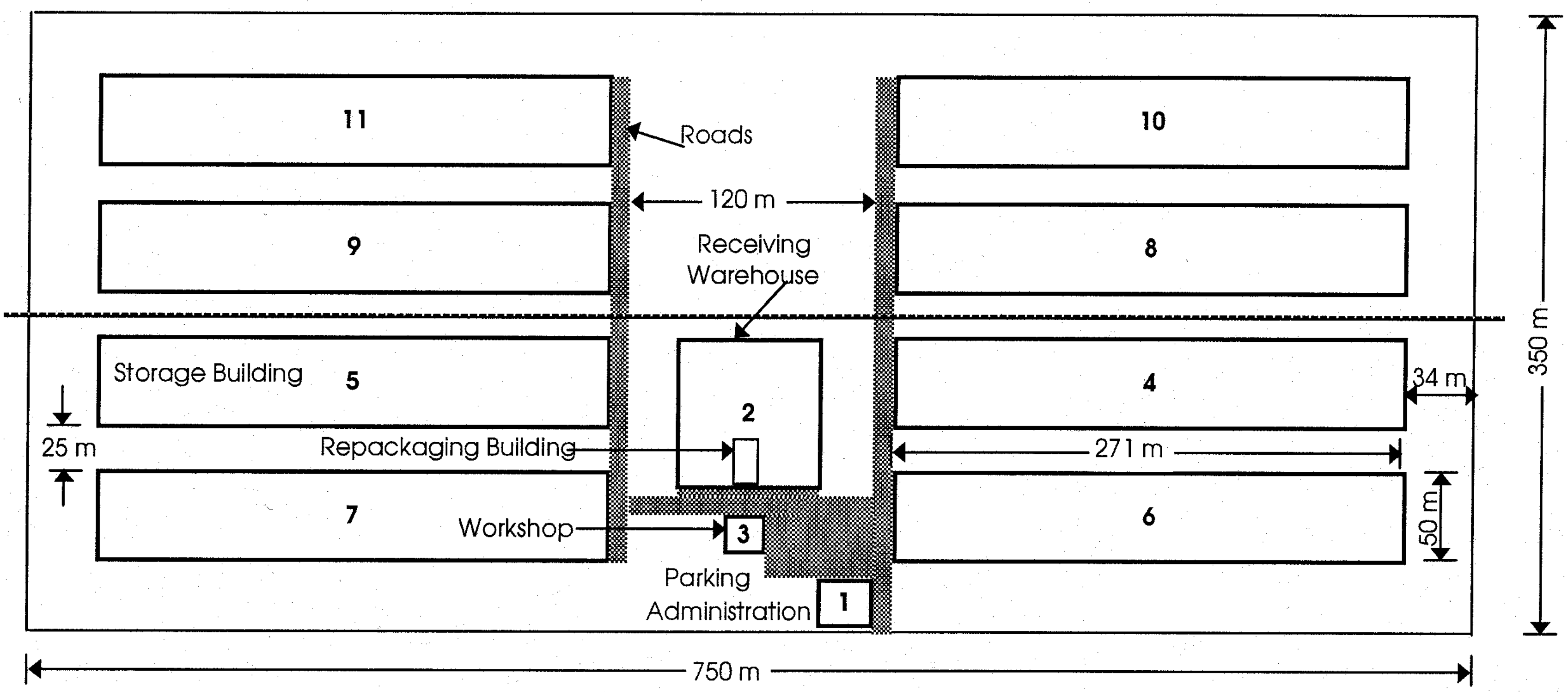

FIGURE 3.1a Site Layout of the Building Storage Facility — Uranium Metal, Base (100%) Case

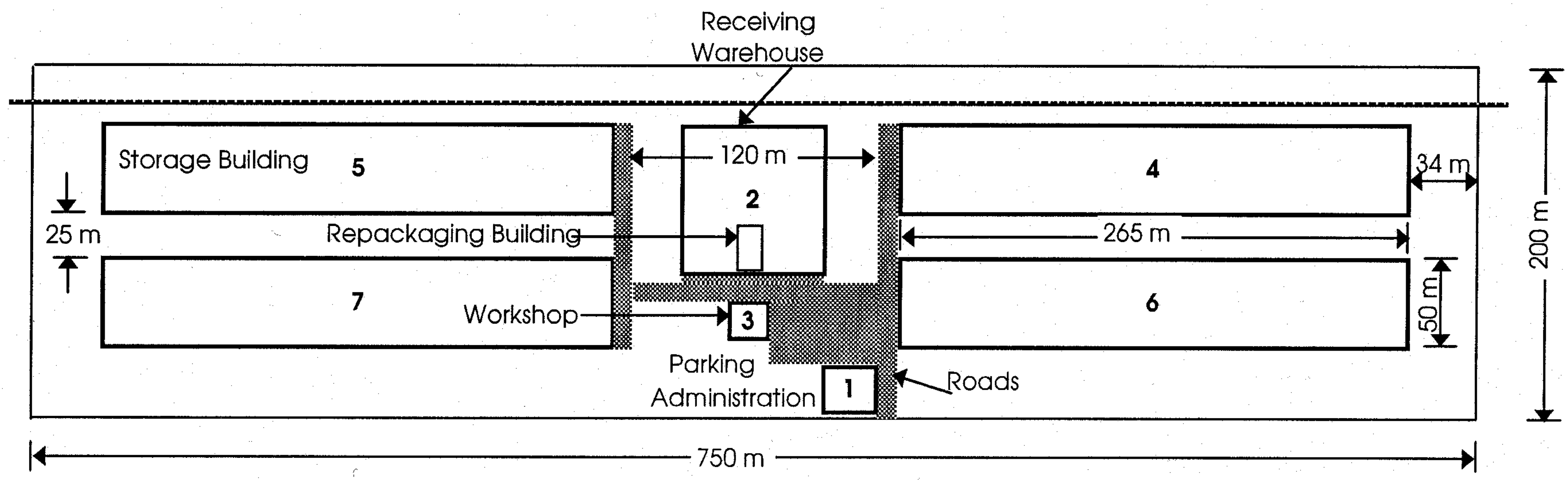

FIGURE 3.1b Site Layout of the Building Storage Facility — Uranium Metal, 50% Case

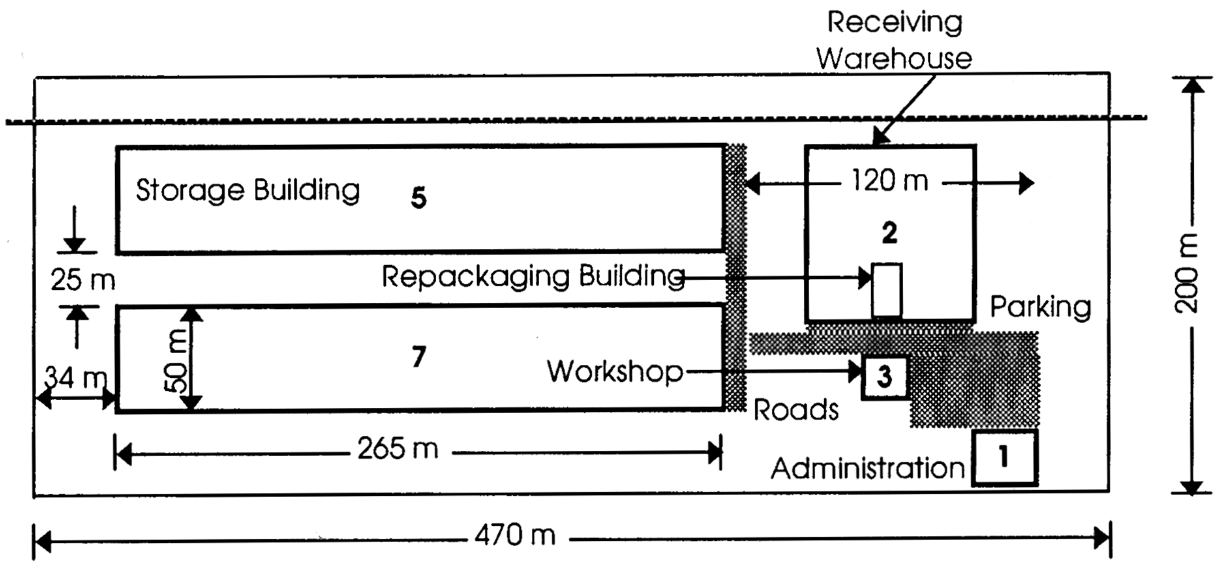

FIGURE 3.1c Site Layout of the Building Storage Facility — Uranium Metal, 25% Case

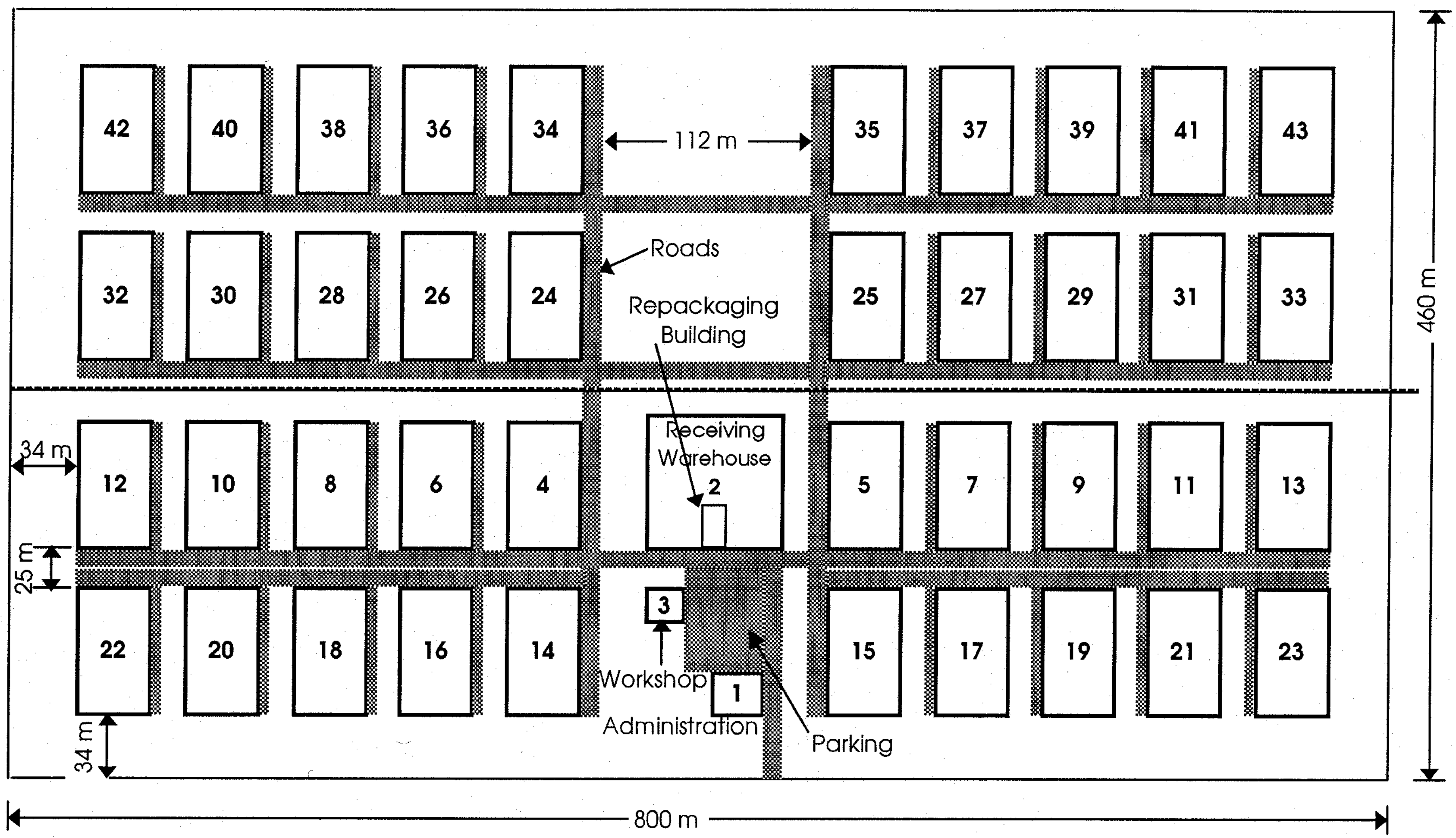

FIGURE 3.2a Site Layout of the Vault Storage Facility — Uranium Metal, Base (100%) Case

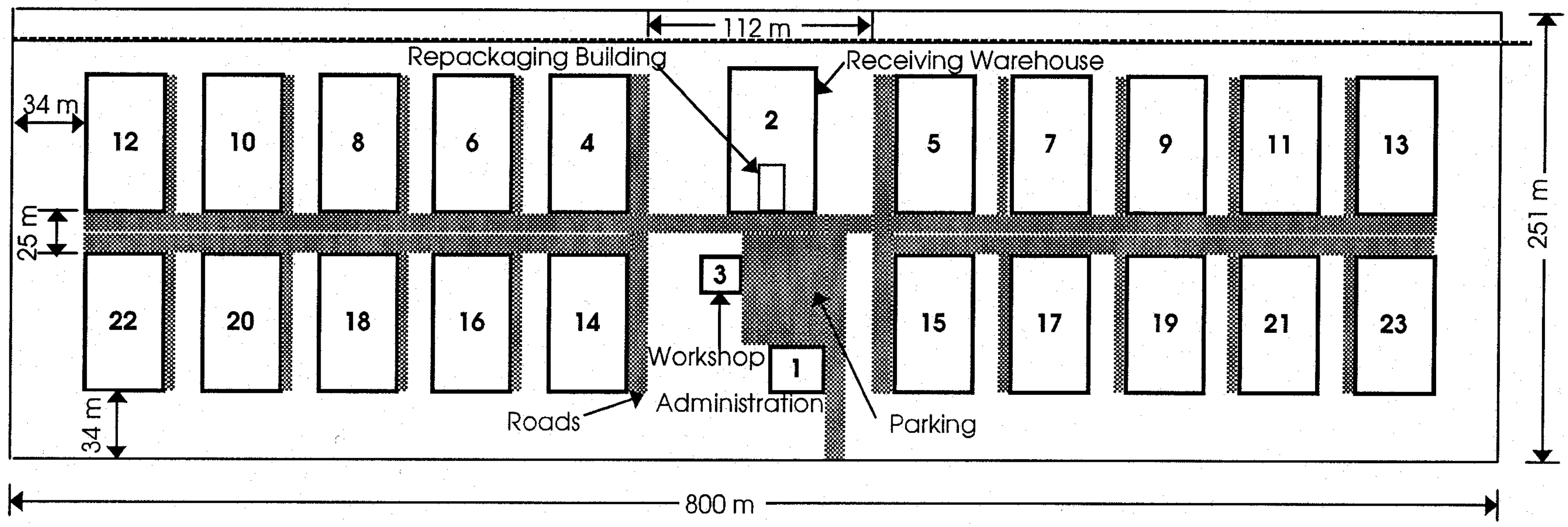

FIGURE 3.2b Site Layout of the Vault Storage Facility — Uranium Metal, 50% Case

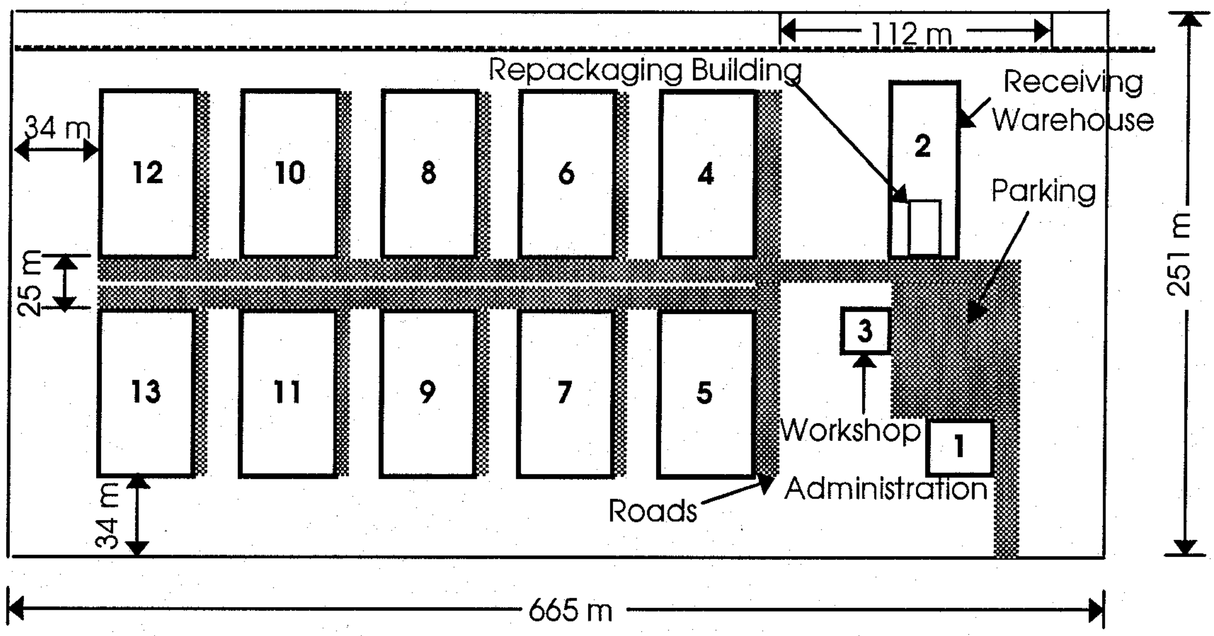

FIGURE 3.2c Site Layout of the Vault Storage Facility — Uranium Metal, 25% Case

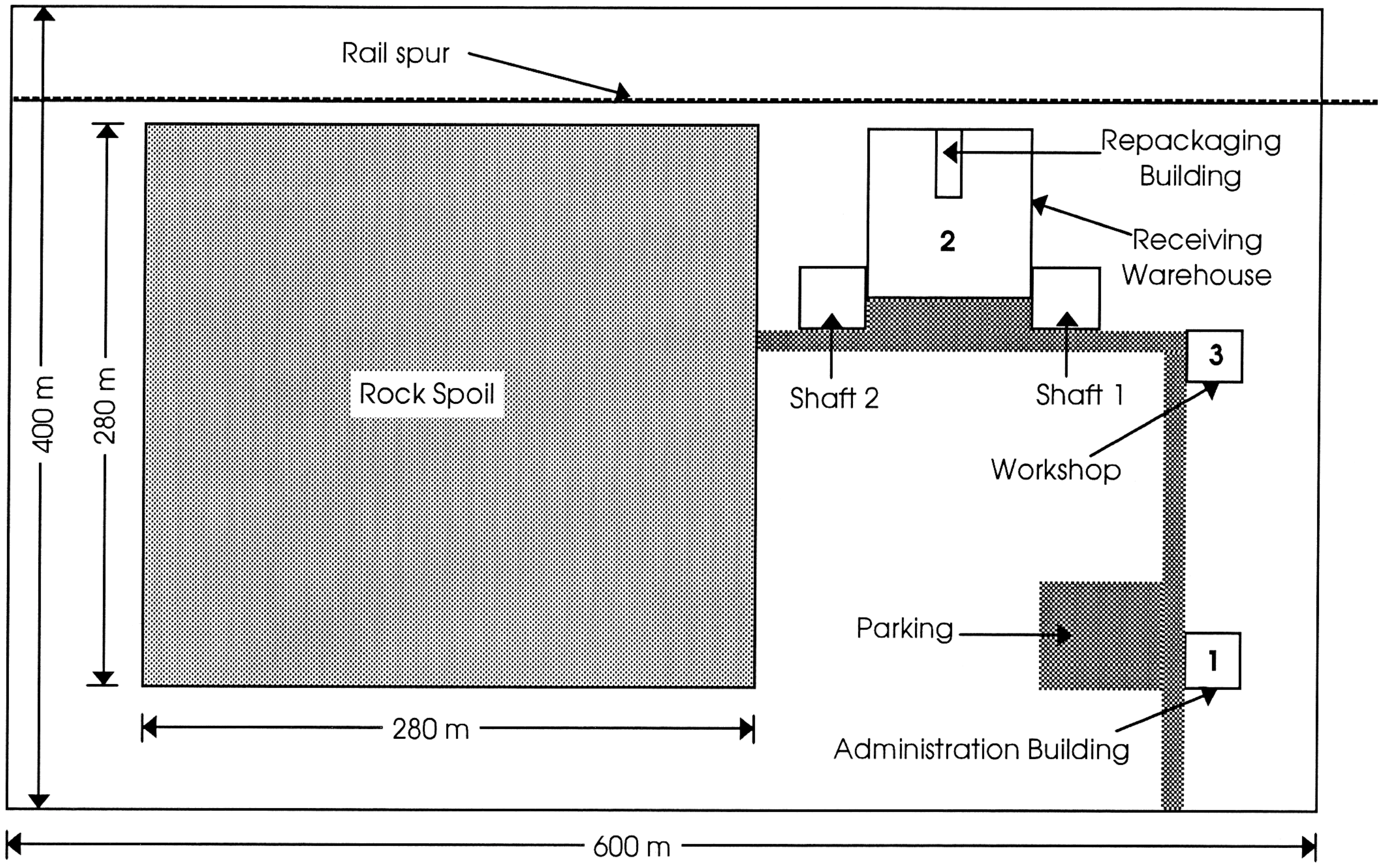

FIGURE 3.3a Site Layout of the Mined-Cavity Storage Facility — Uranium Metal, Base (100%) Case

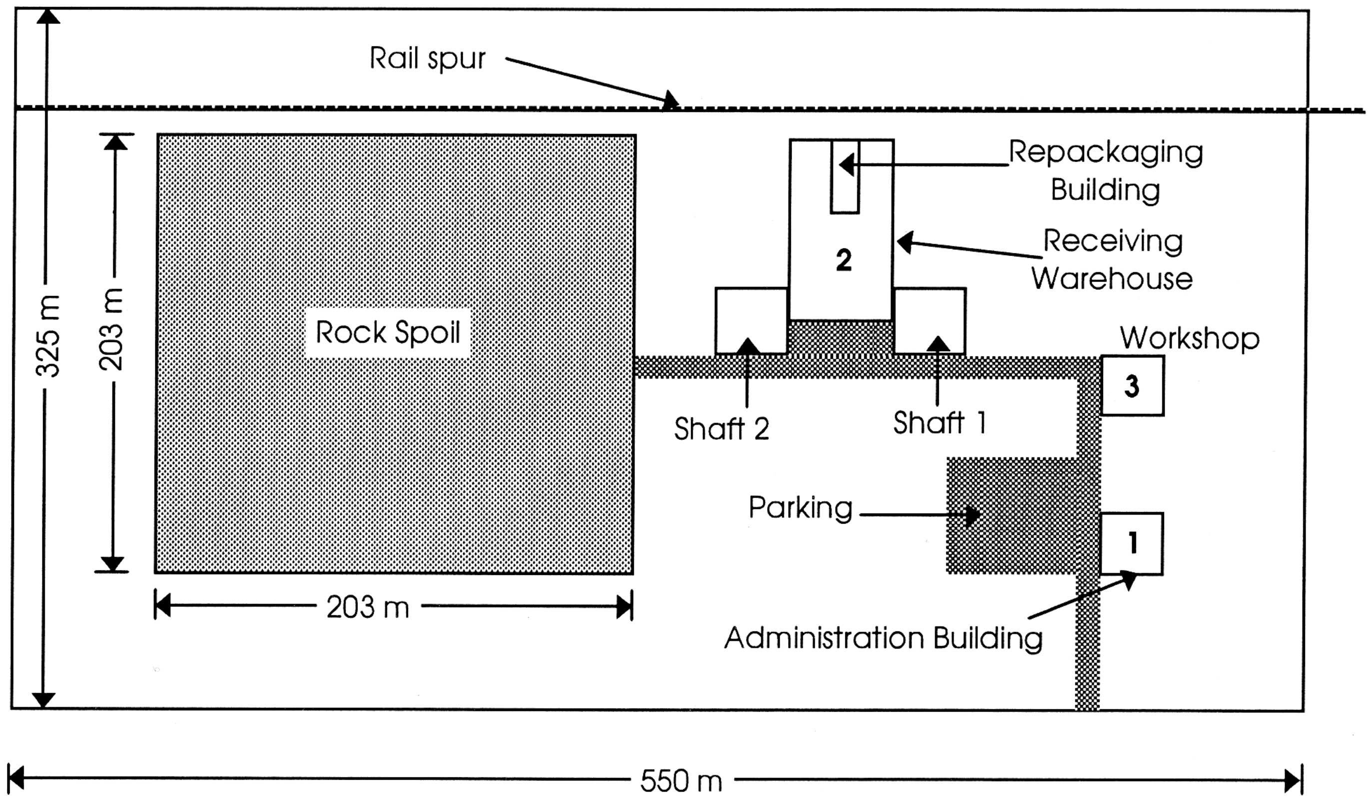

FIGURE 3.3b Site Layout of the Mined-Cavity Storage Facility — Uranium Metal 50% Case

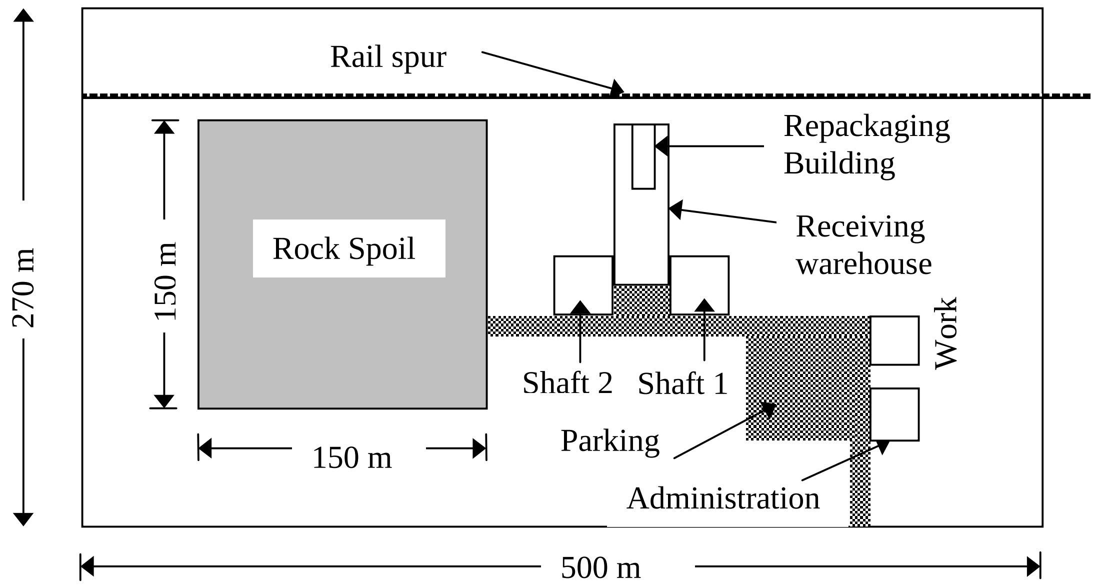

FIGURE 3.3c Site Layout of the Mined-Cavity Storage Facility — Uranium Metal, 25% Case

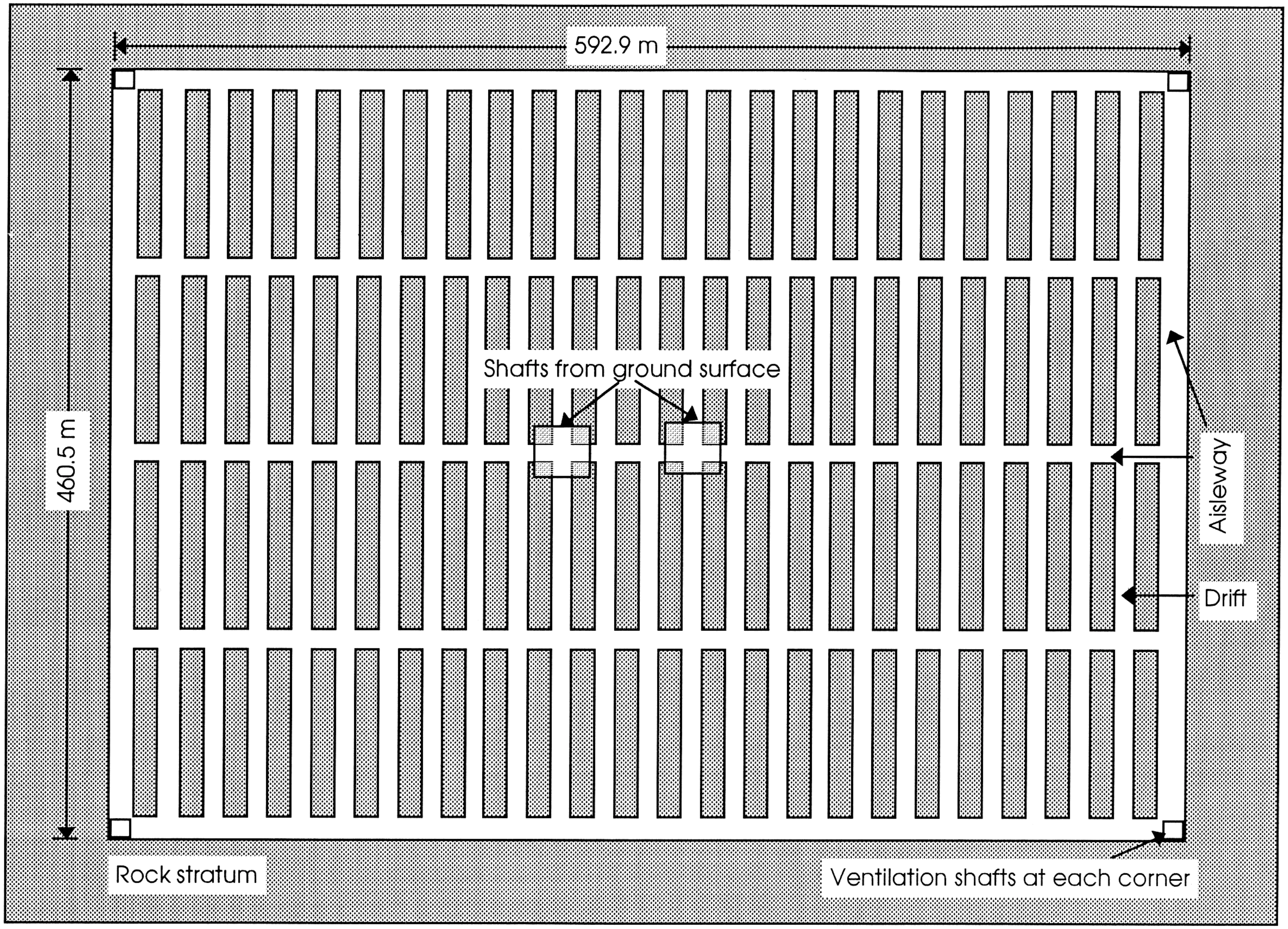

FIGURE 3.4a Underground Site Layout of the Mined-Cavity Storage Facility — Uranium Metal, 100% Case

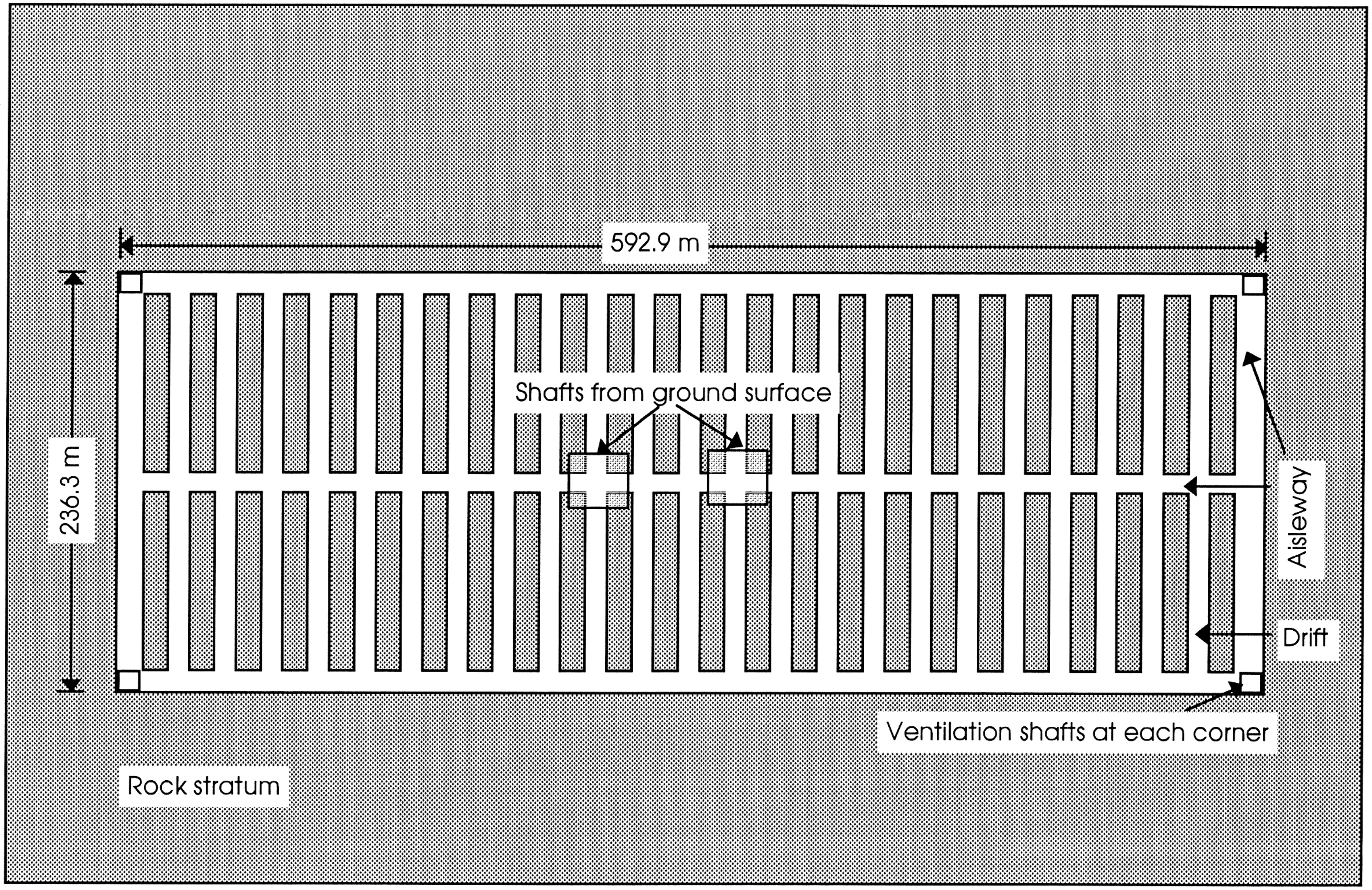

FIGURE 3.4b Underground Site Layout of the Mined-Cavity Storage Facility — Uranium Metal, 50% Case

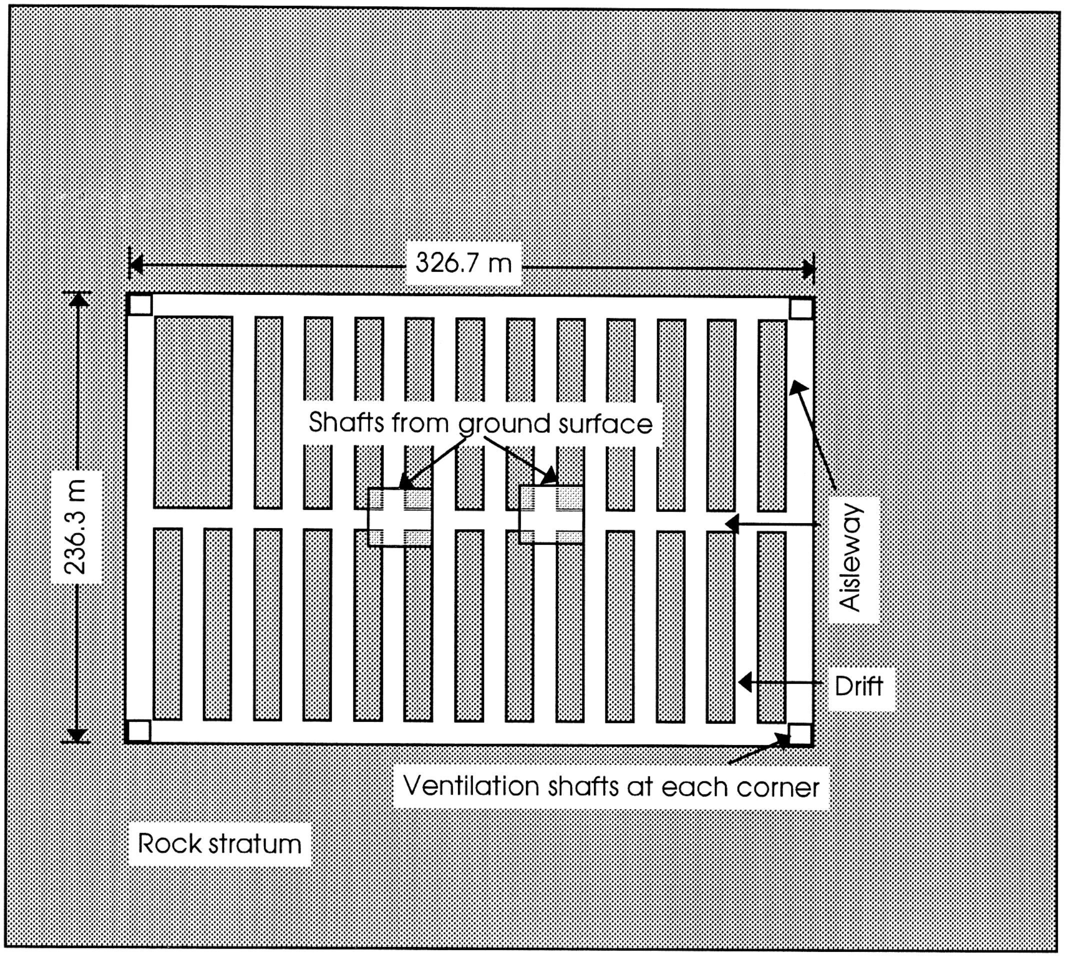

FIGURE 3.4c Underground Site Layout of the Mined-Cavity Storage Facility — Uranium Metal, 25% Case

TABLE 3.1 Site Land Area Requirements for the Building Storage Facility

Land Area, hectares (ha)	100%	50%	25%
Total site area	2.63E+1	1.50E+1	9.40
Total disturbed area	1.28E+1	6.72	3.68
Total paved area	1.17	8.10E-1	6.10E-1

TABLE 3.2 Site Land Area Requirements for the Vault Storage Facility

Land Area, hectares (ha)	100%	50%	25%
Total site area	3.68E+01	2.01E+01	1.67E+01
Total disturbed area	1.91E+01	9.83	5.70
Total paved area	5.75	3.01	2.18

TABLE 3.3 Site Land Area Requirements for the Mined-Cavity Storage Facility

Land Area, hectares (ha)	100%	50%	25%
Site surface land area	2.40E+01	1.79E+01	1.35E+01
Disturbed surface land area	9.58	5.44	3.34
Total underground area	2.73E+01	1.40E+01	7.72
Total paved area	8.80E-01	7.40E-01	6.60E-01

4 RESOURCE NEEDS

Resources for the storage facility are required for two stages — the construction stage and the operational stages. The operational stage, in turn, is divided into two phases. Phase I, or the emplacement phase, is the first 20 years of operations during which the storage facility would receive boxes of depleted uranium as well as store and maintain boxes that have already been received. Phase II is the second 20 years of operation. During Phase II, or the maintenance phase, all depleted uranium destined for the storage facility would have been received, and all building construction would have been completed. During Phase II, the operational activities would be to monitor and, if necessary, repackage stored boxes. Phase I would have additional operational activities, namely to receive, repackage (if necessary), and transport boxes to the storage buildings. Also, storage enclosures would be constructed during Phase I.

Construction of the receiving warehouse and repackaging building, the administration building, and the workshop building would occur first. Storage enclosures would be constructed over the 20-year period when the storage facility would be receiving boxes of depleted uranium. The enumerated support buildings would be much smaller than the storage enclosure and, therefore, a small part of the total construction activity. Hence, it is assumed that an equal amount of material would be used for construction each year during the construction stage. However, the amount of materials and resources cited in the tables in this section are for the entire 20-year construction stage, not per year. Exceptions to this rule are the tables with natural gas and electricity usage for year 20 of the emplacement phase or any year of the monitoring phase.

A small percentage of the boxes in which the depleted uranium billets are shipped to the storage facility can be expected to be damaged. Also, monitoring during storage would reveal a few damaged boxes that were not found during inspection prior to storage. Therefore, it would be necessary to transfer billets from the damaged boxes to new boxes, which would be independent of the shipment schedule. It is assumed that damaged wooden boxes would be considered as LLW because of potential surface contamination. These damaged boxes would be broken up and packed in 55-gal drums, 3.675 boxes per drum (refer to Section 6.2). Consistent with the Engineering Analysis Report, it is assumed that 0.1 percent of the boxes arriving at the storage facility would be damaged during shipment. The damaged boxes arriving at the receiving warehouse would be detected during inspection and repackaged. Boxes arriving at the storage facility would be subject to six operations before being stored. It is assumed that 0.1 percent of the boxes would be damaged in each operation; thus, 0.6 percent of the boxes would be damaged before storage. Ninety percent of these would be detected and repackaged prior to storage. Of the remaining damaged boxes, half would be detected and repackaged during Phase I operations and the remaining half during Phase II.

For the 100% Case (602,000 boxes arriving at the storage facility over 20 years), 602 boxes would arrive damaged and, on the average, 3,612 boxes would be damaged prior to storage. Of these, 3,251 boxes would be repackaged prior to storage, and 181 boxes would be detected as damaged during Phase I and would be repackaged. Then, 4,034 boxes would be disposed of as LLW during Phase I, requiring 1,098 55-gal drums during the 20-year duration of Phase I. For the 100% Case, 180 damaged boxes would be detected and repackaged from inspections in Phase II. Annual usage of drums and boxes was obtained by dividing totals by 20 and could be considered as annual averages.

4.1 BUILDING STORAGE FACILITY

Table 4.1 presents the materials that would be used in constructing the building storage facility for the three cases. Materials requirements during construction for cement, gravel, macadam, and steel were estimated from the physical dimensions of the buildings and the types of materials used for floors, walls, and roofs. No allowance was made for internal rooms in the administration building and workshop building. Diesel fuel would be used by trucks, cranes, and generators during construction. Gasoline requirements were estimated on the basis of 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 because of the generic location of the site.

Table 4.1 presents the total construction requirements for one storage building, for all storage buildings (2, 4, or 8), and for all storage buildings and the support buildings (total facility). Commonly used materials (e.g., concrete and steel) would be used for construction. Specialty materials, such as Inconel, would not be required. Any process equipment would be purchased from equipment vendors.

Estimates of annual natural gas consumption by building type and case are given in Table 4.2 for year 20 of the emplacement phase or any year of the monitoring phase. These estimates are based on usage of natural gas of 2.42E-09 million standard cubic meters (MSCM) per hour per square meter of building area and natural gas usage for half the time (4,380 h/yr) for space heating.

Table 4.3 and 4.4 contain estimates of electricity usage for the last year of the emplacement phase (Phase I) and for any year of the monitoring phase (Phase II), respectively. Total annual consumption is displayed as well as consumption for cooling, lighting, air filtration (HEPA), and tools or equipment. In these tables, it is assumed that the electrical capacities needed for a square meter of building area are 0.0065 kW(e) for cooling, 0.0355 kW(e) for lighting, and 0.0079 kW(e) for air filtration, which is consistent with the Engineering Analysis Report. With regard to tools or equipment, it is assumed that the electrical capacity needed is 0.5 kW(e) per full-time equivalent (FTE), except in storage buildings. It is assumed that cooling will be needed half the time, and HEPA filtration will run continuously but will not be needed in the workshop and administration building. It is also assumed that lighting will operate continuously except in the storage buildings, where it will operate 5% of the time.

Finally, it is assumed that electric-driven 7.5-ton davit cranes and bridge cranes will be used in the receiving warehouse and repackaging building, and electric-driven 7.5-ton davit cranes will be used in the storage buildings. Annual electricity consumption by these cranes will depend on how many boxes and pallets are moved in a year, which in turn will depend on the number of boxes received at the storage facility (100% Case, 50% Case, or 25% Case) and on the operational phase (emplacement or maintenance).

With these assumptions, the differences in electricity consumption between Phase I and Phase II are the use of cranes and the number of FTEs in the receiving warehouse and repackaging building, the workshop, and the administration building. In the receiving warehouse and repackaging building, the numbers of FTEs for the three cases are 22, 9, and 5, respectively, during Phase I and 7, 3, and 3, respectively, during Phase II. Similarly. in the administration building, the numbers of FTEs for the three cases are 18, 9, and 9, respectively, during Phase I and 17, 15, and 12, respectively, during Phase II. In the workshop, the number of FTEs for the 100% Case is reduced from 7 for Phase I to 6 for Phase II (FTEs for the other two cases remain at 5 and 4, respectively).

It should be noted that the figures for electrical consumption noted in Tables 4.3 and 4.4 are higher than those shown in the Engineering Analysis Report for long-term storage of the other three chemical forms (i.e., UF_6, UO_2, and U_3O_8). To attenuate any potential airborne releases under normal (incident-free) and accident conditions, continuous operation of the HEPA filtration system was assumed in this report.

Table 4.5 gives the materials and resources used during Phase I operations of the building storage facility for the entire 20-year period. Water requirements were based on the operations and maintenance workforce at the facility. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site, three times a day, in gasoline-powered vehicles. The gasoline consumed by the workers while traveling between home and the storage facility was not included in the estimate.

Materials and resources used during Phase II of operations of the building storage facility would be primarily related to the heating, cooling, and humidity control of the storage buildings, with a minor need for boxes and 55-gal drums from damaged boxes discovered during storage. Materials and resources used during Phase II operations are given in Table 4.6. Total materials and resources used during the operational stages, both Phase I and Phase II, are given in Table 4.7. Table 4.8 contains the total materials and resources used during operation and construction of the building storage facility.

4.2 VAULT STORAGE FACILITY

Table 4.9 presents the materials that would be used in constructing the vault storage facility for the three cases. Materials requirements during construction for cement, gravel, macadam, and steel were estimated from the physical dimensions of the vaults and the types of materials used for floors, walls, and roofs. No allowance was made for internal rooms in the administration building and workshop building. Diesel oil would fuel trucks, cranes, and generators during construction. Gasoline requirements were estimated on the basis of 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 because of the generic location of the site.

Table 4.9 presents the total construction requirements for one storage vault, for all storage vaults (40, 20, or 10), and for all storage vaults and the support buildings (total facility). Commonly used materials (e.g., concrete and steel) would be used for construction. Specialty materials, such as Inconel, would not be required. Any process equipment would be purchased from equipment vendors. Resource usage for vault storage is most markedly different from resource usage for building storage with regard to volumes of excavation and concrete. Vault storage requires more concrete because vaults have concrete walls, and they require more excavation because they are partly subsurface. It should be noted that approximately 71% of the amount of concrete for a given vault is associated with the foundation.

Estimates of annual natural gas consumption by building type and case are given in Table 4.10 for year 20 of the emplacement phase or any year of the monitoring phase. These estimates are based on usage of natural gas of 2.42E-09 MSCM per hour per square meter of area and natural gas usage for half the time (4,380 h/yr) for space heating.

Tables 4.11 and 4.12 contain estimates of electricity usage for the last year of the emplacement phase (Phase I) and for any year of the monitoring phase (Phase II), respectively. Total annual consumption is displayed as well as consumption for cooling, lighting, air filtration (HEPA), and tools or equipment. In these tables, it is assumed that the electrical capacities needed for a square meter of area are 0.0065 kW(e) for cooling, 0.0355 kW(e) for lighting, and 0.0079 kW(e) for air filtration. With regard to tools or equipment, it is assumed that the electrical capacity needed is 0.5 kW(e) per FTE, except in storage vaults. It is assumed that cooling will be needed half the time, and HEPA filtration will run continuously but will be not be needed in the workshop and the administration building. It is also assumed that lighting will operate continuously except in the storage buildings, where it will operate 5% of the time. Electricity usage for the cranes in the vaults and the receiving warehouse and repackaging facility is the same as for the building storage facility.

With these assumptions, the differences in electricity consumption between Phase I and Phase II are use of cranes and the number of FTEs in the receiving warehouse and repackaging building, the workshop, and the administration building. In the receiving warehouse and repackaging building, the numbers of FTEs for the three cases are 22, 9, and 6, respectively, during Phase I and 8, 4, and 4, respectively, during Phase II. Similarly, in the administration building, the numbers of FTEs for the three cases are 18, 16, and 16, respectively, during Phase I and 19, 15, and 12, respectively, during Phase II. In the workshop, the number of FTEs for the

100% Case is reduced from 26 for Phase I to 25 for Phase II (FTEs for the other two cases remain at 14 and 8, respectively). The number of FTEs is greater for vault storage than for building storage because of the greater number of storage vaults than storage buildings. Each of the vaults would require labor-intensive activities, such as maintenance of the HEPA filtration units in the vault.

Table 4.13 gives the material and resources used during Phase I operations of the vault storage facility for the entire 20-year period. Material requirements during operations for natural gas and electricity were based on the heating and lighting requirements for the buildings and vaults (assuming 24-hour lighting and HVAC usage) and electricity usage by cranes. Water requirements were based on the operations and maintenance workforce at the facility. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site, three times a day, in gasoline-powered vehicles. The gasoline consumed by the workers while traveling between home and the storage facility was not included in the estimate.

Materials and resources used during Phase II of operations of the vault storage facility would be primarily related to the heating, cooling, and humidity control of the storage vaults, with a minor need for boxes and 55-gal drums from damaged boxes discovered during storage. Materials and resources used during Phase II operations are given in Table 4.14. Total materials and resources used during the operational stages, both Phase I and Phase II, are given in Table 4.15. Table 4.16 contains the total materials and resources used during operation and construction of the vault storage facility.

4.3 MINED-CAVITY STORAGE FACILITY

Table 4.17 presents the materials that would be used in constructing the mined-cavity storage facility for the three cases. Materials requirements during construction for cement, gravel, macadam, and steel were estimated from the physical dimensions of the mined cavities and aboveground buildings and the types of materials used for floors, walls, and roofs. No allowance was made for internal rooms in the administration building and workshop building. Diesel fuel would be used by trucks, cranes, and generators during construction. Gasoline requirements were estimated on the basis of 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 because of the generic location of the site. Additional features such as grouting fissures or cracks in the rocks are not included.

Table 4.17 presents the total construction requirements for one drift (and associate aisleways), for all drifts (92, 46, or 23), and for all drifts and the support buildings (total facility). Commonly used materials (e.g., concrete and steel) would be used for construction. Specialty materials, such as Inconel, would not be required. Any process equipment would be purchased from equipment vendors.

Estimates of annual natural gas consumption by enclosure type and case are given in Table 4.18 for year 20 of the emplacement phase or any year of the monitoring phase. These estimates are based on consumption of natural gas of 2.42E-09 MSCM per hour per square meter of area and natural gas usage for half the time (4,380 h/yr) for space heating for the support buildings. It is assumed that a nearly uniform moderate temperature would be maintained naturally in the mined cavities and, consequently, space heating would not be necessary.

Tables 4.19 and 4.20 contain estimates of electricity usage for the last year of the emplacement phase (Phase I) and for any year of the monitoring phase (Phase II), respectively. Total annual consumption is displayed as well as consumption for cooling, lighting, air filtration (HEPA), and tools or equipment. In these tables, it is assumed that the electrical capacities needed for a square meter of area are 0.0065 kW(e) for cooling, 0.0355 kW(e) for lighting, and 0.0079 kW(e) for air filtration. With regard to tools or equipment, it is assumed that the electrical capacity needed is 0.5 kW(e) per FTE, except in mined cavities. It is assumed that cooling will be needed half the time in the support buildings, but not the mined cavities, and that HEPA filtration will run continuously but will be not be needed in the workshop and the administration building. It is also assumed that lighting will operate continuously except in the mined cavities, where it will operate 5% of the time.

There will be the same electricity usage by davit cranes and bridge cranes as for the other two types of storage facilities, but there will be additional electricity usage from electric-driven straddle carriers. As is discussed in Chapter 7, it is appropriate to use electric-driven straddle carriers underground to reduce the risk of fire or explosion as a result of the presence of combustible fuels.

With these assumptions, the difference in electricity consumption between Phase I and Phase II are use of cranes and straddle carriers and the number of FTEs in the receiving warehouse and repackaging building and the administration building. In the receiving warehouse and repackaging building, the numbers of FTEs for the three cases are 24, 11, and 5, respectively, during Phase I and 5, 2, and 2, respectively, during Phase II. Similarly, in the administration building, the numbers of FTEs for the three cases are 26, 23, and 23, respectively, during Phase I and 17, 14, and 12, respectively, during Phase II.

Table 4.21 gives the materials and resources used during Phase I operations of the mined-cavity storage facility for the entire 20-year period. Material requirements during operations for natural gas and electricity were based on the heating and lighting requirements for the buildings and mined cavities (assuming 24-hour lighting and HVAC usage) and electricity usage by cranes and straddle carriers. Water requirements were based on the operations and maintenance workforce at the facility. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site, three times a day, in gasoline-powered vehicles. The gasoline consumed by the workers while traveling between home and the storage facility was not included in the estimate.

Materials and resources used during Phase II of operations of the mined-cavity storage facility would be primarily related to the heating, cooling, and humidity control of the mined cavity, with a minor need for boxes and 55-gal drums from damaged boxes discovered during storage. Materials and resources used during Phase II operations are given in Table 4.22. Total materials and resources used during the operational stages are given in Table 4.23. Table 4.24 contains the total materials and resources used during operation and construction of the mined-cavity storage facility.

TABLE 4.1 Materials and Resources Used during Construction of the Building Storage Facility

	One Storage Building		Total Storage Buildings			Total Storage Facility		
Material/ Resource	Units	Unit Quantity	100% Case	50% Case	25% Case	100% Case	50% Case	25% Case
Concrete	m^3	4.06E+3	3.35E+4	1.63E+4	8.13E+3	3.48E+4	1.78E+4	9.22E+3
Cement	te	1.63E+3	1.30E+4	6.50E+3	3.25E+3	1.39E+4	7.14E+3	3.71E+3
Sand	te	2.03E+3	1.63E+4	8.13E+3	4.06E+3	1.74E+4	8.87E+3	4.61E+3
Gravel	te	1.48E+4	1.19E+5	5.94E+4	2.97E+4	1.21E+5	6.08E+4	3.08E+4
Steel	te	1.65E+3	1.40E+4	7.37E+3	4.07E+3	1.49E+4	8.00E+3	4.54E+3
Macadam	m^3					1.75E+3	1.21E+3	9.16E+2
Water	ML	2.40	1.90E+1	1.00E+1	5.00	2.05E+1	1.02E+1	5.13
Diesel fuel	ML					6.76E-1	3.54E-1	1.93E-1
Gasoline	KL					3.01	1.17	4.80E-1
Electricity	MW-yr	8.10E-1	6.40	3.20	1.60	6.91	3.53	1.84
Excavation	m^3	6.78E+3	5.42E+4	2.71E+4	1.36E+4	5.57E+4	2.81E+4	1.43E+4

TABLE 4.2 Annual Natural Gas Consumption for Building Storage Facility Operations

	Area (m^2)				MSCM/yr		
Building Type	100%	50%	25%	Usage (h/yr)	100%	50%	25%
Storage	1.08E+05	5.42E+04	2.71E+04	4,380	1.15	5.74E-01	2.87E-01
Receiving Warehouse	6.22E+03	3.65E+03	2.32E+03	4,380	6.59E-02	3.86E-02	2.46E-02
Workshop	6.25E+02	6.25E+02	6.25E+02	4,380	6.60E-03	6.60E-03	6.60E-03
Admin.	6.75E+03	6.75E+02	6.75E+02	4,380	7.10E-03	7.10E-03	7.10E-03

TABLE 4.3 Annual Electricity Consumption during Phase I for Building Storage

Building	Application	Usage (h/yr)	Consumption (MWh/yr) 100%	50%	25%
Storage	Cooling	4,380	3.08E+03	1.54E+03	7.71E+02
	Lighting	438	1.68E+03	8.42E+02	4.21E+02
	HEPA	8,760	7.50E+03	3.75E+03	1.88E+03
	Davit Crane	Variable[a]	5.75E+01	2.88E+01	1.44E+01
	Tools	None	0.0	0.0	0.0
	Subtotal		**1.23E+04**	**6.16E+03**	**3.09E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.61E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.52E+02	1.61E+02
	Bridge Crane	Variable[b]	4.86	2.48	1.25
	Davit Crane	Variable[c]	1.14E+02	5.68E+01	2.84E+01
	Tools	8,760	9.82E+01	3.94E+01	2.19E+01
	Subtotal		**2.66E+03**	**1.59E+03**	**1.00E+03**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1.94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	3.07E+01	2.19E+01	1.75E+01
	Subtotal		**2.42E+02**	**2.34E+02**	**2.29E+02**
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	7.88E+01	7.01E+01	7.01E+01
	Subtotal		**3.08E+02**	**2.99E+02**	**2.99E+02**
ALL	**TOTAL**		**1.55E+04**	**8.28E+03**	**4.62E+03**

[a] Hours of operation: 3,853 for the 100% Case; 1,927 for the 50% Case; 964 for the 25% Case.

[b] Hours of operation: 326 for the 100% Case; 166 for the 50% Case; 84 for the 25% Case.

[c] Hours of operation: 7,611 for the 100% Case; 3,806 for the 50% Case; 1,903 for the 25% Case.

TABLE 4.4 Annual Electricity Consumption during Phase II for Building Storage

Building	Application	Usage (h/yr)	Consumption (MWh/yr) 100%	50%	25%
Storage	Cooling	4,380	3.08E+03	1.54E+03	7.71E+02
	Lighting	438	1.68E+03	8.42E+02	4.21E+02
	HEPA	8,760	7.50E+03	3.75E+03	1.88E+02
	Davit Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Tools	None	0.0	0.0	0.0
	Subtotal		**1.23E+04**	**6.14E+03**	**3.07E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.61E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.52E+02	1.61E+02
	Bridge Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Davit Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Tools	8,760	3.07E+01	1.31E+01	1.31E+01
	Subtotal		**2.57E+03**	**1.51E+03**	**9.62E+02**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1.94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	2.63E+01	2.19E+01	1.75E+01
	Subtotal		**2.82E+02**	**2.77E+02**	**2.72E+02**
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	7.45E+01	6.57E+01	5.26E+01
	Subtotal		**3.08E+02**	**2.95E+02**	**2.82E+02**
ALL	**TOTAL**		**1.54E+04**	**8.18E+03**	**4.54E+03**

[a] Hours of operation: 10 for the 100% Case; 4 for the 50% Case; 2 for the 25% Case.

TABLE 4.5 Materials and Resources Used during Phase I Operation of the Building Storage Facility

Material/ Resource	Units	Annual 100%	Annual 50%	Annual 25%	Over 20 Years 100%	Over 20 Years 50%	Over 20 Years 25%
Diesel	kL	4.08	3.00	2.0	8.16E+1	6.01E+1	3.99E+1
Gasoline	kL	8.32	4.26	2.5	1.66E+2	8.53E+1	4.89E+1
Electricity	MW-h	1.55E+4	8.28E+3	4.62E+3	3.09E+5	1.66E+5	9.24E+4
Natural Gas	MSCM	1.23	6.30E-1	3.30E-1	2.45E+1	1.25E+1	6.50
Water	ML	5.25	3.56	2.58	1.05E+2	7.12E+1	5.16E+1
55-gal drums	drums	55	27	14	1,098	549	274
Boxes	boxes	202	101	51	4,040	2,020	1,010

TABLE 4.6 Materials and Resources Used during Phase II Operation of the Building Storage Facility

Material/ Resource	Units	Annual			Over 20 Years		
		100%	50%	25%	100%	50%	25%
Diesel	kL	1.2E-3	9.00E-4	6.00E-4	2.40E-2	1.80E-3	1.20E-2
Gasoline	kL	6.20	3.52	2.11	1.24E+2	7.04E+1	4.22E+1
Electricity	MW-h	1.54E+4	8.18E+3	4.54E+3	3.08E+5	1.63E+5	9.08E+4
Natural Gas	MSCM	1.23	6.30E-1	3.30E-1	2.45E+1	1.25E+1	6.50
Water	ML	3.91	2.94	2.22	7.83E+1	5.87E+1	4.45E+1
55-gal drums	drums	2.5	1.3	0.6	49	25	12
Boxes	boxes	9	4.5	2.3	181	90	45

TABLE 4.7 Materials and Resources Used over the 40-Year Operation of the Building Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	kL	8.16E+1	6.01E+1	3.99E+1
Gasoline	kL	2.90E+2	1.56E+2	9.11E+1
Electricity	MW-h	6.17E+5	3.29E+5	1.83E+5
Natural Gas	MSCM	4.91E+1	2.50E+1	1.30E+1
Water	ML	1.83E+2	1.30E+2	9.61E+1
55-gal drums	drums	1,147	574	287
Boxes	boxes	4,221	2,110	1,055

[a] Does not include construction.

TABLE 4.8 Materials and Resources Used over the Total Life Cycle of the Building Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	ML	7.58E-1	4.14E-1	2.33E-1
Gasoline	kL	2.94E+2	1.57E+2	9.16E+1
Electricity	MW-yr	7.74E+1	4.10E+1	2.32E+1
Natural Gas	MSCM	4.91E+1	2.50E+1	1.30E+1
Water	ML	2.04E+2	1.40E+2	1.01E+2
55-gal drums	drums	1,147	574	287
Boxes	boxes	4,221	2,110	1,055

[a] Includes construction use of the materials and resources listed, but does not include construction material such as steel and concrete.

TABLE 4.9 Materials and Resources Used during Construction of the Vault Storage Facility

	One Vault		Total Storage Vaults			Total Storage Facility		
Material/ Resource	Units	Unit Quantity	100% Case	50% Case	25% Case	100% Case	50% Case	25% Case
Concrete	m^3	1.36E+3	5.46E+4	2.73E+4	1.35E+4	5.68E+4	2.88E+4	1.47E+4
Cement	te	5.46E+2	2.18E+4	1.09E+4	5.46E+3	2.27E+4	1.15E+4	5.92E+3
Sand	te	6.82E+2	2.73E+4	1.36E+4	6.82E+3	2.84E+4	1.44E+4	7.36E+3
Gravel	te	3.88E+3	1.55E+5	7.75E+4	3.88E+4	1.57E+5	7.90E+4	3.98E+4
Steel	te	4.65E+2	1.92E+4	9.91E+3	5.26E+3	2.01E+4	1.05E+4	5.73E+3
Macadam	m^3					8.62E+3	4.52E+3	3.26E+3
Water	ML	8.00E-1	3.20E+1	1.60E+1	8.00	3.30E+1	1.60E+1	8.40
Diesel fuel	ML					3.59	1.81	9.19E-1
Gasoline	kL					5.60	2.20	1.00
Electricity	MW-yr	2.30E-1	9.10	4.50	2.30	9.60	4.90	2.50
Excavation[a]	m^3	1.58E+4	6.32E+5	3.16E+5	1.58E+5	6.75E+5	3.38E+5	1.69E+5

[a] Excavation of ramps included in total storage facility, but not in total storage vaults.

TABLE 4.10 Annual Natural Gas Consumption for Vault Storage Facility Operations

Enclosure Type	Area (m^2)			Usage (h/yr)	MSCM/yr		
	100%	50%	25%		100%	50%	25%
Storage vaults	1.28E+05	6.32E+04	3.16E+04	4,380	1.34	6.69E-01	3.34E-01
Receiving warehouse	6.22E+03	3.65E+03	2.32E+03	4,380	6.59E-02	3.86E-02	2.46E-02
Workshop	6.25E+02	6.25E+02	6.25E+02	4,380	6.60E-02	6.60E-02	6.60E-02
Admin.	6.75E+02	6.75E+02	6.75E+02	4,380	7.10E-02	7.10E-02	7.10E-02

TABLE 4.11 Annual Electricity Consumption during Phase I for Vault Storage

			Consumption (MWh/yr)		
Enclosure	Application	Usage (h/yr)	100%	50%	25%
Storage Vaults	Cooling	4,380	3.60E+03	1.80E+03	9.00E+02
	Lighting	438	1.96E+03	9.82E+02	4.91E+02
	HEPA	8,760	8.75E+03	4.37E+03	2.19E+03
	Davit Crane	Variable[a]	5.75E+01	2.88E+01	1.44E+01
	Tools	None	0.0	0.0	0.0
	Subtotal		**1.44E+04**	**7.18E+03**	**3.60E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.62E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.53E+02	1.61E+02
	Bridge Crane	Variable[b]	4.86	2.48	1.25
	Davit Crane	Variable[c]	1.14E+02	5.68E+01	2.84E+01
	Tools	8,760	9.64E+01	3.94E+01	2.62E+01
	Subtotal		**2.76E+03**	**1.60E+03**	**1.01E+03**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1.94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	1.14E+02	6.14E+01	3.50E+01
	Subtotal		**3.26E+02**	**2.73E+02**	**2.47E+02**
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	7.88E+01	7.00E+01	7.00E+01
	Subtotal		**3.08E+02**	**2.99E+02**	**2.99E+02**
ALL	**TOTAL**		**1.78E+04**	**9.35E+03**	**5.16E+03**

[a] Hours of operation: 3,853 for the 100% Case; 1,927 for the 50% Case; 964 for the 25% Case.

[b] Hours of operation: 326 for the 100% Case; 166 for the 50% Case; 84 for the 25% Case.

[c] Hours of operation: 7,611 for the 100% Case; 3,806 for the 50% Case; 1,903 for the 25% Case.

TABLE 4.12 Annual Electricity Consumption during Phase II for Vault Storage

Enclosure	Application	Usage (h/yr)	Consumption (MWh/yr) 100%	50%	25%
Storage Vaults	Cooling	4,380	3.60E+03	1.80E+03	9.00E+02
	Lighting	438	1.96E+03	9.83E+02	4.91E+02
	HEPA	8,760	8.75E+03	4.37E+03	2.19E+03
	Davit Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Tools	None	0.0	0.0	0.0
	Subtotal		**1.43E+04**	**7.15E+03**	**3.58E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.62E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.53E+02	1.61E+02
	Bridge Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Davit Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Tools	8,760	3.50E+01	1.75E+01	1.75E+01
	Subtotal		**2.58E+03**	**1.51E+03**	**9.67E+02**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1.94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	1.10E+02	6.13E+01	3.50E+01
	Subtotal		**3.22E+02**	**2.73E+02**	**2.47E+02**
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	7.88E+01	6.57E+01	5.26E+01
	Subtotal		**3.08E+02**	**2.95E+02**	**2,82E+02**
ALL	**TOTAL**		**1.75E+04**	**9.23E+03**	**5.07E+03**

[a] Hours of operation: 10 for the 100% Case; 4 for the 50% Case; 2 for the 25% Case.

TABLE 4.13 Materials and Resources Used during Phase I Operation of the Vault Storage Facility

Material/ Resource	Units	Annual 100%	Annual 50%	Annual 25%	Over 20 Years 100%	Over 20 Years 50%	Over 20 Years 25%
Diesel	kL	4.20	3.06	2.02	8.40E+01	6.12E+01	4.04E+01
Gasoline	kL	1.30E+01	6.04	3.82	2.60E+02	1.21E+02	7.65E+01
Electricity	MW-h	1.78E+04	9.35E+03	5.16E+03	3.56E+05	1.87E+05	1.03E+05
Natural Gas	MSCM	1.42	7.20E-01	3.73E-01	2.83E+01	1.44E+01	7.50
Water	ML	6.94	4.36	3.02	1.39E+02	7.72E+01	6.05E+01
55-gal drums	drums	202	101	51	4,040	2,020	1,010
Boxes	boxes	55	27	14	1,098	549	274

TABLE 4.14 Materials and Resources Used during Phase II Operation of the Vault Storage Facility

Material/ Resource	Units	Annual			Over 20 Years		
		100%	50%	25%	100%	50%	25%
Diesel	kL	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline	kL	1.07E+01	5.18	3.37	2.14E+02	1.04E+02	6.75E+01
Electricity	MW-h	1.75E+04	9.23E+03	5.07E+03	3.50E+05	1.85E+05	1.01E+05
Natural Gas	MSCM	1.42	7.25E-01	3.73E-01	2.83E+01	1.44E+01	7.50
Water	ML	5.70	3.75	2.65	1.14E+02	7.50E+01	5.30E+01
55-gal drums	drums	9	4.5	2.3	181	90	45
Boxes	boxes	2.5	1.3	0.6	49	25	12

TABLE 4.15 Materials and Resources Used over the 40-Year Operation of the Vault Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	kL	8.40E+01	6.10E+01	4.00E+01
Gasoline	kL	4.74E+02	2.24E+02	1.44E+02
Electricity	MW-h	7.06E+05	3.72E+05	2.04E+05
Natural Gas	MSCM	5.67E+01	2.88E+01	1.49E+01
Water	ML	2.53E+02	1.62E+02	1.14E+02
55-gal drums	drums	4,221	2,110	1,055
Boxes	boxes	1,147	574	286

[a.] Does not include construction.

TABLE 4.16 Materials and Resources Used over the Total Life Cycle of the Vault Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	ML	3.70	1.90	1.00
Gasoline	kL	4.80E+02	2.27E+02	1.45E+02
Electricity	MW-yr	8.99E+01	4.73E+01	2.59E+01
Natural Gas	MSCM	5.67E+01	2.88E+01	1.49E+01
Water	ML	2.86E+02	1.78E+02	1.22E+02
55-gal drums	drums	4,221	2,110	1,055
Boxes	boxes	1,147	574	286

[a] Includes construction use of the materials and resources listed; but does not include construction material such as steel and concrete.

TABLE 4.17 Materials and Resources Used during Construction of the Mined-Cavity Storage Facility

		One Drift	Total Storage Drifts			Total Storage Facility		
Material/ Resource	Units	Value	100% Case	50% Case	25% Case	100% Case	50% Case	25% Case
Concrete	m^3	3.36E+2	3.09E+4	1.55E+4	7.74E+3	3.32E+4	1.70E+4	8.82E+3
Cement	te	1.35E+2	1.24E+4	6.19E+3	3.09E+3	1.33E+4	6.82E+3	3.55E+3
Sand	te	1.68E+2	1.55E+4	7.74E+3	3.87E+3	1.66E+4	8.48E+3	4.41E+3
Gravel	te	1.30E+3	1.19E+5	5.97E+4	2.99E+4	1.22E+5	6.12E+4	3.09E+4
Steel	te	8.40E+1	7.74E+3	3.87E+3	1.93E+3	8.71E+3	4.54E+3	2.45E+3
Macadam	m^3					1.32E+3	1.12E+3	9.86E+2
Water	ML	2.00E-1	1.80E+1	9.00	5.00	2.00E+1	1.00E+1	4.90
Diesel fuel	ML					3.98E-1	2.11E-1	1.14E-1
Gasoline	kL					8.90	3.9	1.7
Electricity	MW-yr		4.92E+2	2.57E+2	1.39E+2	4.93E+2	2.58E+2	1.40E+2
Excavation[a]	m^3	6.05E+3	2.28E+5	1.32E+5	8.35E+4	7.85E+5	4.11E+5	2.23E+5

[a] Excavation of aisleways included in total storage facility but not in total storage drifts.

TABLE 4.18 Annual Natural Gas Consumption for Mined-Cavity Storage Facility Operations

Enclosure Type	Area (m^2)			Usage (h/yr)	MSCM/yr		
	100%	50%	25%		100%	50%	25%
Mined Cavity	1.11E+05	5.57E+04	2.78E+04	0	0.0	0.0	0.0
Receiving Warehouse	6.22E+03	3.65E+03	2.32E+03	4,380	6.59E-02	3.86E-02	2.46E-02
Workshop	6.25E+02	6.25E+02	6.25E+02	4,380	6.60E-03	6.60E-03	6.60E-03
Admin.	6.75E+02	6.75E+02	6.75E+02	4,380	7.10E-03	7.10E-03	7.10E-03

TABLE 4.19 Annual Electricity Consumption during Phase I for Mined-Cavity Storage

Enclosure	Application	Usage (h/yr)	Consumption (MWh/yr) 100%	50%	25%
Mined Cavities	Cooling	None	0.0	0.0	0.0
	Lighting	438	1.73E+03	8.65E+02	4.33E+02
	HEPA	8,760	7.70E+03	3.85E+03	1.93E+03
	Davit Crane	Variable[a]	5.75E+01	2.88E+01	1.44E+01
	Straddle Carrier	Variable[b]	2.02E+02	1.01E+02	5.05E+01
	Tools	None	0.0	0.0	0.0
	Subtotal		**9.69E+03**	**4.84E+03**	**2.43E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.61E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.53E+02	1.61E+02
	Bridge Crane	Variable[c]	4.86	2.48	1.25
	Davit Crane	Variable[d]	1.14E+02	5.68E+01	2.84E+01
	Tools	8,760	1.05E+02	4.82E+01	2.19E+01
	Subtotal		**2.77E+03**	**1.60E+03**	**1.00E+03**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1 .94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	2.19E+01	2.19E+01	2.19E+01
	Subtotal		**2.34E+02**	**2.34E+02**	**2.34E+02**
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	1.14E+02	1.01E+02	1.01E+02
	Subtotal		**3.43E+02**	**3.30E+02**	**3.30E+02**
All	TOTAL		**1.30E+04**	**7.00E+03**	**3.99E+03**

[a] Hours of operation: 3,853 for the 100% Case; 1,927 for the 50% Case; 964 for the 25% Case.

[b] Hours of operation: 13,521 for the 100% Case; 6,761 for the 50% Case; 3,384 for the 25% Case.

[c] Hours of operation: 326 for the 100% Case; 166 for the 50% Case; 84 for the 25% Case.

[d] Hours of operation: 7,611 for the 100% Case; 3,806 for the 50% Case; 1,903 for the 25% Case.

TABLE 4.20 Annual Electricity Consumption during Phase II for Mined-Cavity Storage

Enclosure	Application	Usage (h/yr)	Consumption (MWh/yr) 100%	50%	25%
Mined-Cavities	Cooling	none	0.0	0.0	0.0
	Lighting	438	1.73E+03	8.65E+02	4.33E+02
	HEPA	8,760	7.70E+03	3.85E+03	1.93E+03
	Davit Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Straddle Carrier	Variable[b]	9.70E-01	4.48E-01	2.39E-01
	Tools	none	0.0	0.0	0.0
	Subtotal		**9.43E+03**	**4.72E+03**	**2.36E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.61E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.53E+02	1.61E+02
	Bridge Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Davit Crane	Variable[a]	1.49E-01	5.97E-02	2.98E-02
	Tools	8,760	2.19E+01	8.76	8.76
	Subtotal		**2.57E+03**	**1.50E+03**	**9.58E+02**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1 .94E+02	1.94E+02
	HEPA	none	0.0	0.0	0.0
	Tools	8,760	2.19E+01	2.19E+01	2.19E+01
	Subtotal		**2.34E+02**	**2.34E+02**	**2.34E+02**
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	none	0.0	0.0	0.0
	Tools	8,760	7.45E+01	6.13E+01	5.26E+01
	Subtotal		**3.04E+02**	**2.90E+02**	**2.82E+02**
All	**TOTAL**		**1.25E+04**	**6.74E+03**	**3.83E+03**

[a] Hours of operation: 10 for the 100% Case; 4 for the 50% Case; 2 for the 25% Case.

[b] Hours of operation: 65 for the 100% Case; 30 for the 50% Case; 16 for the 25% Case.

TABLE 4.21 Materials and Resources Used during Phase I Operation of the Mined-Cavity Storage Facility

Material/ Resource	Units	Annual 100%	Annual 50%	Annual 5%	Over 20 Years 100%	Over 20 Years 50%	Over 20 Years 25%
Diesel	kL	3.97	2.96	1.97	7.94E+01	5.93E+01	3.94E+01
Gasoline	kL	9.17	5.70	3.84	1.83E+02	1.14E+02	7.69E+01
Electricity	MW-h	1.30E+04	7.00E+03	3.99E+03	2.60E+05	1.40E+05	7.98E+04
Natural Gas	MSCM	8.00E-02	5.00E-02	3.80E-02	1.60	1.00	8.00E-01
Water	ML	6.05	4.36	3.38	1.21E+02	8.72E+01	6.76E+01
55-gal drums	drums	202	101	51	4,040	2,020	1,010
Boxes	boxes	55	27	14	1,098	549	274

TABLE 4.22 Materials and Resources Used during Phase II Operation of the Mined-Cavity Storage Facility

Material/ Resource	Units	Annual 100%	Annual 50%	Annual 5%	Over 20 Years 100%	Over 20 Years 50%	Over 20 Years 25%
Diesel	kL	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline	kL	5.40	3.60	2.60	1.08E+02	7.21E+01	5.26E+01
Electricity	MW-h	1.25E+04	6.74E+03	3.83E+03	2.51E+05	1.35E+05	7.66E+04
Natural Gas	MSCM	8.00E-02	5.00E-02	3.80E-02	1.60	1.00	8.00E-01
Water	ML	3.60	2.80	2.30	7.10E+01	5.50E+01	4.60E+01
55-gal drums	drums	9	4.5	2.3	181	90	45
Boxes	boxes	2.5	1.3	0.6	49	25	12

TABLE 4.23 Materials and Resources Used over the 40-Year Operation of the Mined-Cavity Storage Facility

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	kL	7.94E+01	5.93E+1	3.94E+01
Gasoline	kL	2.91E+02	1.86E+02	1.29E+02
Electricity	MW-h	5.11E+05	2.75E+05	1.56E+05
Natural Gas	MSCM	3.20	2.10	1.50
Water	ML	2.12E+02	1.52E+02	1.19E+02
55-gal drums	drums	4,221	2,110	1,055
Boxes	boxes	1,147	574	286

TABLE 4.24 Materials and Resources Used during the Total Life Cycle of the Mined-Cavity Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	ML	4.77E-01	2.70E-01	1.53E-01
Gasoline	kL	3.00E+02	1.90E+02	1.31E+02
Electricity	MW-yr	5.51E+02	2.89E+02	1.58E+02
Natural Gas	MSCM	3.20	2.10	1.50
Water	ML	2.12E+02	1.52E+02	1.19E+02
55-gal drums	drums	4,221	2,110	1,055
Boxes	boxes	1,147	574	286

[a] Includes construction use of the materials and resources listed; but does not include construction material such as steel and concrete.

5 PERSONNEL STAFFING ESTIMATES

5.1 CONSTRUCTION LABOR FORCE FOR ALL FACILITIES

It was assumed in estimating the construction labor force that construction would take place during the entire emplacement phase (Phase I) of 20 years. The support buildings (receiving warehouse and repackaging building, administration building, and workshop) would be built before the storage enclosures. Table 5.1 contains the estimated labor force for construction per year and aggregated over 20 years. In estimating the annual construction force, it was assumed that a storage area sufficient to store a year's receipt of depleted uranium would be constructed each year to arrive at annual average values.

5.2 OPERATIONS LABOR FORCE

The required labor force for Phase I (emplacement) and Phase II (maintenance) was estimated on the basis of the activities occurring in each type of storage structure, the number of workers needed for each operation, the time required for each operation, and the number of operations per year. Detailed time-operations tables for the three storage options are given in Appendix B. Some of the activities do not require full-time effort. Therefore, the summaries of the required labor force (in FTEs) given in Tables 5.2 through 5.4 for building, vault, and mined-cavity storage, respectively, are provided in terms of broad labor categories such as line supervisors, which includes supervisors for repackaging activity, storage activity and receipt activity. For Phase I, estimates are for year 20, when all support buildings and storage enclosures are in operation and depleted uranium is still being received. The relatively large number of craft (maintenance) workers for operation of the vault storage facility is due to the assumed rate of 10 person-hours per week (520 person-hours per year) for maintenance of the HVAC equipment in each vault and a total of 40 vaults for the 100% case.

In general, workers would not use respiratory or breathing equipment during normal operations. Respirators or air masks might be used during certain activities, such as repackaging billets or compacting damaged boxes, or during maintenance activities involving potentially contaminated equipment such as HEPA filtration units.

TABLE 5.1 Estimated Labor Force for Construction of the Storage Facilities

Enclosure Type	FTEs/yr			FTE-yr (over 20 yr)		
	100% Case	50% Case	25% Case	100% Case	50% Case	25% Case
Building	32	16.5	8.5	640	330	170
Vault	52	27	14	1,042	530	274
Mined cavity	99	50	25	1,973	996	507

TABLE 5.2 Estimated Labor Force (FTEs) for Operation of the Building Storage Facility

	Phase I			Phase II		
Labor Category	100%	50%	25%	100%	50%	25%
Officials and Managers	9	8	7	9	7	6
Professionals	6	5	4	6	5	4
Office and Clerical	3	3	2	3	3	2
Craft Workers (maintenance)	7	5	4	6	5	4
Operators/Technicians	18	7	4	5	3	2
Line Supervisors	4	2	1	2	1	1
Security	12	10	7	13	9	6
Total	59	40	29	44	33	25

TABLE 5.3 Estimated Labor Force (FTEs) for Operation of the Vault Storage Facility

	Phase I			Phase II		
Labor Category	100%	50%	25%	100%	50%	25%
Officials and Managers	9	8	7	9	7	7
Professionals	6	5	4	6	5	4
Office and Clerical	3	3	2	3	3	2
Craft Workers (maintenance)	26	14	8	25	14	8
Operators/Technicians	18	7	5	6	3	2
Line Supervisors	4	2	1	2	1	1
Security	12	10	7	13	9	6
Total	78	49	34	64	42	30

TABLE 5.4 Estimated Labor Force (FTEs) for Operation of the Mined-Cavity Storage Facility

	Phase I			Phase II		
Labor Category	100%	50%	25%	100%	50%	25%
Officials and Managers	12	11	10	8	6	6
Professionals	9	8	7	6	5	4
Office and Clerical	5	4	4	3	3	2
Craft Workers (maintenance)	5	5	5	5	5	5
Operators/Technicians	20	9	4	4	1	1
Line Supervisors	4	2	1	1	1	1
Security	13	10	7	13	10	7
Total	68	49	38	40	31	26

6 FACILITY EMISSIONS AND WASTES

6.1 ESTIMATE OF EMISSIONS AND WASTES GENERATED DURING CONSTRUCTION OF THE STORAGE FACILITIES

Wastes generated during construction of the storage facility would be typical of large construction projects. Wastes would be primarily construction debris, including concrete fragments, and sanitary wastes from the labor force. Emissions would result primarily from the consumption of fuels used in construction, removal of construction debris, and disturbance of the land (dust). These estimates are entered in Tables 6.1 through 6.3 for a building storage facility, vault storage facility, and mined-cavity storage facility, respectively. In these tables, the amount of concrete waste was estimated with the assumption that two percent of the concrete usage would be spoilage. The other solid wastes, which would include construction debris and rock cuttings, are taken to be eight times the volume of the concrete spoilage. These solid non-hazardous wastes would be disposed of in a municipal solid waste landfill. The amount of sanitary waste was estimated on the basis of the total construction workforce. Liquid (sanitary) non-hazardous wastes would be treated in a portable system or hauled to off-site facilities for treatment and disposal.

Criteria pollutant emissions generated during construction were based on the amount of fuel consumed by the trucks and cranes during construction, as indicated by standard U.S. Environmental Protection Agency (EPA) emission factors (EPA 1993). The emission factors used in this report are consistent with those used in the Engineering Analysis Report for depleted uranium management options, such as Conversion, Cylinder Treatment, Cylinder Transfer, and so forth. However, the emission factors applied in the Engineering Analysis Report for the long-term storage option are anomalous with respect to the other depleted uranium management options. As such, the calculated emissions during construction shown in Tables 6.1 through 6.3 are higher than those for long-term storage of the other chemical forms (UF_6, UO_2, and U_3O_8). Emissions were calculated from the total quantity of liquid fuel consumed (gasoline and diesel). Dust was estimated on the basis of the amount of disturbed land area and the duration that the disturbed area would be under construction.

6.2 ESTIMATE OF EMISSIONS AND WASTES GENERATED DURING THE OPERATIONAL STAGE

Phase I operation of the storage facility would involve receipt, inspection, and repackaging (if damaged) of the depleted uranium boxes and transfer of these boxes to the storage buildings. The major wastes and emissions generated during the operational stage would consist of sanitary wastes from the on-site labor force; empty, damaged boxes (considered to be radioactively contaminated) that must be repackaged; and criteria pollutant emissions from transport of the containers and from facility space heating. Emissions of criteria pollutants were calculated on the basis of the amount of diesel fuel, gasoline, and natural gas consumed annually.

Under normal (incident-free) conditions, the amount of radioactive emissions would be insignificant. (Such emissions, primarily generated during repackaging of damaged wooden boxes, could be reduced through administrative procedures.)

During Phase II operation, boxes in long-term storage would be inspected annually. Depleted uranium billets in damaged boxes would be replaced from storage, repackaged, and returned to storage. Waste and emissions generated during this phase would include sanitary wastes from the on-site labor force; empty, damaged boxes (considered to be radioactively contaminated); and emissions of criteria pollutants from transport of the boxes and from facility space heating.

The boxes determined to be damaged, either upon receipt or during long-term storage, are assumed to be noncombustible, compatible solid LLW that would require disposal. It is assumed that these boxes would be only slightly contaminated by U^{238} and would be Class A waste under the U.S. Nuclear Regulatory Commission's (NRC) classification system. It is important for disposal that LLW have structural stability to preclude slumping, collapse, or failure of a disposal unit (10 CFR 61.56). Damaged boxes would not be stable when buried because they are empty (subject to compaction) and would deteriorate from moisture and microbial action. It is assumed that stability would be provided by breaking down the boxes, which have a wood volume of 1 ft^3 per box, and packing them into 55-gal drums. (This activity would be performed within the airlock located in the repackaging area to minimize potential spread of airborne contamination.) It is reasonable to estimate that the boxes packed in a drum would occupy approximately 50% of the volume (bulking factor of 2). Then, the wood equivalent of 3.675 damaged boxes would be packed in a 55-gal drum for disposal. There would be small volumes of wipes, personal protective equipment, and other slightly contaminated items that could be disposed of in the same drums to further reduce the void fraction. It is expected that administrative procedures would minimize the generation of LLW.

The amount of contamination that could adhere to a box is estimated as follows. The surface of a uranium metal billet would become tarnished (oxidized) to form a surface layer of UO_2, as discussed in Appendix C. It is assumed that this oxide layer is 100 microns thick. (A literature search did not indicate oxidation rates specific to the uranium metal-iron alloy considered for long-term storage. A 200-micron-thick layer of UO_2 oxide was assumed for heavily corroded N-reactor fuel assemblies [Cooper et al. 1996]. This analysis assumes 50% of the literature value because the corrosion of the depleted uranium metal billets is not expected to be as severe. This value is consistent with the Engineering Analysis Report, which assumed a 100-micron-thick oxide layer for handling of uranium metal under the Shielding option.)

If each of these billets had a layer of UO_2 100-micron thick, with a surface area of 1,966 cm^2, 19 billets per box, and UO_2 density of 3 g/cm^3, there would be 1,121 g of UO_2 or 988 g of U^{238} available to contaminate the boxes, assuming that the entire surface layer is dislodged during repackaging and that it would contaminate the inner surfaces of the damaged box. With a specific activity of 3.36×10^{-7} Ci/g, the level of contamination of a damaged box could be 3.3×10^{-4} Ci. The packaged LLW would be surveyed prior to off-site transport and presumably shipped to a shallow land disposal facility.

Three types of non-hazardous wastes would be generated during operations. These wastes would consist of liquid sanitary waste released to a local sanitary system; municipal solid waste (office waste, domestic trash, and food waste) transported to an off-site municipal landfill for disposal; and recyclable waste (aluminum, steel, paper, and cardboard) picked up by recycling companies.

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 boxes. This gives a conservative estimate of emissions. For each type of storage facility, a corresponding set of four tables details the estimated emissions and wastes relative to the particular facility (Tables 6.4 through 6.15). The first table is for Phase I, the second table is for Phase II, the third table is for total wastes and emissions from Phase I and Phase II, and the fourth table is for total wastes and emissions (i.e., from construction as well as from both phases of operations). Tables 6.4 through 6.7 pertain to the building storage facility, Tables 6.8 through 6.11 refer to the vault storage facility, and Tables 6.12 through 6.15 relate to the mined-cavity storage facility.

TABLE 6.1 Estimated Emissions and Wastes from Construction of the Building Storage Facility

	Units	100% Case	50% Case	25% Case
EMISSIONS				
Carbon monoxide	te	2.04E+01	1.06E+01	5.79
Hydrocarbons	te	8.10E-01	4.30E-01	2.30E-01
NO_x	te	3.05	1.60	8.70E-01
SO_x	te	2.00E-01	1.10E-01	6.00E-02
Dust	te	3.43E+01	1.81E+01	9.90
PM-10	te	4.56	2.38	1.30
WASTES				
Concrete	m^3	7.00E+02	3.60E+02	1.90E+02
Other solid waste	m^3	5.60E+03	2.88E+03	1.52E+03
Sanitary liquids	m^3	5.82E+03	3.00E+03	1.55E+03
Other liquids	m^3	2.59E+03	1.33E+03	6.90E+02

TABLE 6.2 Estimated Emissions and Wastes from Construction of the Vault Storage Facility

	Units	100% Case	50% Case	25% Case
EMISSIONS				
Carbon monoxide	te	1.08E+02	5.43E+01	2.76E+01
Hydrocarbons	te	4.31	2.17	1.10
NO_x	te	1.62E+01	8.14	4.13
SO_x	te	1.08	5.40E-01	2.80E-01
Dust	te	5.15E+01	2.64E+01	1.53E+01
PM-10	te	2.41E+01	1.22E+01	6.17
WASTES				
Concrete	m^3	1.14E+03	5.80E+02	3.00E+02
Other solid waste	m^3	9.12E+03	4.64E+03	2.40E+03
Sanitary liquids	m^3	9.47E+03	4.82E+03	2.50E+03
Other liquids	m^3	4.21E+03	2.14E+03	1.11E+03

TABLE 6.3 Estimated Emissions and Wastes from Construction of the Mined-Cavity Storage Facility

	Units	100% Case	50% Case	25% Case
EMISSIONS				
Carbon monoxide	te	1.22E+01	6.44	3.48
Hydrocarbons	te	4.90E-01	2.60E-01	1.40E-01
NO_x	te	1.83	9.70E-01	5.20E-01
SO_x	te	1.20E-01	6.00E-02	3.00E-02
Dust	te	2.58E+01	1.46E+01	8.99
PM-10	te	2.73	1.44	7.80E-01
WASTES				
Concrete	m^3	6.70E+02	3.40E+02	1.80E+02
Other solid waste	m^3	5.36E+03	2.72E+03	1.44E+03
Sanitary liquids	m^3	1.79E+04	9.05E+03	4.61E+03
Other liquids	m^3	7.97E+03	4.02E+03	2.05E+03

TABLE 6.4 Estimated Emissions and Wastes from Phase I Operations of the Building Storage Facility

		Annual			Over 20 years		
Parameter	Units	100%	50%	25%	100%	50%	25%
EMISSIONS							
CO	kg	1.16E+3	6.19E+2	3.41E+2	2.31E+4	1.24E+4	6.83E+3
Hydrocarbons	kg	4.82E+1	2.58E+1	1.42E+1	9.65E+2	5.15E+2	2.83E+2
NO_x	kg	1.65E+3	8.44E+2	4.42E+2	3.29E+4	1.69E+4	8.83E+3
SO_x	kg	1.55E+1	8.19	4.45	3.10E+2	1.64E+2	8.91E+1
PM-10	kg	1.42E+2	7.88E+1	4.54E+1	2.84E+3	1.58E+3	9.08E+2
WASTES							
Non-haz solid	m^3	1.11E+2	7.45E+1	5.54E+1	2.22E+3	1.49E+3	1.11E+3
Recyclable solid	m^3	4.40E+1	3.00E+1	2.20E+1	8.80E+2	6.00E+2	4.40E+2
Sanitary liquid	m^3	493E+3	3.32E+3	2.46E+3	9.86E+4	6.63E+4	4.93E+4
LLW	te	5.94	2.97	1.48	1.19E+2	5.94E+1	2.97E+1

TABLE 6.5 Estimated Emissions and Wastes from Phase II Operations of the Building Storage Facility

		Annual			Over 20 years		
Parameter	Units	100%	50%	25%	100%	50%	25%
EMISSIONS							
CO	kg	9.72E+2	5.06E+2	2.71E+2	1.94E+4	1.01E+4	5.43E+3
Hydrocarbons	kg	4.08E+1	2.12E+1	1.14E+1	8.16E+2	4.38E+2	2.27E+2
NO_x	kg	1.62E+3	8.28E+2	4.31E+2	3.24E+4	1.66E+4	8.62E+3
SO_x	kg	1.36E+1	7.07	3.76	2.73E+2	1.45E+2	7.51E+1
PM-10	kg	1.01E+2	5.37E+1	2.98E+1	2.01E+3	1.15E+3	5.98E+2
WASTES							
Non-haz solid	m^3	8.41E+1	6.31E+1	4.78E+1	1.68E+3	1.26E+3	9.56E+2
Recyclable solid	m^3	3.40E+1	2.50E+1	1.90E+1	6.80E+2	5.00E+2	3.80E+2
Sanitary liquid	m^3	3.74E+3	2.80E+3	2.12E+3	7.48E+4	5.60E+4	4.25E+4
LLW	te	2.66E-1	1.33E-1	6.66E-2	5.32	2.66	1.33

TABLE 6.6 Estimated Emissions and Wastes over the 40-Year Operation of the Building Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	4.26E+01	2.25E+01	1.23E+01
Hydrocarbons	te	1.78	9.40E-01	7.43E-01
NO_x	te	6.53E+01	3.34E+01	1.83E+01
SO_x	te	5.83E-01	3.05E-01	1.64E-01
PM-10	te	4.85	2.65	1.50
WASTES				
Non-haz solid	m^3	3.86E+03	2.71E+03	2.06E+03
Recyclable solid	m^3	1.54E+03	1.08E+03	8.20E+02
Sanitary liquid	m^3	1.72E+05	1.21E+05	9.18E+04
LLW	te	1.24E+02	6.21E+01	3.10E+01

TABLE 6.7 Estimated Emissions and Wastes over the Total Life Cycle (Including Construction) of the Building Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	6.29E+01	3.31E+01	1.80E+01
Hydrocarbons	te	2.60	1.37	7.43E-01
NO_x	te	6.84E+01	3.50E+01	1.83E+01
SO_x	te	7.86E-01	4.12E-01	2.22E-01
Dust	te	3.43E+01	1.81E+01	9.90
PM-10	te	9.41	5.03	2.85
WASTES				
Concrete	m^3	7.00E+02	3.60E+02	1.90E+02
Other const. solid	m^3	5.60E+03	2.88E+03	1.52E+03
Non-haz solid	m^3	3.86E+03	2.71E+03	2.06E+03
Recyclable solid	m^3	1.54E+03	1.08E+03	8.20E+02
Sanitary liquid	m^3	1.78E+05	1.24E+05	9.34E+04
Other non-haz liquid	m^3	2.70E+04	1.70E+04	9.00E+03
LLW	te	1.24E+02	6.21E+01	3.10E+01

TABLE 6.8 Estimated Emissions and Wastes from Phase I Operations of the Vault Storage Facility

		Annual			Over 20 years		
Parameter	Units	100%	50%	25%	100%	50%	25%
EMISSIONS							
CO	kg	1.43E+3	7.35E+2	4.14E+2	2.85E+4	1.47E+4	8.28E+3
Hydrocarbons	kg	5.92E+1	3.05E+1	1.72E+1	1.18E+3	6.11E+2	3.43E+2
NO_x	kg	1.92E+3	9.76E+2	5.10E+2	3.83E+4	1.95E+4	1.02E+4
SO_x	kg	1.88E+1	9.66	5.33	3.75E+2	1.93E+2	1.07E+2
PM-10	kg	1.84E+2	9.57E+1	5.71E+1	3.67E+3	1.91E+3	1.14E+3
WASTES							
Solid	m^3	1.49E+3	9.37E+2	6.50E+2	2.98E+4	1.87E+4	1.30E+4
Recyclable	m^3	6.00E+1	3.70E+1	2.60E+1	1.20E+3	7.40E+2	5.20E+2
Sanitary	m^3	6.63E+3	4.16E+3	2.89E+3	1.33E+5	8.32E+4	5.78E+4
LLW	te	5.94	2.97	1.48	1.19E+2	5.94E+1	2.97E+1

TABLE 6.9 Estimated Emissions and Wastes from Phase II Operations of the Vault Storage Facility

		Annual			Over 20 years		
Parameter	Units	100%	50%	25%	100%	50%	25%
EMISSIONS							
CO	kg	1.23E+3	6.17E+2	3.40E+2	2.45E+4	1.23E+4	6.80E+3
Hydrocarbons	kg	5.10E+1	2.60E+1	1.40E+1	1.03E+3	5.17E+2	2.84E+2
NO_x	kg	1.89E+3	9.59E+2	4.99E+2	3.77E+4	1.92E+4	9.97E+3
SO_x	kg	1.70E+1	8.00	5.00	3.36E+2	1.70E+2	9.20E+1
PM-10	kg	1.40E+2	6.90E+1	4.10E+1	2.80E+3	1.39E+3	1.14E+3
WASTES							
Solid	m^3	1.22E+2	8.03E+1	5.73E+1	2.44E+3	1.61E+3	1.15E+3
Recyclable	m^3	4.90E+1	3.20E+1	2.30E+1	9.80E+2	6.40E+2	4.60E+2
Sanitary	m^3	5.44E+3	3.57E+3	2.55E+3	1.09E+5	7.14E+4	5.10E+4
LLW	te	2.66E-1	1.33E-1	6.66E-2	5.32	2.66	1.33

TABLE 6.10 Estimated Emissions and Wastes over the 40-Year Operation of the Vault Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	5.30E+01	2.70E+01	1.51E+01
Hydrocarbons	te	2.21	1.13	6.27E-01
NO_x	te	7.60E+01	3.87E+01	2.02E+01
SO_x	te	7.12E-01	3.63E-01	1.98E-01
PM-10	te	6.47	3.30	1.95
WASTES				
Solid	m^3	3.22E+04	2.03E+04	1.42E+04
Recyclable	m^3	2.18E+03	1.38E+03	9.80E+02
Sanitary	m^3	2.42E+05	1.79E+05	1.09E+05
LLW	te	1.24E+02	6.20E+01	3.10E+01

TABLE 6.11 Estimated Emissions and Wastes over the Total Life Cycle (Including Construction) of the Vault Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	1.61E+02	8.13E+01	4.26E+01
Hydrocarbons	te	6.52	3.30	1.73
NO_x	te	9.22E+01	4.68E+01	2.43E+01
SO_x	te	1.79	9.05E-01	4.74E-01
PM-10	te	3.06E+01	1,54E+01	8.12
Dust	te	5.15E+01	2.64E+01	1.53E+01
WASTES				
Concrete	m^3	6.70E+02	3.40E+02	1.80E+02
Other const. solid	m^3	5.36E+03	2.72E+03	1.44E+03
Solid	m^3	3.22E+04	2.03E+04	1.42E+04
Recyclable	m^3	2.18E+03	1.38E+03	9.80E+02
Sanitary	m^3	2.51E+05	1.84E+05	1.11E+05
Other liquid	m^3	4.21E+03	2.14E+03	1.11E+03
LLW	te	1.24E+02	6.20E+01	3.10E+01

TABLE 6.12 Estimated Emissions and Wastes from Phase I Operations of the Mined-Cavity Storage Facility

		Annual			Over 20 years		
Parameter	Units	100%	50%	25%	100%	50%	25%
EMISSIONS							
CO	kg	4.45E+2	2.93E+2	1.99E+2	8.89E+3	5.86E+3	3.97E+3
Hydrocarbons	kg	1.79E+1	1.18E+1	8.01	3.58E+2	2.36E+2	1.60E+2
NO_x	kg	1.62E+2	1.07E+2	7.59E+1	3.25E+3	2.14E+3	1.52E+3
SO_x	kg	4.70	3.10	2.11	9.40E+1	6.20E+1	4.22E+1
PM-10	kg	9.20E+1	6.07E+1	4.09E+1	1.84E+3	1.21E+3	8.17E+2
WASTES							
Solid	m^3	1.30E+2	9.37E+1	7.26E+1	2.60E+3	1.87E+3	1.47E+3
Recyclable	m^3	5.20E+1	3.70E+1	2.90E+1	1.04E+3	7.40E+2	5.80E+2
Sanitary	m^3	5.78E+3	4.16E+3	3.23E+3	1.16E+5	8.32E+4	6.46E+4
LLW	te	5.94	2.97	1.48	1.19E+2	5.94E+1	2.97E+1

TABLE 6.13 Estimated Emissions and Wastes from Phase II Operations of the Mined-Cavity Storage Facility

		Annual			Over 20 years		
Parameter	Units	100%	50%	25%	100%	50%	25%
EMISSIONS							
CO	kg	2.13E+2	1.42E+2	1.03E+2	4.25E+3	2.83E+3	2.07E+3
Hydrocarbons	kg	9	6	4	1.73E+2	1.15E+2	8.40E+1
NO_x	kg	1.28E+2	8.40E+1	6.20E+1	2.55E+3	1.68E+3	1.23E+3
SO_x	kg	2	2	1	4.80E+1	3.20E+1	2.30E+1
PM-10	kg	4.00E+1	2.70E+1	1.90E+1	8.00E+2	5.35E+2	3.90E+2
WASTES							
Solid	m^3	7.65E+1	5.92E+1	4.97E+1	1.53E+3	1.18E+3	9.94E+2
Recyclable	m^3	3.10E+1	2.40E+1	2.00E+1	6.20E+2	4.80E+2	4.00E+2
Sanitary	m^3	3.40E+3	2.64E+3	2.21E+3	6.80E+4	5.28E+4	4.42E+4
LLW	te	2.66E-1	1.33E-1	6.66E-2	5.32	2.66	1.33

TABLE 6.14 Estimated Emissions and Wastes over the 40-Year Operation of the Mined-Cavity Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	1.31E+1	8.70	6.04
Hydrocarbons	te	5.31E-1	3.51E-1	2.44E-1
NO_x	te	5.80	3.82	2.75
SO_x	te	1.42E-1	9.37E-2	6.53E-2
PM-10	te	2.64	1.75	1.21
WASTES				
Solid	m^3	4.13E+03	3.05E+03	2.46E+03
Recyclable	m^3	1.66E+03	1.22E+03	9.80E+02
Sanitary	m^3	1.84E+05	1.36E+05	1.09E+05
LLW	te	1.24E+02	6.20E+01	3.10E+01

TABLE 6.15 Estimated Emissions and Wastes over the Total Life Cycle (Including Construction) of the Mined-Cavity Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	2.53E+1	1.51E+1	9.52
Hydrocarbons	te	1.02	6.09E-1	3.83E-1
NO_x	te	7.63	4.79	3.27
SO_x	te	2.64E-1	1.58E-1	1.00E-1
PM-10	te	5.37	3.19	1.99
Dust	te	2.58E+1	1.46E+1	8.99
WASTES				
Concrete	m^3	1.14E+03	5.80E+02	3.00E+02
Other const. solid	m^3	9.12E+03	4.64E+03	2.40E+03
Solid	m^3	4.13E+03	3.05E+03	2.46E+03
Recyclable	m^3	1.66E+03	1.22E+03	9.80E+02
Sanitary	m^3	2.02E+05	1.45E+05	1.14E+05
Other liquid	m^3	4.21E+03	2.14E+03	1.11E+03
LLW	te	1.24E+02	6.20E+01	3.10E+01

7 DESCRIPTION OF POTENTIAL ACCIDENTS

Accidents that could occur during long-term storage are analyzed in this section. Potential accidents could be initiated during facility operations or could be caused by external events, including natural phenomena (earthquake and wind). Reasonably foreseeable accidents have been screened to identify the accidents that have the greatest consequences to workers and the public. These are the "bounding" accidents that provide an envelope for the consequences of other potential accidents that would have less impact on workers and the public.

Four types of events were considered credible: a handling accident, a fire or explosion, an earthquake, and a tornado. A flood was considered to be incredible because it is assumed that the facility would be sited to preclude severe flooding. Figure 7.1 summarizes the results of the accident analysis and gives the accident scenario, a description of the accident, the frequency range, and information about the source term.

The source term, which is the amount of radioactive material released, is the product of four factors: the material at risk (MAR); the damage fraction (DF); the respirable airborne release fraction (RARF); and the fraction of respirable airborne material released to the environment, or leak path factor (LPF).

7.1 HANDLING ACCIDENTS

Mechanical upsets are events such as spills, forklift punctures, loss of filtration, and piping failures. In general, mechanical upset-initiated accidents would result in small releases to the atmosphere. Here it is assumed that a forklift in the receiving warehouse and repackaging building damages an entire pallet (4 boxes with 19 billets each). This causes the four boxes to fall to the floor, break, and release the UO_2 patina that had formed on the uranium metal billets. The MAR is the total radioactive material, uranium metal with oxide coating, in four boxes (5,700 lb. uranium metal, or 6,466 lb if all metal is converted to UO_2). It is assumed that the damage fraction is unity, that all of the oxide becomes airborne and is in the respirable range, and that none of the metal becomes airborne. Then, the RARF would be 1.73×10^{-4}, as estimated for an oxide layer 100 microns thick, with a surface area of approximately 37,000 cm^2 for 19 billets per box and an oxide density of 3 g/cm^3 (refer to Section 6.2 for further details on the derivation of the RARF). As in the Engineering Analysis Report, it is assumed that the uranium dioxide release would be filtered as it passes through the HEPA filters with an efficiency of 99.9% (LPF = 0.001) as a puff. (The accident scenario would not result in failure of off-gas filters because of the absence of energetic processes.) The release is estimated to be 0.0011 lb (0.50 g of uranium) or 1.7×10^{-7} Ci.

The frequency of this accident per year is the product of the number of pallets received per year, the number of operations per pallet, and the probability that a mishandling accident would cause damage to the boxes on a pallet and result in release of radioactive material per operation. It is assumed that the number of operations (six) and the mishandling accident probability (1.1×10^{-5}) are the same as for mishandling of drums in the Engineering Analysis Report. For the 100% Case, where 7,525 pallets would be handled per year, the frequency of this accident would be 0.5/yr. For the 50% Case and the 25% Case, the frequency of this accident would be reduced proportionately. This accident is considered to be anticipated, because it has a frequency greater than 0.01/yr.

7.2 FIRE OR EXPLOSION

Here it is assumed that a fire or explosion within the receiving warehouse would affect the contents of four boxes on a pallet. The absence of combustible materials or a fire source within the receiving warehouse would limit the material-at-risk to a single pallet. This accident scenario assumes that the fire is initiated by a fuel leak from the forklift, which could be ignited by a number of sources. Because a forklift is used only within the receiving warehouse, a comparable scenario within the storage facilities was not considered.

The fire or explosion would initiate burning of uranium metal to form U_3O_8 particulates (refer to Appendix C) that would be filtered through the HEPA filter (LPF = 0.001). The material at risk and damage fraction would be the same as for the mishandling accident. The RARF (0.001) is based on thermal stress (oxidation) of uranium (refer to DOE-HDBK-0013 [DOE, 1994b], page 4-2). The frequency of this accident is assumed to be the same as in the Engineering Analysis Report for a fire or explosion accident (9.6×10^{-6}). It is estimated that 0.0067 lb of U_3O_8 particulates would be released with an activity of 8.7×10^{-7} Ci. The release would continue for 30 minutes, at which point appropriate measures would result in extinguishing the fire.

As noted in DOE-HDBK-1081-94 (DOE 1994c), metallic uranium handled in massive forms does not present a significant fire risk unless exposed to a severe and prolonged external fire, which would be highly unlikely because of the absence of combustible material necessary to support a fire of any significant magnitude. Unlike plutonium, uranium is difficult to ignite. The presence of an adherent, protective layer of hyperstoichiometric dioxide at the interface limits oxygen availability. At surface to mass ratios greater than 1.0 cm^2/g, the ignition temperature of bulk metallic uranium exceeds 500 ^oC and increases rapidly, indicating that large pieces of uranium are very difficult to ignite because large amounts of external heat must be supplied and serious heat loss prevented (Mishima et al. 1985). Therefore, this accident is considered to be extremely unlikely; that is, it has a frequency of between 10^{-6}/yr and 10^{-4}/yr.

An accident scenario that has been examined in a number of environmental studies concerns a diesel fire in an underground disposal facility (DOE 1980; DOE 1990) and its potential to affect the entire facility. This accident scenario was projected to be risk-dominant compared with other plausible scenarios for disposal of transuranic waste at the Waste Isolation Pilot Plant (DOE 1990). However, because of concerns about air quality in the drifts and aisleways of the mined-cavity storage facility, it was decided to use electric-driven straddle carriers in this study. Consequently, it was deemed incredible that a sufficient quantity of combustible material would accumulate in the mined cavities to initiate a significant accident. Thus, this accident scenario was not considered further in this analysis.

7.3 EARTHQUAKE

Here, the receiving warehouse and repackaging building would be damaged in a design basis earthquake. Review of the on-site structures indicated that this building had the greatest potential for a significant airborne release due to the potential for the overhead crane to fall during the event, resulting in crushing of the wooden boxes located underneath with subsequent atmospheric release. (Although the storage buildings contain a higher inventory of uranium metal, the storage buildings do not contain an overhead crane, so it is difficult to postulate a scenario that results in a significant airborne release. An accident scenario in which more than one building would collapse simultaneously was considered so unlikely that it is not reasonably foreseeable.)

The material at risk would be the entire amount of depleted uranium metal in storage at the receiving warehouse and repackaging building; that is, material received during a 5.8-week period (4,788,000 lb of uranium metal, or 5,427,000 lb if all metal is converted to UO_2). The damage fraction is taken as 10%. The RARF would be the same as for the mishandling accident. The seismic event is assumed to cause failure of the building structure and its confinement system so that 10% of the oxide released from the boxes would be released from the building, resulting in a ground-level unfiltered release of 9.41 lb of UO_2 (1.3×10^{-3} Ci). (A damage fraction of 10% is reasonable given the cross section of the overhead crane; refer to Figure 2.2.) The release is assumed to continue for a 30-minute period. The frequency of this event (5×10^{-4}/yr), as well as the LPF, DF, and release duration, are assumed to be the same as for the earthquake event in the Engineering Analysis Report. DOE hazard category 2 buildings are constructed such that earthquakes (and tornadoes as well) could cause failure of the building structure and confinement at this annual frequency.

Although it might appear intuitively that the potential consequences of an earthquake on an underground facility would be more severe than on a surface facility, that does not appear to be the case. Available data on the effects of earthquakes in underground mines and tunnels indicate that they are significantly less susceptible to damage from earthquakes than are surface facilities (DOE 1980). Investigations measuring earthquake acceleration underground and at the surface indicated that underground motion was four to six times less than at the surface. A study of the Alaskan earthquake of 1964 by the U.S. Geological Survey reported no significant damage to underground facilities, such as mines and tunnels, although some rocks were shaken loose in places. Therefore, it is expected that damage to mined cavities would be much less than for aboveground facilities, such as the receiving warehouse and repackaging building. Thus, the scenario considered in Table 7.1 could be considered the bounding earthquake event for a mined-cavity storage facility.

7.4 TORNADO — WAREHOUSE AND REPACKAGING BUILDING

Here, the warehouse and repackaging building would be damaged when a major tornado and associated tornado missiles sweep across the building in 30 seconds. The material at risk would be the material received during a 5.8-week period (4,784,000 lb of uranium metal, or 5,427,000 lb if all metal is converted to UO_2), and the fraction damaged is taken as 10%. Based on the Engineering Analysis Report, the RARF would be the same as for the mishandling accident and the earthquake event. (Because the billets are heavy, dense, metallic objects, it would be expected that an insignificant fraction of uranium would be broken into airborne respirable particles.) There would be failure of the building structure and its confinement system so that 10% of the oxide released from the boxes would be released from the building, resulting in ground-level unfiltered release of 9.41 lb of UO_2 (1.3×10^{-3} Ci). The released powder would be highly dispersed because of tornado wind conditions. The release is assumed to continue for a 30-second period. The frequency of this event (5×10^{-4}/yr), as well as the LPF, DF, and release duration, are assumed to be the same as for the earthquake event in the Engineering Analysis Report.

7.5 TORNADO — SINGLE STORAGE BUILDING

This accident considers the potential impacts of a major tornado and associated missiles sweeping across an aboveground storage building in 30 seconds. This scenario was not included in the Engineering Assessment Report, but is included here because the Design Team believes that the consequences of this event would bound the consequences of the same tornado sweeping across the receiving warehouse and repackaging facility. It should be noted that a major tornado would not have as great an impact on a partly underground vault or on a completely underground mined cavity.

The material at risk would be the material stored within a single storage building (approximately 107 million lb of uranium metal, or 122 million lb UO_2 if all uranium metal is converted to uranium oxide). The damage fraction was estimated assuming that only the outer row of stored pallets would be at risk (1 row out of 22 total rows) and that 20% of the material in that row would be affected. The damage fraction would then be approximately 0.009. The RARF would be the same as for the mishandling accident and the mishandling accident and the earthquake event. There would be failure of the storage building structure and its confinement system so that 10% of the oxide released from the boxes would be released from the building. This would result in a ground-level unfiltered release of 19.2 lb of UO_2 (2.5×10^{-3} Ci).

The released powder would be highly dispersed because of tornado wind conditions. The release is assumed to continue for 30 seconds. The frequency of this event (5×10^{-4}/yr) and the release duration are assumed to be the same as for the tornado event in the Engineering Analysis Report.

TABLE 7.1 Assessment of Accidents for the 100% Case

Accident Scenario	Accident Description	Frequency Range	Release (Source Term) Chemical Form	Amount (lb)	Duration (minutes)	Release Level
Mishandling or drop of drum or billet inside building	An entire pallet of uranium metal billets is damaged by a forklift and spills its contents onto the ground inside the receiving warehouse and repackaging building.	>10E-2/yr	UO_2	1.1E-03	Puff	Stack
Fire or explosion within the warehouse and repackaging building	A fire or explosion within the receiving warehouse and repackaging building affects the contents of a single pallet of 4 wooden boxes.	10E-6/yr - 10E-4/yr	U_3O_8	6.7E-3	30	Stack
Earthquake	The receiving warehouse and repackaging building is assumed to be damaged during a design basis earthquake with resulting failure of the structure and confinement occurring.	10E-4/yr - 10E-2/yr	UO_2	9.41	30	Ground
Tornado	A major tornado and associated tornado missiles results in failure of the receiving warehouse and repackaging building structure and confinement systems.	10E-4/yr - 10E-2/yr	UO_2	9.41	0.5	Ground
Flood	It is assumed that the facility would be sited to preclude severe flooding.	<10E-6/yr	No Release	NA[a]	NA	NA
Tornado – Single Storage building	A major tornado and associated tornado missiles results in failure of a single storage building structure and confinement systems.	10E-4/yr – 10E-2/yr	UO_2	1.92E+1	0.5	Ground

[a] NA = not applicable.

8 TRANSPORTATION

This section primarily addresses on-site transportation of depleted uranium. In addition, off-site shipments of LLW for disposal are discussed.

Operation of a storage facility requires the following types of on-site transportation of depleted uranium: movement of the depleted uranium in boxes from the site boundary to the receiving warehouse by rail or truck, movement within the receiving warehouse and repackaging facility by overhead crane, movement from the receiving warehouse and repackaging building to storage enclosures by truck, and movement within storage enclosures by straddle carrier. Except for 55-gal drums containing damaged boxes to be disposed of as LLW, wooden boxes would be the only other major stream that would be transported on-site. These wooden boxes would, for the most part, contain 19 billets of depleted uranium, although some empty boxes would be needed for repackaging of billets in damaged boxes. Table 8.1 contains on-site transportation requirements.

As discussed earlier, boxes contaminated with UO_2 and small amounts of other radiologically contaminated solids (e.g., wipes and protective clothing) will be placed in 55-gal drums and transported to an off-site LLW disposal facility. The 55-gal drums will serve as transportation packages and disposal containers. It is assumed that these drums will be transported to an LLW disposal facility by truck, and the truck has a capacity of 28 drums. It is also assumed that a shipment does not occur until 28 drums have accumulated. With these assumptions, and the quantities of LLW shown in Tables 6.2 and 6.3, the off-site transportation of LLW would be as shown in Table 8.2 for the emplacement phase (Phase I) and in Table 8.3 for the maintenance phase (Phase II).

TABLE 8.1 On-Site Transportation

Parameter	100% Case	50% Case	25% Case
Physical form	Solid, metal	Solid, metal	Solid, metal
Container type	2'×2'×1' wood box	2'×2'×1' wood box	2'×2'×1' wood box
Weight per container, gross	669 kg	669 kg	669 kg
Annual quantity, mass of billets	19,455 te	9,727 te	4,864 te
Annual quantity, number of containers	30,100	15,050	7,525
Annual quantity, number of pallets	7,525	3,763	1,881
Transportation mode (from site boundary)	Rail	Rail	Rail
Containers per railcar	80	80	80
Annual number of railcar shipments, 12 railcars per shipment	32	16	8
Transportation mode (from site boundary)	Truck	Truck	Truck
Containers per truck	28	28	28
Annual number of truck trips	1,075	538	269
Transportation mode (receiving warehouse to storage)	Truck	Truck	Truck
Containers per truck trailer	7 pallets	7 pallets	7 pallets
Annual number of truck trips	1,075	538	269
Transportation mode (within storage building)	Straddle carrier	Straddle carrier	Straddle carrier
Containers per lift	1 pallet	1 pallet	1 pallet
Annual number of lifts	7,525	3,763	1,882

TABLE 8.2 Off-Site Transportation of Low-Level Radioactive Waste, Emplacement Phase (Phase I)

Transported Materials	100% Case	50% Case	25% Case
Type	Low-level rad waste	Low-level rad waste	Low-level rad waste
LLW type	Noncombustible, compactible solid	Noncombustible, compactible solid	Noncombustible, compactible solid
Physical form	Solid	Solid	Solid
Chemical composition	Wood & UO_2	Wood & UO_2	Wood & UO_2
Temperature and pressure	Ambient	Ambient	Ambient
Packaging			
Type	55-gal drum	55-gal drum	55-gal drum
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (kg)	23	23	23
Material weight (kg)	108	108	108
Contamination content (wt%)	3.8%	3.8%	3.8%
Contaminant	UO_2	UO_2	UO_2
Shipments			
Average volume (m^3) per year	5.7	2.9	1.4
Packages per year	54.9	27.4	13.7
Packages during Phase I	1,098	549	274
Packages per shipment	28	28	28
Shipments per year	1.96	0.98	0.49
Shipments during Phase I	40	20	10
Form of Transportation/Routing			
Form of transportation	Truck	Truck	Truck
Destination	LLW disposal facility	LLW disposal facility	LLW disposal facility

TABLE 8.3 Off-Site Transportation of Low-Level Radioactive Waste, Maintenance Phase (Phase II)

Transported Materials	100% Case	50% Case	25% Case
Type	Low-level rad waste	Low-level rad waste	Low-level rad waste
LLW type	Noncombustible, compactible solid	Noncombustible, compactible solid	Noncombustible, compactible solid
Physical form	Solid	Solid	Solid
Chemical composition	Wood & UO_2	Wood & UO_2	Wood & UO_2
Temperature and pressure	Ambient	Ambient	Ambient
Packaging			
Type	55-gal drum	55-gal drum	55-gal drum
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (kg)	23	23	23
Material weight (kg)	108	108	108
Contamination content (wt%)	3.8%	3.8%	3.8%
Contaminant	UO_2	UO_2	UO_2
Shipments			
Average volume (m^3) per year	0.26	0.13	0.06
Packages per year	2.46	1.23	0.61
Packages during Phase II	49.1	24.6	12.3
Packages per shipment	28	28	28
Shipments per year	0.09	0.04	0.02
Shipments during Phase II	2	1	1
Form of Transportation/Routing			
Form of transportation	Truck	Truck	Truck
Destination	LLW disposal facility	LLW disposal facility	LLW disposal facility

9 PERMITTING AND REGULATORY COMPLIANCE

This section addresses the regulatory framework within which a storage facility for depleted uranium would be constructed and operated with respect to nuclear and occupational safety and environmental safety. The enabling legislation for DOE is the Atomic Energy Act (AEA) of 1954 (P.L. 83-703), as amended by the Energy Reorganization Act of 1974 (P.L. 93-438) and the Energy Reorganization Act of 1977 (P.L.95-91). The AEA is concerned with the proper management —production, possession, and use — of nuclear and radioactive materials. These statutes generally authorize the DOE to manage nuclear safety on DOE sites and at DOE facilities. They also authorize the U.S. Nuclear Regulatory Commission (NRC) to regulate nuclear safety at non-DOE sites and facilities. Specific statutes also authorize to the NRC to regulate nuclear safety at specific kinds of DOE facilities. For example, the Nuclear Waste Policy Act of 1982 authorized the NRC to regulate disposal of high-level radioactive waste in geological repositories.

The definition of source material in the AEA includes uranium. The NRC has promulgated regulations in 10 CFR Part 40 governing licensing of receiving, possessing, using, transferring, or delivering source material. Commercial depleted uranium storage facilities would then be subject to relevant provisions of 10 CFR Part 40.

DOE depleted uranium storage facilities would have to comply with DOE's regulatory regime. This consists primarily of DOE orders, which are roughly equivalent to NRC regulations. An example is DOE Order 151.1, which describes the roles and responsibilities for the DOE Emergency Management System to respond promptly, efficiently, and effectively to any emergency involving DOE facilities, activities, or operations. DOE orders may be supplemented with manuals, which provide detailed guidance in complying with orders. However, occasionally DOE's requirements are promulgated in regulations published in the Code of Federal Regulations (CFR). For example 10 CFR 835 establishes radiation protection standards, limits, and program requirements addressing occupational exposure at DOE facilities and operations.

The current intent is that the depleted uranium storage facilities would be regulated pursuant to DOE orders and regulations. For completeness, the salient DOE and NRC provisions are identified. In other matters, the same environmental and occupational safety statutes will be complied with, regardless of whether the facility is regulated with regard to nuclear safety by DOE or the NRC.

Some major statutes or regulations that the storage facility must comply with that are not related to nuclear safety are briefly described below.

National Environmental Policy Act of 1969 (NEPA). NEPA establishes a national policy that promotes awareness of the environmental consequences of activities on the environment and consideration of the environmental impacts during the planning and decision-making stages of a project. NEPA requires all federal agencies to prepare an Environmental Impact Statement (EIS) that details the environmental effects of proposed major federal actions that may significantly affect the quality of the human environment.

Clean Air Act (CAA). The Clean Air Act, as stated in its Congressional findings, is intended to "to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 requires that each federal agency with jurisdiction over any property or facility that might result in the discharge of air pollutants comply with "all federal, state, interstate, and local requirements" with regard to control and abatement of air pollution. The EPA promulgates regulations pursuant to the CAA. Hazardous air pollutants, including radionuclides, are regulated by EPA under the National Emission Standards for Hazardous Air Pollutants Program.

Safe Drinking Water Act (**SDWA**). The primary objective of the SWDA is to protect the quality of the public water supplies and all sources of drinking water. The implementing regulations, which are administered by EPA unless delegated to the states, establish standards and maximum contamination levels in public water systems. There are maximum contamination levels for radioactive materials.

Clean Water Act (CWA). The Clean Water Act was enacted to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." It prohibits the "discharge of toxic pollutants in toxic amounts" to the navigable waters of the United States. Section 313 of the CWA requires that all branches of the federal government engaged in any activity that might result in a discharge or runoff of pollution to surface waters comply with federal, state, and local requirements.

Occupational Safety and Health Act of 1970. The Occupational Safety and Health Act establishes standards to enhance safe and healthful working conditions in places of employment. The Act is administered by the Occupational Safety and Health Administration (OSHA). In general, employers have the duty to furnish all employees with a place of employment free of recognized hazards likely to cause death or serious physical harm. Employees have a duty to comply with occupational safety and health standards and rules. DOE emphasizes compliance with these regulations.

9.1 MAJOR REGULATIONS AFFECTING CONSTRUCTION

During construction of a long-term storage facility for depleted uranium, there would be emissions released and wastes produced, as presented in Section 6.1. These emissions would have to comply with the Clean Air Act, Safe Drinking Water Act, Clean Water Act, and the Noise Control Act, regardless of whether the storage facility is a DOE facility or a commercial facility. In addition, a DOE facility would have to comply with the DOE requirements discussed in Section 9.1.1, and commercial facilities would have to comply with the NRC requirements discussed in Section 9.1.2.

9.1.1 Regulatory Requirements for DOE Facility Construction

DOE's regulatory system employs orders, manuals with detailed guidance about the orders, and contractor requirements documents (CRDs). The order that is relevant for managing physical assets from acquisition through operations and disposition is DOE O 430.1A, *Life Cycle Asset Management.* Attachment 2 to DOE O 430.1A is its CRD. This CRD identifies items that must be included in project planning for approval before commencement of construction. These include life-cycle cost analysis, preliminary safety assessment, and verification of performance criteria through test and evaluation.

The general design requirements for the construction of a DOE storage facility are given in DOE Order 6430.1A, *General Design Criteria*. A storage facility for depleted uranium would be a "special facility," so Division 13 of the Order would apply in addition to other divisions. More specifically, the type of specific facility that best describes this storage facility is a "Uranium Processing and Handling Facility (UPHF)," which is addressed in Subdivision 1319. The subdivision is mainly concerned with facilities that process and handle enriched uranium; hence, some of the provisions, such as those concerned with nuclear criticality, are not applicable to a facility that stores depleted uranium.

9.1.2 Regulatory Requirements for Commercial Facility Construction

A commercial facility for storage of depleted uranium would have to comply with the requirements of the NRC regulations. It would have to be granted a license pursuant to 10 CFR Part 40, *Domestic Licensing of Source Material*. Part 40 provides for two kinds of licenses: general licenses for certain identified purposes and specific licenses. Storage of large amounts of depleted uranium is not an identified purpose for a general license. Therefore, the requirements of 10 CFR 40.31 and 40.32 for specific licenses would have to be met. These requirements include the completion of an environmental study pursuant to 10 CFR Part 51 prior to start of construction. 10 CFR 40.36 requires that a decommissioning funding plan would have to be submitted for licenses for facilities that possess more than 0.1 Ci in a readily dispersible form. The UO_2 coating on billets could be considered a source material in a readily dispersible form. One box is estimated to contain 0.00036 Ci. The number of boxes delivered in a year for the 100% Case (30,100) would then contain 10.8 Ci of uranium oxide, far above the threshold for a decommissioning plan.

In addition to regulations, which have the force of law, the NRC issues documents called "Regulatory Guides (RGs)" that give guidance on how to comply with its regulations. An RG that is applicable to commercial depleted uranium storage facilities is RG 3.76, *Standard Format* *and Content for Emergency Plans for Fuel Cycle and Material Facilities*. RG 3.76 contains guidance on how to comply with the emergency plans requirement for an application for a special source facility license. NRC guidance may also be contained in NRC reports in the NUREG series or NRC contractor reports in the NUREG/CR series.

9.2 MAJOR REGULATIONS AFFECTING OPERATIONS

Just as for construction, during operation of a depleted uranium storage facility there would be emissions released and wastes produced, as presented in Section 6.1. These emissions would have to comply with the Clean Air Act, Safe Drinking Water Act, and Clean Water Act, regardless of whether the storage facility is a DOE facility or a commercial facility. Also, a facility must comply with OSHA requirements to enhance safe working conditions. In addition, a DOE facility would have to comply with the DOE requirements discussed in Section 9.2.1, and commercial facilities would have to comply with the NRC requirements discussed in Section 9.2.2.

9.2.1 Regulatory Requirements for DOE Facility Operation

Key DOE requirements address radiation protection. Requirements for radiation protection of the public and of the environment are found in DOE 5400.5, *Radiation Protection of the Public and the Environment*. This order imposes a limit of 100 mrem (1 mSv) total effective dose equivalent (TEDE) as the limit from all exposure modes. Of this dose, no greater than 10 mrem (0.1 mSv) could result from airborne emissions, the standard adopted by the EPA under the Clean Air Act in 40 CFR 61. Occupational radiation protection is addressed in 10 CFR 835, which provides that an annual dose of 5 rem (0.05 Sv) TEDE should not be exceeded. DOE has adopted an approach to radiation protection to manage and control radiological exposure to the work force and the public so that it is As Low As is Reasonably Achievable (ALARA). DOE also has adopted a design objective for facilities to limit worker exposure to 1 rem annually.

Some LLW would be generated in a storage facility for depleted uranium metal. Management of this waste would be in accordance with Chapter III of DOE 5820.2A, *Radioactive Waste Management*. This waste would be shipped off-site to a disposal facility. Therefore, it would have to be packaged to meet the U.S. Department of Transportation (DOT) regulations for transportation of radioactive materials, as cited in 49 CFR Part 173, Subpart I.

9.2.2 Regulatory Requirements for Commercial Facility Operation

Commercial storage facilities would be subject to the NRC's requirements for radiation protection and LLW management. The requirements cited in 10 CFR Part 20, *Standards for Protection Against Radiation*, contain standards for workers and the general public that are substantially the same as DOE's standards, including ALARA requirements. A commercial storage facility would manage its LLW so that it could meet the requirements for disposal in 10 CFR Part 61, *Licensing Requirements for Land Disposal of Radioactive Waste*. NRC's scheme for disposal of LLW differs slightly from DOE's scheme. NRC classifies LLW (as Class A, Class B, or Class C) and imposes stability requirements that are dependent on classification. Under this classification system, depleted uranium would be Class A waste, the least radioactive class. DOE Order 5820.2A does not classify LLW. However, individual DOE disposal facilities have their own classification system. The NRC transportation regulations in 10 CFR Part 71, *Packaging and Transportation of Radioactive Waste*, are the same as DOT's regulations in 49 CFR Part 173, Subpart I.

10 PRELIMINARY SCHEDULE ESTIMATES

Figure 10.1 shows an estimated schedule for the entire life cycle of the depleted uranium storage facility that mirrors the estimated schedule and discussion in the Engineering Analysis Report.

After a DOE Record of Decision (ROD), there would be a period of approximately one year for developing management plans and obtaining approvals and initial budgeting. Next, there would be a period of approximately three years for developing and testing the form (alloy) for the depleted uranium billets and generating baseline design parameters. Parallel to this technology verification task would be a design task and a safety approval and NEPA process task. After four years, it is estimated that these tasks should be far enough along that a construction application could be submitted. After two more years, the final design and final safety analysis would be completed, so that construction approval would be granted.

It is estimated that three years would be required to build the support buildings and the first storage enclosures, and operation would begin nine years from the start of the schedule. During the first 20 years of operation, boxes of depleted uranium billets would be received and placed in storage enclosures, which would be constructed as needed over this 20-year period. Then there would be a 20-year period during which no more depleted uranium would be received and operations would be mainly surveillance and monitoring, with repackaging of billets from boxes that were found to be damaged. During the last three years of this phase, decontamination and decommissioning would occur and, after 49 years, the life cycle of the storage facility would be completed.

The schedule shown in Figure 10.1 is based on experience with actual construction and operations of non-reactor nuclear-type facilities. A “fast track” approach is clearly possible, which would decrease the time to operations. However, for comparison of discounted life-cycle costs between the various storage options and chemical forms, the decision was made in this analysis to apply the generic schedule shown in the Engineering Analysis Report for long-term storage of UO_2 and U_3O_8, as appropriate, for storage of depleted uranium metal. A shorter time to operations would result in higher discounted life-cycle costs compared to the other chemical forms considered for long-term storage.

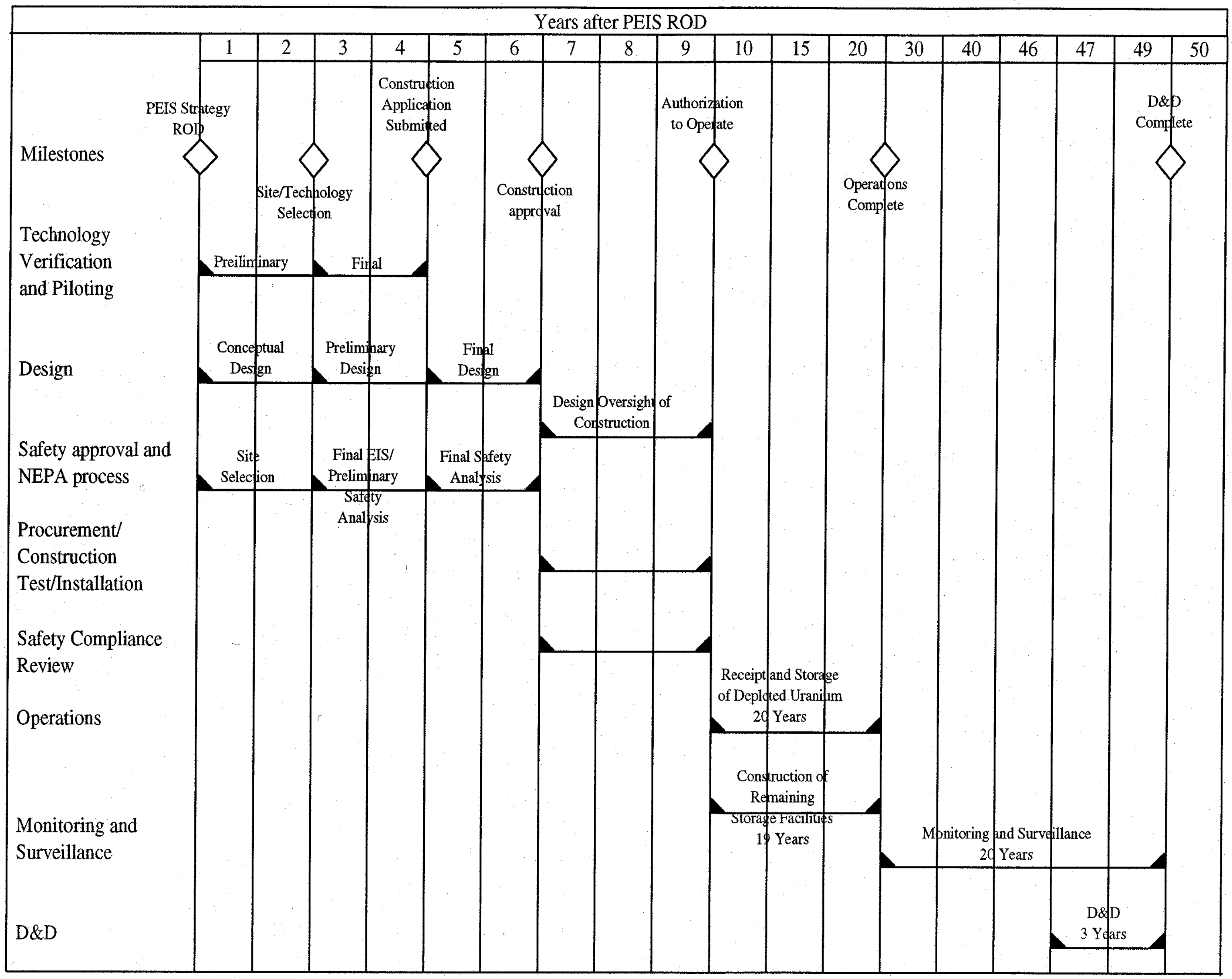

FIGURE 10.1 Estimated Overall Schedule for the Depleted Uranium Storage Facility

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APPENDIX A:

EQUIPMENT LIST

APPENDIX A:

EQUIPMENT LIST

TABLE A.1 Support Buildings

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, chairs, 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	1
		Printer	One each office group	4
	Kitchen	Kitchen equipment	Microwave, refrigerator, sink, storage area, cupboards	1
	Washroom	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 exposure data	1
	Security station	Badging equipment, location monitors, computer	Make security badges, activate badge numbers, monitor badge locations in complex	1

TABLE A.1 (Cont.)

Building	Area	Equipment	Use/Explanation	Number
Workshop	General	General maintenance equipment	Metal joining, drilling, cutting, and shaping equipment; woodworking equipment; electrical and electronic test equipment	1
		HVAC	Maintain working temperature	1
	Washroom	Toilets, sinks	Human waste and personal hygiene	1 M & F
Receiving Warehouse	Unloading bay	Davit crane, 5 ton	Unload pallets from truck or railcar	2
		Scales, 3 ton	Weigh received pallets for material accountability	1
		Hand-held bar coding equipment with computer link	Bar code boxes and record in box database	1
		Prime mover	Move railcar of drums	1
	Loading bay	Davit crane, 5 ton	Load pallets to truck	2
		Flatbed trailer truck	Moving pallets from receiving warehouse to storage areas	3
		Hand-held bar coding equipment with computer link	Record box shipment to storage building	2
	Inspection area	Bridge crane, 5 ton	Move pallets from unloading bay to storage area and from storage area to loading bay	2
		Computer attached to LAN	Record inventory movements	2

TABLE A.1 (Cont.)

Building	Area	Equipment	Use/Explanation	Number
	General	Radiation monitoring station	Monitor radiation levels in receiving warehouse and loading and unloading bays, monitor incoming boxes, monitor workers on entry/exit	1
		Security station (automated)	Control personnel access to building	1
		Fire sensors/alarms, sprinkler system	Fire protection	1
		HVAC	Maintain working temperature	1
		Generator	Back-up power for repackaging during power outage	1
		Uninterruptible power supply	For computers during initial stages of power outage	1
Repackaging area	Repackaging area	Forklift, 5 ton	Move overpacked, damaged boxes between receiving warehouse and scales and hoist	2
		Scales, 3 ton	Weigh overpacked, damaged boxes and refilled boxes 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 boxes and make codes for new boxes	1
		Computer attached to LAN	Recording movements and conditions of boxes in database	1

TABLE A.1 (Cont.)

Building	Area	Equipment	Use/Explanation	Number
		Decontamination showers	Decontamination of 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 airlocks	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
		Hoist	Lifts billets from damaged boxes to hopper	1
		Hopper	Distributes billets from damaged box to new box	1
		Packer	Packs damaged boxes (LLW) in 55-gal drums	1
		Billet packing station	Packing new boxes with billets	1

TABLE A.2 Equipment Specific to Storage Buildings

Building	Area	Equipment	Use/Explanation	Number
Storage Building	Unloading bay	Davit crane, 5 ton	Load boxes on pallets from truck to unloading bay, or vice versa	4 per building
	Storage area	Straddle carrier, 5 ton	Move boxes on pallets from unloading bay to storage area, and vice versa	3 max. (100% Case)
		Scales, 3 ton	Weigh boxes on receipt or shipment for material accountability	1 per building
		Hand-held bar coding equipment with computer link	Track receipt or shipment of boxes from receiving warehouse or to repackaging area	1 per building
		Computer attached to LAN	Record inventory movements	1 per building
		Radiation monitoring station	Measure radiation in ambient air, on received boxes, and on workers at entry or exit	1 per building
		Fire sensors/alarms, sprinkler system	Fire protection	1 per building
		Security station (automated)	Control personnel entry to building	1 per building
		HEPA filter	Periodically trap particles on exhaust for radiation monitoring	1 per building
		HVAC	Periodically heat or cool building during inspection; maintain temperature for computer during operation	1 per building
		Generator, 350 kW	Back-up power during outage	1 per building

TABLE A.3 Equipment Specific to Storage Vaults

Building	Area	Equipment	Use/Explanation	Number
Storage Vault	Storage bay	Straddle carrier, 5 ton	Load boxes on pallets from truck to storage area, or vice versa	3 (total for all vaults)
		Scale, 3 ton	Weigh boxes on receipt or shipment for material accountability	1 per vault
		Hand-held bar coding equipment with computer link	Track receipt or shipment of boxes from receiving warehouse or to repackaging area	1 per vault
		Computer attached to LAN	Record inventory movements	1 per vault
		Radiation monitoring station	Measure radiation in ambient air, on received boxes, and on workers at entry or exit	1 per vault
		Fire sensors/alarms, sprinkler system	Fire protection	1 per vault
		HEPA Filter	Trap articles on exhaust for radiation monitoring	1 per vault
		HVAC	Maintain temperature for safe storage, computers	1 per vault
		Generator, 75 kW	Back-up power during outage	1 per vault

TABLE A.4 Equipment Specific to Mined-Cavity Storage

Building	Area	Equipment	Use/Explanation	Number
Surface to underground access	Access shafts	Elevator, 20 ton	Move depleted uranium in boxes to or from drifts; remove mined rock;	2
		Scales, 3 ton	weigh boxes on entry to or exit from underground for material accountability	1
		Hand-held bar coding equipment with computer link	Track receipt or shipment of boxes from receiving warehouse or to repackaging area; record condition of boxes	1
		Computer attached to LAN	Record inventory movements	1
		Radiation monitoring station	Measure radiation in ambient air, on received boxes, and on workers at entry or exit	1
		Fire sensors/alarms, sprinkler system	Fire protection	1
		Security station (automated)	Control personnel entry to underground area	1
	Ventilation shafts	Compressor	Feed clean air to underground areas; exhaust dirty air	4
		Radiation monitoring station	Monitor ambient air in underground facility	1
	Underground area	Straddle carrier, 5 ton	Move boxes from access shaft to storage areas and vice versa	4
		Generator, 1 MW	Maintain elevator power, lighting, air flow during outage	8

APPENDIX B:

RADIATION EXPOSURE AND PERSONPOWER DISTRIBUTION ESTIMATING DATA

APPENDIX B:

RADIATION EXPOSURE AND PERSONPOWER DISTRIBUTION ESTIMATING DATA

The following paragraphs provide the assumptions and basis for Tables B.1 through B.12 in this appendix, similar to that provided in the Engineering Analysis Report (LLNL 1997). Due to the conceptual nature of the facility designs in this report, it is not possible to perform an absolute analysis of worker radiation exposure. The data will allow comparison as to relative levels of worker exposure.

In these tables, the numbers in the "Source" column refer to the notes at the end of each table. These notes identify the radiation source that is judged to be the most significant for the particular operation.

The "Material" column in each table describes the primary containment of the source. Walls between operating areas were not included. It is known that areas such as the laboratory and offices will be separated from the storage facilities by one or more walls. The thickness and material of construction for exterior walls are a function of the type of storage enclosure, whether building, vault, or mined cavity.

Additional notes at the end of each table provide the basis for the number of operations per year or the amount of maintenance estimated.

TABLE B.1 Building Storage Facility (Uranium Metal Boxes): Operational Activities — Phase I

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 9)	Source	Distance (ft)	Material (Note 10)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Unload arriving pallet	2	0.25	7525	1	3	Wood	3/4"	3763	3763	1882	1882	941
Inspect arriving pallet	1	0.25	7525	1	3	Wood	3/4"	1881	3763	941	1882	471
Transfer undamaged pallet to warehouse storage	2	0.25	7494	1	6	Wood	3/4"	3747	3747	1874	1874	937
Transfer damaged pallet to repackaging area (8)	2	2	31	1	6	Wood	3/4"	124	16	64	8	32
Unload failed box pallet	2	0.25	202	1	3	Wood	3/4"	101	101	51	51	26
Transfer failed box to repackaging area	2	0.25	202	2	6	Wood	3/4"	101	101	51	51	26
Repackage damaged/failed box contents	1	1	202	2	3	Wood	3/4"	202	101	101	51	51
Transfer repackaged box pallet to warehouse storage	2	0.25	202	1	6	Wood	3/4"	101	101	51	51	26
Failed box size reduction	2	0.1	202	3	15	Wood	3/4"	40	101	20	51	10
Transfer new boxes into repackaging area	2	0.25	202	2,3	15	Wood	3/4"	101	101	51	51	26
Transfer pallet from warehouse storage to loading bay	2	0.25	7696	1	6	Wood	3/4"	3848	3848	1924	1924	962
Load pallet on truck	2	0.25	7696	1	3	Wood	3/4"	3848	3848	1924	1924	962
Transfer pallet to storage building	1	0.25	1100	4	6	Wood	3/4"	275	550	138	275	69
Warehouse storage surveillance	1	1	520	6	3	Wood	3/4"	520	520	520	520	520
Building management	2	8	260	6	10	Wood	3/4"	4160	260	4160	260	4160
Security	1	2	1095	6	15	Wood	3/4"	2190	830	1660	629	1258
WORKSHOP												
Building operations	4	8	260	7	80	Wood	3/4"	8320	260	8320	260	8320
Security	1	2	1095	7	80	Wood	3/4"	2190	830	1660	629	1258
ADMINISTRATION BUILDING												
Building operations	9	8	260	7	160	Wood	3/4"	18720	260	14187	260	10752
Security	2	8	1095	7	160	Wood	3/4"	17520	830	13278	629	10063

TABLE B.1 (Cont.)

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 9)	Source	Distance (ft)	Material (Note 10)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
STORAGE BUILDINGS - 8, 4 and 2 Buildings												
Unload transferred pallet	2	0.25	7696	1	3	Wood	3/4"	3848	3848	1924	1924	962
Transfer pallet to storage position	1	0.25	7696	7	6	Wood	3/4"	1924	3848	962	1924	481
Unload pallet into position	2	0.25	7696	7	3	Wood	3/4"	3848	3848	1924	1924	962
Load failed box pallet from storage position (8)	2	2	10	7	3	Wood	3/4"	40	5	20	3	12
Transfer failed pallet to bay	1	0.25	10	7	6	Wood	3/4"	3	5	1	3	1
Load failed pallet onto truck	2	0.25	10	1	3	Wood	3/4"	5	5	3	3	2
Transfer failed pallet to warehouse	1	0.25	10	1	6	Wood	3/4"	3	5	1	3	1
Monitor HEPA filtration/air monitor	1	1	260	7	10	Wood	3/4"	260	260	260	260	260
Storage area/container integrity surveillance	8	8	260	7	3	Wood	3/4"	16640	260	8320	260	4160
Building management	1	8	260	7	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	7	15	Wood	3/4"	2190	830	1660	629	1258

1) Single pallet with four uranium metal boxes
2) Single uranium metal box
3) Single empty uranium metal box
4) Seven pallets (28 uranium metal boxes)
5) Four pallets (16 uranium metal boxes)
6) Up to 840 pallets in receiving warehouse
7) Cumulative inventory of a storage building
8) Includes handling of damaged/failed box
9) 30,100 boxes received per year (602,000 boxes received over 20 years); 7,525 pallets (30,100 uranium metal boxes/4 boxes per pallet); 31 damaged uranium metal boxes received per year (0.1% failure rate/year); 181 boxes damaged in on-site operations per year; 162 newly damaged boxes discovered and repackaged; 19 newly damaged boxes stored damaged; 10 failed uranium metal boxes in storage discovered each year; 7,697 received and repackaged box pallets per year; 1,100 on-site transfers per year (7,697 pallets/7 pallets per transfer); 365 days per year × 3 shifts per day = 1,095 per year
10) Materials do not include walls between operating areas

TABLE B.2 Building Storage Facility (Uranium Metal Boxes): Maintenance Activities — Phase I

	100%								50%		25%	
Equipment	Number of workers per station	Time per operation (hr) (Note 4)	Number of components	Source	Distance (ft)	Material (Note 5)	Thickness	Person Hours per year	Number of components	Person hours per year	Number of components	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Overhead crane	2	52	2	1	10	Wood	3/4"	208	2	208	2	208
Electrically powered transfer equipment	2	104	1	2	3	Wood	3/4"	208	1	208	1	208
Air lock system (2 per building)	2	52	2	1	20	Wood	3/4"	208	2	208	2	208
HVAC	2	520	1	1	10	Wood	3/4"	1040	1	1040	1	1040
HEPA	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
Generator	2	52	1	1	10	Wood	3/4"	104	1	104	1	104
UPS	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
WORKSHOP												
HVAC	2	520	1	3	80	Wood	3/4"	1040	1	1040	1	1040
ADMINISTRATION BUILDING												
HVAC	2	520	1	3	160	Wood	3/4"	1040	1	1040	1	1040
STORAGE BUILDING -- 8, 4 and 2 Buildings												
HVAC	2	520	8	3	10	Wood	3/4"	8320	4	4160	2	2080
HEPA	2	26	8	3	10	Wood	3/4"	416	4	208	2	104
Air monitoring equipment	2	52	8	3	10	Wood	3/4"	832	4	416	2	208

1) Up to 840 pallets in receiving warehouse
2) Single uranium metal box
3) Cumulative inventory of a storage building
4) 2 hours per week (104) for complex systems with multiple active components; 1 hour per week (52) on active components (compressors, air lock systems, cranes) -- includes instrumentation; 0.5 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

TABLE B.3 Building Storage Facility (Uranium Metal Boxes): Operational Activities — Phase II

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Unload failed box pallet	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed box to repackaging area	2	0.25	9	2	6	Wood	3/4"	5	4.515	2	2.2575	1
Repackage damaged/failed box contents	1	1	9	2	3	Wood	3/4"	9	4.515	5	2.2575	2
Transfer repackaged box to warehouse storage	2	0.25	9	2	6	Wood	3/4"	5	4.515	2	2.2575	1
Failed box size reduction	2	0.1	9	3	15	Wood	3/4"	2	4.515	1	2.2575	0
Transfer new boxes into repackaging area	2	0.25	9	2,3	15	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet from warehouse storage to loading bay	2	0.25	9	1	6	Wood	3/4"	5	4.515	2	2.2575	1
Load pallet on truck	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet to storage building	1	0.25	9	4	6	Wood	3/4"	2	1.12875	0	0.564375	0
Building management	2	8	260	4	10	Wood	3/4"	4160	260	4160	260	4160
Security	1	2	1095	4	15	Wood	3/4"	2190	830	1660	629	1258
WORKSHOP												
Building operations	4	8	260	5	80	Wood	3/4"	8320	260	8320	260	8320
Security	1	2	1095	5	80	Wood	3/4"	2190	830	1660	629	1258
ADMINISTRATION BUILDING												
Building operations	9	8	260	5	160	Wood	3/4"	18720	260	14187	260	10752
Security	2	8	1095	5	160	Wood	3/4"	17520	830	13278	629	10063
STORAGE BUILDINGS -- 8, 4 and 2 Buildings												
Unload transferred pallet	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet to storage position	1	0.25	9	5	6	Wood	3/4"	2	4.515	1	2.2575	1
Unload pallet into position	2	0.25	9	5	3	Wood	3/4"	5	4.515	2	2.2575	1
Load failed box pallet from storage position (7)	2	2	9	5	3	Wood	3/4"	36	4.515	18	2.2575	9
Transfer failed pallet to bay	1	0.25	9	5	6	Wood	3/4"	2	4.515	1	2.2575	1
Load failed pallet onto truck	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed pallet to warehouse	1	0.25	9	1	6	Wood	3/4"	2	4.515	1	2.2575	1

TABLE B.3 (Cont.)

Activity	100%								50%		25%	
	Number of workers per station	Time per operation (hr)	Operation per year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
Monitor HEPA filtration/air monitor	1	1	260	5	10	Wood	3/4"	260	260	260	260	260
Storage area/container integrity surveillance	8	8	260	5	3	Wood	3/4"	16640	260	8320	260	4160
Building management	1	8	260	5	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	5	15	Wood	3/4"	2190	830	1660	629	1258

1) Single pallet with four uranium metal boxes
2) Single U-metal box
3) Single empty uranium box
4) Four pallets (16 uranium metal boxes)
5) Cumulative inventory of a storage building
6) Includes handling of damaged/failed box
7) 602,000 boxes in storage; 9 failed uranium metal boxes per year; 4 on-site transfers per year (4 pallets/1 pallet per transfer); 365 days per year × 3 shifts per day = 1,095 per year
8) Materials do not include walls between operating areas

TABLE B.4 Building Storage Facility (Uranium Metal Boxes): Maintenance Activities – Phase II

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr) (Note 4)	Number of components	Source	Distance (ft)	Material (Note 5)	Thickness	Person hours per year	Number of components	Person hours per year	Number of components	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Overhead crane	2	52	2	1	10	Wood	3/4"	208	2	208	2	208
Electrically powered transfer equipment	2	104	1	2	3	Wood	3/4"	208	1	208	1	208
Air lock system (2 per building)	2	52	2	1	20	Wood	3/4"	208	2	208	2	208
HVAC	2	520	1	1	10	Wood	3/4"	1040	1	1040	1	1040
HEPA	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
Generator	2	52	1	1	10	Wood	3/4"	104	1	104	1	104
UPS	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
WORKSHOP												
HVAC	2	520	1	3	80	Wood	3/4"	1040	1	1040	1	1040
ADMINISTRATION BUILDING												
HVAC	2	520	1	3	160	Wood	3/4"	1040	1	1040	1	1040
STORAGE BUILDING -- 8, 4 and 2 Buildings												
HVAC	2	520	8	3	10	Wood	3/4"	8320	4	4160	2	2080
HEPA	2	26	8	3	10	Wood	3/4"	416	4	208	2	104
Air monitoring equipment	2	52	8	3	10	Wood	3/4"	832	4	416	2	208

1) Up to four pallets (16 uranium metal boxes)
2) Single uranium metal box
3) Cumulative inventory of a storage building
4) 2 hours per week (104) for complex systems with multiple active components; 1 hour 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

TABLE B.5 Vault Storage Facility (Uranium Metal Boxes): Operational Activities — Phase I

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 9)	Source	Distance (ft)	Material (Note 10)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Unload arriving pallet	2	0.25	7525	1	3	Wood	3/4"	3763	3763	1882	1882	941
Inspect arriving pallet	1	0.25	7525	1	3	Wood	3/4"	1881	3763	941	1882	471
Transfer undamaged pallet to warehouse storage	2	0.25	7494	1	6	Wood	3/4"	3747	3747	1874	1874	937
Transfer damaged pallet to repackaging area (8)	2	2	31	1	6	Wood	3/4"	124	16	64	8	32
Unload failed box pallet	2	0.25	202	1	3	Wood	3/4"	101	101	51	51	26
Transfer failed box to repackaging area	2	0.25	202	2	6	Wood	3/4"	101	101	51	51	26
Repackage damaged/failed box contents	1	1	202	2	3	Wood	3/4"	202	101	101	51	51
Transfer repackaged box pallet to warehouse storage	2	0.25	202	1	6	Wood	3/4"	101	101	51	51	26
Failed box size reduction	2	0.1	202	3	15	Wood	3/4"	40	101	20	51	10
Transfer new boxes into repackaging area	2	0.25	202	2,3	15	Wood	3/4"	101	101	51	51	26
Transfer pallet from warehouse storage to loading bay	2	0.25	7696	1	6	Wood	3/4"	3848	3848	1924	1924	962
Load pallet on truck	2	0.25	7696	1	3	Wood	3/4"	3848	3848	1924	1924	962
Transfer pallet to storage building	1	0.25	1100	4	6	Wood	3/4"	275	550	138	275	69
Warehouse storage surveillance	1	1	520	6	3	Wood	3/4"	520	520	520	520	520
Building management	2	8	260	6	10	Wood	3/4"	4160	260	4160	260	4160
Security	1	2	1095	6	15	Wood	3/4"	2190	830	1660	629	1258
WORKSHOP												
Building operations	4	8	260	7	80	Wood	3/4"	8320	260	8320	260	8320
Security	1	2	1095	7	80	Wood	3/4"	2190	830	1660	629	1258
ADMINISTRATION BUILDING												
Building operations	9	8	260	7	160	Wood	3/4"	18720	260	14187	260	10752
Security	2	8	1095	7	160	Wood	3/4"	17520	830	13278	629	10063
STORAGE VAULT AREA - 40, 20 and 10 Vaults												
Unload transferred pallet	2	0.25	7696	1	3	Wood	3/4"	3848	3848	1924	1924	962
Transfer pallet to storage position	1	0.25	7696	7	6	Wood	3/4"	1924	3848	962	1924	481
Unload pallet into position	2	0.25	7696	7	3	Wood	3/4"	3848	3848	1924	1924	962

TABLE B.5 (Cont.)

Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 9)	Source	Distance (ft)	Material (Note 10)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
	100%								50%		25%	
Load failed box pallet from storage position (8)	2	2	10	7	3	Wood	3/4"	40	5	20	3	12
Transfer failed pallet to bay	1	0.25	10	7	6	Wood	3/4"	3	5	1	3	1
Load failed pallet onto truck	2	0.25	10	1	3	Wood	3/4"	5	5	3	3	2
Transfer failed pallet to warehouse	1	0.25	10	1	6	Wood	3/4"	3	5	1	3	1
Monitor HEPA filtration/air monitor	1	1	260	7	10	Wood	3/4"	260	260	260	260	260
Storage area/container integrity surveillance	8	8	260	7	3	Wood	3/4"	16640	260	8320	260	4160
Building management	1	8	260	7	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	7	15	Wood	3/4"	2190	830	1660	629	1258

1) Single pallet with four uranium metal boxes
2) Single uranium metal box
3) Single empty uranium metal box
4) Seven pallets (28 uranium metal boxes)
5) Four pallets (16 uranium boxes)
6) Up to 840 uranium box pallets in receiving warehouse
7) Cumulative inventory of a storage vault
8) Includes handling of damaged/failed box
9) 30,100 boxes received per year (602,000 boxes received over 20 years); 7,525 pallets (30,100 uranium metal boxes/4 boxes per pallet); 31 damaged uranium metal boxes received per year (0.1% failure rate/year); 181 boxes damaged in on-site operations per year; 162 newly damaged boxes discovered and repackaged; 19 newly damaged boxes stored damaged; 10 failed uranium boxes in storage discovered each year; 7,697 received and repackaged box pallets per year; 1,100 on-site transfers per year (7,697 pallets/7 pallets per transfer; 365 days per year × 3 shifts per day = 1,095 per year)
10) Materials do not include walls between operating areas

TABLE B.6 Vault Storage Facility (Uranium Metal Boxes): Maintenance Activities — Phase I

	100%								50%		25%	
Equipment	Number of workers per station	Time per operation (hr) (Note 4)	Number of components	Source	Distance (ft)	Material (Note 5)	Thickness	Person hours per year	Number of components	Person hours per year	Number of components	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Overhead crane	2	52	2	1	10	Wood	3/4"	208	2	208	2	208
Electrically powered transfer equipment	2	104	1	2	3	Wood	3/4"	208	1	208	1	208
Air lock system (2 per building)	2	52	2	1	20	Wood	3/4"	208	2	208	2	208
HVAC	2	520	1	1	10	Wood	3/4"	1040	1	1040	1	1040
HEPA	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
Generator	2	52	1	1	10	Wood	3/4"	104	1	104	1	104
UPS	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
WORKSHOP												
HVAC	2	520	1	3	80	Wood	3/4"	1040	1	1040	1	1040
ADMINISTRATION BUILDING												
HVAC	2	520	1	3	160	Wood	3/4"	1040	1	1040	1	1040
STORAGE VAULT AREA -- 40, 20 and 10 Vaults												
HVAC	2	520	40	3	10	Wood	3/4"	41600	20	20800	10	10400
HEPA	2	26	40	3	10	Wood	3/4"	2080	20	1040	10	520
Air monitoring equipment	2	52	40	3	10	Wood	3/4"	4160	20	2080	10	1040

1) Up to 840 pallets in receiving warehouse
2) Single uranium metal box
3) Cumulative inventory of a storage vault
4) 2 hours per week (104) for complex systems with multiple active components; 1 hour per week (52) on active components (compressors, air lock systems, cranes) -- includes instrumentation; 0.5 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

TABLE B.7 Vault Storage Facility (Uranium Metal Boxes): Operational Activities — Phase II

Activity	100%								50%		25%	
	Number of workers per station	Time per operation (hr)	Operation per year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Unload failed box pallet	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed box to repackaging area	2	0.25	9	2	6	Wood	3/4"	5	4.515	2	2.2575	1
Repackage damaged/failed box contents	1	1	9	2	3	Wood	3/4"	9	4.515	5	2.2575	2
Transfer repackaged box to warehouse storage	2	0.25	9	2	6	Wood	3/4"	5	4.515	2	2.2575	1
Failed box size reduction	2	0.1	9	3	15	Wood	3/4"	2	4.515	1	2.2575	0
Transfer new boxes into repackaging area	2	0.25	9	2,3	15	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet from warehouse storage to loading bay	2	0.25	9	1	6	Wood	3/4"	5	4.515	2	2.2575	1
Load pallet on truck	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet to storage building	1	0.25	9	4	6	Wood	3/4"	2	1.12875	0	0.564375	0
Building management	2	8	260	4	10	Wood	3/4"	4160	260	4160	260	4160
Security	1	2	1095	4	15	Wood	3/4"	2190	830	1660	629	1258
WORKSHOP												
Building operations	4	8	260	5	80	Wood	3/4"	8320	260	8320	260	8320
Security	1	2	1095	5	80	Wood	3/4"	2190	830	1660	629	1258
ADMINISTRATION BUILDING												
Building operations	9	8	260	5	160	Wood	3/4"	18720	260	14187	260	10752
Security	2	8	1095	5	160	Wood	3/4"	17520	830	13278	629	10063
STORAGE VAULT AREA -- 40, 20 and 10 Vaults												
Unload transferred pallet	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet to storage position	1	0.25	9	5	6	Wood	3/4"	2	4.515	1	2.2575	1
Unload pallet into position	2	0.25	9	5	3	Wood	3/4"	5	4.515	2	2.2575	1
Load failed box pallet from storage position (7)	2	2	9	5	3	Wood	3/4"	36	4.515	18	2.2575	9
Transfer failed pallet to bay	1	0.25	9	5	6	Wood	3/4"	2	4.515	1	2.2575	1
Load failed pallet onto truck	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed pallet to warehouse	1	0.25	9	1	6	Wood	3/4"	2	4.515	1	2.2575	1

TABLE B.7 (Cont.)

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation Per Year (Note 7)	Person Hours per year
Monitor HEPA filtration/air monitor	1	1	260	5	10	Wood	3/4"	260	260	260	260	260
Storage area/container integrity surveillance	8	8	260	5	3	Wood	3/4"	16640	260	8320	260	4160
Building management	1	8	260	5	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	5	15	Wood	3/4"	2190	830	1660	629	1258

1) Single pallet with four uranium metal boxes
2) Single uranium metal box
3) Single empty uranium metal box
4) Four pallets (16 uranium metal boxes)
5) Cumulative inventory of a storage vault
6) Includes handling of damaged/failed box
7) 602,000 boxes in storage; 9 failed uranium metal boxes per year; 4 on-site transfers per year (4 pallets/1 pallet per transfer; 365 days per year × 3 shifts per day = 1,095 per year)
8) Materials do not include walls between operating areas

TABLE B.8 Vault Storage Facility (Uranium Metal Boxes): Maintenance Activities — Phase II

	100%								50%		25%	
Equipment	Number of workers per station	Time per operation (hr) (Note 4)	Number of components	Source	Distance (ft)	Material (Note 5)	Thickness	Person hours per year	Number of components	Person hours per year	Number of components	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Overhead crane	2	52	2	1	10	Wood	3/4"	208	2	208	2	208
Electrically powered transfer equipment	2	104	1	2	3	Wood	3/4"	208	1	208	1	208
Air lock system (2 per building)	2	52	2	1	20	Wood	3/4"	208	2	208	2	208
HVAC	2	520	1	1	10	Wood	3/4"	1040	1	1040	1	1040
HEPA	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
Generator	2	52	1	1	10	Wood	3/4"	104	1	104	1	104
UPS	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
WORKSHOP												
HVAC	2	520	1	3	80	Wood	3/4"	1040	1	1040	1	1040
ADMINISTRATION BUILDING												
HVAC	2	520	1	3	160	Wood	3/4"	1040	1	1040	1	1040
STORAGE VAULT AREA -- 40, 20 and 10 Vaults												
HVAC	2	520	40	3	10	Wood	3/4"	41600	20	20800	10	10400
HEPA	2	26	40	3	10	Wood	3/4"	2080	20	1040	10	520
Air monitoring equipment	2	52	40	3	10	Wood	3/4"	4160	20	2080	10	1040

1) Up to four pallets (16 uranium metal boxes)
2) Single uranium metal box
3) Cumulative inventory of a storage vault
4) 2 hours per week (104) for complex systems with multiple active components; 1 hour per week (52) on active components (compressors, air lock systems, cranes) -- includes instrumentation; 0.5 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

TABLE B.9 Mined-Cavity Storage Facility (Uranium Metal Boxes): Operational Activities — Phase I

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 9)	Source	Distance (ft)	Material (Note 10)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Unload arriving pallet	2	0.25	7525	1	3	Wood	3/4"	3763	3763	1882	1882	941
Inspect arriving pallet	1	0.25	7525	1	3	Wood	3/4"	1881	3763	941	1882	471
Transfer undamaged pallet to warehouse storage	2	0.25	7494	1	6	Wood	3/4"	3747	3747	1874	1874	937
Transfer damaged pallet to repackaging area (8)	2	2	31	1	6	Wood	3/4"	124	16	64	8	32
Unload failed box pallet	2	0.25	202	1	3	Wood	3/4"	101	101	51	51	26
Transfer failed box to repackaging area	2	0.25	202	2	6	Wood	3/4"	101	101	51	51	26
Repackage damaged/failed box contents	1	1	202	2	3	Wood	3/4"	202	101	101	51	51
Transfer repackaged box pallet to warehouse storage	2	0.25	202	1	6	Wood	3/4"	101	101	51	51	26
Failed box size reduction	2	0.1	202	3	15	Wood	3/4"	40	101	20	51	10
Transfer new boxes into repackaging area	2	0.25	202	2,3	15	Wood	3/4"	101	101	51	51	26
Transfer pallet from warehouse storage to loading bay	2	0.25	7696	1	6	Wood	3/4"	3848	3848	1924	1924	962
Load pallet on truck	2	0.25	7696	1	3	Wood	3/4"	3848	3848	1924	1924	962
Transfer pallet to mine shaft	1	0.25	1100	4	6	Wood	3/4"	275	550	138	275	69
Warehouse storage surveillance	1	1	520	6	3	Wood	3/4"	520	520	520	520	520
Building management	2	8	260	6	10	Wood	3/4"	4160	260	4160	260	4160
Security	1	2	1095	6	15	Wood	3/4"	2190	830	1660	629	1258
WORKSHOP												
Building operations	8	8	260	6	80	Wood	3/4"	16640	260	16640	260	16640
Security	1	2	1095	6	80	Wood	3/4"	2190	830	1660	629	1258
ADMINISTRATION BUILDING												
Building operations	12	8	260	6	640	Wood	3/4"	24960	260	18916	260	14336
Security	2	8	1095	6	640	Wood	3/4"	17520	830	13278	629	10063
MINED-CAVITY STORAGE AREA - 92, 46, 23 Drifts												
Unload transferred pallet at mine site	2	0.25	7696	1	3	Wood	3/4"	3848	3848	1924	1924	962
Transfer pallet to mined cavity	1	0.25	7696	4	6	Wood	3/4"	1924	3848	962	1924	481
Transfer pallet to storage position	1	0.5	7696	7	6	Wood	3/4"	3848	3848	1924	1924	962
Unload pallet into position	2	0.25	7696	7	3	Wood	3/4"	3848	3848	1924	1924	962
Return to surface	1	0.5	7696	7	6	Wood	3/4"	3848	3848	1924	1924	962

TABLE B.9 (Cont.)

Activity	100% Number of workers per station	100% Time per operation (hr)	100% Operation per year (Note 9)	100% Source	100% Distance (ft)	100% Material (Note 10)	100% Thickness	100% Person hours per year	50% Operation per year (Note 7)	50% Person hours per year	25% Operation per year (Note 7)	25% Person hours per year
Load failed box pallet from storage position (8)	2	2	10	7	3	Wood	3/4"	40	5	20	3	12
Transfer failed pallet to mine shaft	1	0.5	10	7	6	Wood	3/4"	5	5	3	3	2
Transfer failed pallet to surface	1	0.25	10	1	6	Wood	3/4"	3	5	1	3	1
Load failed pallet onto truck	2	0.25	10	1	3	Wood	3/4"	5	5	3	3	2
Transfer failed pallet to warehouse	1	0.25	10	1	6	Wood	3/4"	3	5	1	3	1
Monitor HEPA filtration/air monitor	1	1	260	6	460	Wood	3/4"	260	260	260	260	260
Storage area/container integrity surveillance	8	8	260	7	3	Wood	3/4"	16640	260	8320	260	4160
Building management	1	8	260	7	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	7	15	Wood	3/4"	2190	830	1660	629	1258

1) Single pallet with four uranium metal boxes
2) Single box
3) Single empty uranium metal box
4) Seven pallets (28 uranium metal boxes)
5) Four pallets (16 uranium metal boxes)
6) Up to 840 pallets in receiving warehouse
7) Cumulative inventory of a single mine drift
8) Includes handling of damaged/failed box
9) 30,100 boxes received per year (602,000 boxes received over 20 years); 7,525 pallets (30,100 uranium metal boxes/4 boxes per pallet); 31 damaged uranium metal boxes received per year (0.1% failure rate/year); 181 boxes damaged in on-site operations per year; 162 newly damaged boxes discovered and repackaged; 19 newly damaged boxes stored damaged; 10 failed uranium metal boxes in storage discovered each year; 7,697 received and repackaged box pallets per year; 1,100 on-site transfers per year (7,697 pallets/7 pallets per transfer); 365 days per year × 3 shifts per day = 1,095 per year
10) Materials do not include walls between operating areas

TABLE B.10 Mined-Cavity Storage Facility (Uranium Metal Boxes): Maintenance Activities — Phase I

	100%								50%		25%	
	Number of workers per station	Time per operation (hr)	Number of components	Source	Distance (ft)	Material (Note 5)	Thickness	Person hours per year	Number of components	Person hours per year	Number of components	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Overhead crane	2	52	2	1	10	Wood	3/4"	208	2	208	2	208
Electrically powered transfer equipment	2	104	1	2	3	Wood	3/4"	208	1	208	1	208
Air lock system (2 per building)	2	52	2	1	20	Wood	3/4"	208	2	208	2	208
HVAC	2	520	1	1	10	Wood	3/4"	1040	1	1040	1	1040
HEPA	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
Generator	2	52	1	1	10	Wood	3/4"	104	1	104	1	104
UPS	2	26	1	1	10	Wood	3/4"	52	1	52	1	52
WORKSHOP												
HVAC	2	520	1	1	250	Wood	3/4"	1040	1	1040	1	1040
ADMINISTRATION BUILDING												
HVAC	2	520	1	1	640	Wood	3/4"	1040	1	1040	1	1040
MINED CAVITY STORAGE -- 92, 46 and 23 Drifts												
HVAC	2	520	4	1	460	Wood	3/4"	4160	4	4160	4	4160
HEPA	2	26	4	1	460	Wood	3/4"	208	4	208	4	208
Air monitoring equipment	2	52	4	1	460	Wood	3/4"	416	4	416	4	416
Mine elevator equipment	2	104	2	1	20	Wood	3/4"	416	2	416	2	416
Emergency power system	2	52	1	3	20	Wood	3/4"	104	1	104	1	104

1) Up to 840 pallets in receiving warehouse
2) Single box
3) Cumulative inventory of a single mine drift
4) 2 hours per week (104) for complex systems with multiple active components; 1 hour per week (52) on active components (compressors, air lock systems, cranes) -- includes instrumentation; 0.5 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

TABLE B.11 Mined-Cavity Storage Facility (Uranium Metal Boxes): Operational Activities — Phase II

	100%								50%		25%	
Activity	Number of workers per station	Time per operation (hr)	Operation per year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Unload failed box pallet	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed box to repackaging area	2	0.25	9	2	6	Wood	3/4"	5	4.515	2	2.2575	1
Repackage damaged/failed box contents	1	1	9	2	3	Wood	3/4"	9	4.515	5	2.2575	2
Transfer repackaged box to warehouse storage	2	0.25	9	2	6	Wood	3/4"	5	4.515	2	2.2575	1
Failed box size reduction	2	0.1	9	3	15	Wood	3/4"	2	4.515	1	2.2575	0
Transfer new boxes into repackaging area	2	0.25	9	2,3	15	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet from warehouse storage to loading bay	2	0.25	9	1	6	Wood	3/4"	5	4.515	2	2.2575	1
Load pallet on truck	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet to mine shaft	1	0.25	9	4	6	Wood	3/4"	2	1.12875	0	0.564375	0
Building management	1	8	260	4	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	4	15	Wood	3/4"	2190	830	1660	629	1258
WORKSHOP												
Building operations	4	8	260	4	250	Wood	3/4"	8320	260	8320	260	8320
Security	1	2	1095	4	250	Wood	3/4"	2190	830	1660	629	1258
ADMINISTRATION BUILDING												
Building operations	9	8	260	4	640	Wood	3/4"	18720	260	14187	260	10752
Security	2	8	1095	4	640	Wood	3/4"	17520	830	13278	629	10063
MINED CAVITY STORAGE AREA -- 40, 20 and 10 Vaults												
Unload transferred pallet at mine shaft	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer pallet to mined cavity	1	0.25	9	4	6	Wood	3/4"	2	4.515	1	2.2575	1
Transfer pallet to storage position	1	0.5	9	5	6	Wood	3/4"	5	4.515	2	2.2575	1
Unload pallet into position	2	0.25	9	5	3	Wood	3/4"	5	4.515	2	2.2575	1
Return to surface	1	0.5	9	5	6	Wood	3/4"	5	4.515	2	2.2575	1
Load failed box pallet from storage position (7)	2	2	9	5	3	Wood	3/4"	36	4.515	18	2.2575	9
Transfer failed pallet to mine shaft	1	0.5	9	5	6	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed pallet to surface	1	0.25	9	1	6	Wood	3/4"	2	4.515	1	2.2575	1
Load failed pallet onto truck	2	0.25	9	1	3	Wood	3/4"	5	4.515	2	2.2575	1
Transfer failed pallet to warehouse	1	0.25	9	1	6	Wood	3/4"	2	4.515	1	2.2575	1

TABLE B.11 (Cont.)

Activity	100%								50%		25%	
	Number of workers per station	Time per operation (hr)	Operation per year (Note 7)	Source	Distance (ft)	Material (Note 8)	Thickness	Person hours per year	Operation per year (Note 7)	Person hours per year	Operation per year (Note 7)	Person hours per year
Monitor HEPA filtration/air monitor	2	2	260	4	460	Wood	3/4"	1040	260	1040	260	1040
Storage area/container integrity surveillance	6	8	260	5	3	Wood	3/4"	12480	260	6240	260	3120
Building management	1	8	260	5	10	Wood	3/4"	2080	260	2080	260	2080
Security	1	2	1095	5	15	Wood	3/4"	2190	830	1660	629	1258

1) Single pallet with four uranium metal boxes
2) Single uranium metal box
3) Single empty box
4) Four pallets (16 boxes)
5) Cumulative inventory of a single mine drift
6) Includes handling of damaged/failed box
7) 602,000 boxes in storage; 9 failed uranium metal boxes per year; 4 on-site transfers per year (4 pallets/1 pallet per transfer); 365 days per year × 3 shifts per day = 1,095 per year
8) Materials do not include walls between operating areas

TABLE B.12 Mined-Cavity Storage Facility (Uranium Metal Boxes): Maintenance Activities — Phase II

Equipment	100%								50%		25%	
	Number of workers per station	Time per operation (hr)	Number of components	Source	Distance (ft)	Material (Note 5)	Thickness	Person hours per year	Number of components	Person hours per year	Number of components	Person hours per year
RECEIVING WAREHOUSE/REPACKAGING BUILDING												
Overhead crane	2	52	2	1	10	Wood	0.053"	208	2	208	2	208
Electrically powered transfer equipment	2	104	1	2	3	Wood	0.053"	208	1	208	1	208
Air lock system (2 per building)	2	52	2	1	20	Wood	0.053"	208	2	208	2	208
HVAC	2	520	1	1	10	Wood	0.053"	1040	1	1040	1	1040
HEPA	2	26	1	1	10	Wood	0.053"	52	1	52	1	52
Generator	2	52	1	1	10	Wood	0.053"	104	1	104	1	104
UPS	2	26	1	1	10	Wood	0.053"	52	1	52	1	52
WORKSHOP												
HVAC	2	520	1	1	250	Wood	0.053"	1040	1	1040	1	1040
ADMINISTRATION BUILDING												
HVAC	2	520	1	1	640	Wood	0.053"	1040	1	1040	1	1040
MINED CAVITY STORAGE AREA -- 40, 20 and 10 Vaults												
HVAC	2	520	4	4	460	Wood	0.053"	4160	4	4160	4	4160
HEPA	2	26	4	4	460	Wood	0.053"	208	4	208	4	208
Air monitoring equipment	2	52	4	4	460	Wood	0.053"	416	4	416	4	416
Mine elevator equipment	2	104	2	2	20	Wood	0.053	416	2	416	2	416
Emergency power system	2	52	1	1	20	Wood	0.053	104	1	104	1	104

1) Up to four pallets (16 boxes)
2) Single uranium metal box
3) Cumulative inventory of a single mine drift
4) 2 hours per week (104 per year) for complex systems with multiple active components; 1 hour per week (52) on active components (compressors, air lock systems, cranes) -- includes instrumentation; 0.5 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

APPENDIX C:

EXPECTED BEHAVIOR OF DEPLETED URANIUM METAL DURING LONG-TERM STORAGE

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EXPECTED BEHAVIOR OF DEPLETED URANIUM METAL DURING LONG-TERM STORAGE

This appendix provides information concerning the potential behavior of depleted uranium metal during long-term storage. It should be noted that the U.S. Department of Energy (DOE) and predecessor agencies have been storing uranium metal in enriched form safely since the 1940s.

Uranium metal is a dense, bright silvery, ductile, and malleable metal. Uranium is highly electropositive, resembles magnesium, and tarnishes rapidly on exposure to air. Even a polished surface becomes coated with a hard, dark-colored oxide layer in a short time upon exposure to air. At elevated temperatures, uranium metal reacts with most common metals and refractory materials. Finely divided uranium reacts, even at room temperature, with all components of the atmosphere except the noble gases. The silvery luster of freshly cleaned uranium metal is rapidly converted first to a golden yellow, and then to a black oxide-nitride film within three to four days. Some physical properties of uranium metal are presented in Table C.1 (Kirk-Othmer 1997).

The long-term storage of uranium metal near room temperature can result in fire hazards and/or continual uranium corrosion. Uranium itself, especially in large pieces, is not pyrophoric at room temperatures, but the powdered hydride that forms from the reaction of water vapor and uranium metal is pyrophoric and combustible. Hydrogen, which is also formed from that reaction, is also combustible.

The oxidation of pure unalloyed uranium is a function of the amount of surface area exposed to the oxidizing atmosphere and the amount of oxidant reaching the metal. A thin adherent layer of oxide forms at the interface and controls the rate at which the oxidant reacts

TABLE C.1 Some Physical Properties of Uranium Metal

Property	Value
Melting Point, ºC	1,132.4 ± 0.8
Enthalpy of Vaporization at 25 ºC, kJ/mol	446.7
Enthalpy of Fusion, kJ/mol	19.7
Enthalpy of Sublimation, kJ/mol	487.9
Thermal Conductivity at 100 ºC, W/(cm - K)	0.263
Poisson’s Ratio	0.20
Bulk Modulus, kPa	97.9×10^6

with the surface. The outer surface of the oxide reacts with the oxidant, diffusing throughout to form hyperstoichiometric uranium dioxide and, subsequently, the higher oxides of uranium. Due to the similarity in matrix spacing, hyperstoichiometric uranium dioxide formed at the metal-atmosphere interface is adhering and limits oxygen availability. At temperatures less than 200 ^{o}C, the hyperstoichiometric dioxide, UO_{2+x}, is the principal product. At slightly higher temperatures, mixtures of various suboxides (e.g., U_3O_7, U_3O_8, etc.) are found. The physicochemical characteristics of the higher oxides formed are dependent upon the temperature and oxidant availability. The factors that could influence the oxidation of uranium are shown in Table C.2 (Mishima et al. 1985).

The presence of water vapor accelerates oxidation in air at temperatures less than 300 ^{o}C and in carbon dioxide at temperatures less than 350 ^{o}C to 500 ^{o}C. Uranium reacts with hydrogen, nitrogen, and carbon at elevated temperatures and the presence of surface inclusions accelerates oxidation.

An important fact that must be accounted for when considering storage options for uranium metal is the accelerated corrosion of uranium metal by water vapor in the absence of oxygen. This condition is commonly found in situations where uranium metal has been stored in sealed containers in an inert gas atmosphere (Totemeier 1995). Water vapor will react with uranium metal to produce uranium oxide (UO_2) and hydrogen (H_2), according to the reaction:

$$\text{U-metal} + 2\,H_2O \rightarrow 2\,UO_2 + 2\,H_2$$

If the hydrogen cannot escape, it will react slowly with uranium to form uranium hydride (UH_3), according to the reaction:

$$2\,\text{U-metal} + 3\,H_2 \rightarrow 2\,UH_3$$

The UH_3 is a loose, fine, black particulate. The rates of this reaction appear to be slow and are accompanied by an incubation period, especially if an oxide is also forming or has formed (Solbrig et al. 1994).

TABLE C.2 Factors Potentially Influencing Oxidation of Uranium Metal

Step	Possible Factors Influencing Rate
Uranium metal surface of unit area oxidizing in air	1) Metal purity 2) Metallurgical condition (grain size, strains, etc.) 3) Temperature 4) Time 5) Gas composition 6) Type of oxide film formed (protective or not)

The UH_3 is pyrophoric at room temperature when exposed to air. If oxygen is present, it can react quickly, and sometimes violently, with the UH_3 to produce more water and UO_2, according to the reaction:

$$2\ UH_3 + 3.5\ O_2 \rightarrow 2\ UO_2 + 3\ H_2O$$

The explosive limit of the UH_3 powder in air ranges from 45 to 300 mg/L. The UO_2 is in the form of powder because the UH_3 was a powder. Thus, the reaction of uranium metal with water vapor ultimately can turn the metal into an oxide powder.

Oxygen has a strong inhibiting effect on the oxidation of uranium by water vapor. The addition of oxygen to the uranium-water vapor system considerably slows the rate of reaction, although these rates are still greater than those observed for the reaction with dry air. The effect of water vapor pressure (relative humidity) in the uranium-oxygen-water vapor system has been investigated, with the conclusion that the reaction rate increases as water vapor is added to the uranium-oxygen system, up to a relative humidity (RH) of 1-2%. In the humidity range from 1-2% to 90%, the reaction rate is constant with respect to humidity; above 90%, the reaction rate increases again (Totemeier 1995). The products of the uranium-oxygen-water vapor reaction are nominally identical to the products of the uranium-water vapor reaction (i.e., mostly UO_2 or UO_{2+x} with some uranium hydride, hydroxide, or hydrated oxide).

Either the H_2 or the UH_3 generated during the reaction of uranium metal with water vapor can produce a dangerous situation, as demonstrated by two different incidents that occurred in the recent past. The Fernald Environmental Management Project reported that two drum lids on containers used for permanent storage of depleted uranium blew off on June 19, 1992. (Weapons Complex Monitor 1992). The lids probably blew off because the H_2 produced in the corrosion cycle reacted with the air in the containers. The drums were designed to be vented to allow the H_2 to escape, but the ventilation system apparently malfunctioned.

An incident that illustrates the fire hazard associated with UH_3 occurred at the Oak Ridge National Laboratory in 1992 (Solbrig et al. 1994). A bottle with uranium foil was sealed with air containing atmospheric moisture. The water vapor and oxygen were totally consumed, leaving only uranium metal, UO_2, UH_3, and a reduced cover gas containing only nitrogen. When the bottle was opened, air rushed in due to the reduced pressure. The UH_3 reacted immediately with the oxygen in the incoming air and released enough heat to cause the uranium to reach its ignition point and burn.

The best solution, theoretically, to the problem of accelerated corrosion of uranium metal would be removal of all cover gas during long-term storage. This would stop undesirable reactions, but vacuum storage may be impractical because of the difficulty of maintaining a vacuum over a long time period. The design of the vacuum pumping would also have to take into account any H_2 generated due to initial moisture.

Another option would be to repackage the uranium metal billets into sealed canisters in an ultra-dry nitrogen atmosphere (Solbrig et al. 1994). A hydrogen-oxygen-water getter, consisting of a packer of unsaturated hydrocarbon containing a palladium catalyst and a packet of lithium hydride, could be used to eliminate H_2, water, and oxygen by the following reactions:

$$H_2O + LiH \rightarrow Li\,OH + H_2$$

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$ <over the palladium catalyst>

$$2\,H_2 + (-\,C \equiv C\,-) \rightarrow (-\,CH_2 - CH_2\,-)$$ <over the palladium catalyst>

This approach is currently being applied to mitigate corrosion of U-235 fuel plates from the Zero Power Physics Reactor at Argonne National Laboratory-West (Solbrig et al. 1994). However, this approach was not considered for long-term storage of depleted uranium metal billets, because it would require a change in the design proposed in the Engineering Analysis Report (LLNL 1997) for uranium metal packaging. Also, a certain degree of oxidation would have occurred during interim storage after conversion, prior to shipment to the storage facility. A more cost-effective approach was believed to be dehumidification of the areas storing the depleted uranium metal.

A more practical solution to the problem of accelerated corrosion of uranium metal by water vapor would be to store the uranium under conditions of free-flowing dry air, as suggested by Waber (1958), to provide oxygen to inhibit the water-uranium reaction and to prevent the accumulation of any hydrogen gas product.

The approach taken in this report is to provide relatively-dry ventilation air from the facility ventilation system. The boxes in which the uranium metal are packaged would be vented to minimize moisture retention or condensation. Mechanical ventilation would be used to induce positive air circulation within the uranium metal storage areas. Dehumidification would be provided to assure removal of moisture during long-term storage. One dehumidification option that could be used is a dual bed, dry desiccant type. Self-contained, free-standing machines would be installed inside each storage facility (whether building, vault, or mined-cavity) and located to effect proper distribution of dry air without ductwork. An electronic-type humidity controller would control each dehumidifier. The power supply to the dehumidifier would be interlocked with the fire alarm system or sprinkler system to cut off power to the machine in case of fire. Exhaust ventilation systems would be provided with HEPA filtration to minimize the release of uranium and other hazardous materials through the exhaust path.

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APPENDIX D:

MORE EFFICIENT STORAGE IN BUILDINGS

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MORE EFFICIENT STORAGE IN BUILDINGS

D.1 INTRODUCTION

In the main body of this report, one option is that the boxes of depleted uranium metal would be stored in aboveground buildings that would be 271 m (890 ft) long, 50 m (164 ft) wide, and 5 m (16 ft) long. It was assumed that the wood boxes would be stored on pallets, four boxes per pallet, with the pallets stacked four high (16 boxes per pallet). With these assumptions, eight buildings would be needed to store 602,000 boxes of depleted uranium metal. A major cost of the storage facility is the cost of constructing the storage buildings, where the cost of construction depends strongly on the size of the storage buildings. In the base case, space in the storage buildings is not efficiently utilized, in large part because of the relatively low bulk density of uranium metal in the boxes.

In this appendix, the engineering analysis for storage of uranium metal in aboveground buildings is revisited. To use space in storage buildings more efficiently, the bulk density of uranium in storage should be increased. It is assumed that the height of a box is reduced from 12 in. to 8 in., that the number of billets in a box is increased from 19 to 21, and that pallets are stacked six high instead of four. With these changes, the storage area occupied by a stack of boxes is unchanged; however, the number of billets of depleted uranium in a stack is increased from 304 to 504. Figure D.1.1 shows the revised storage configuration for uranium metal. This change allows the dimensions of each storage building to be reduced to a length of 168 m, with an unchanged width of 50 m.

In the main body of this report, three types of storage enclosures are considered — aboveground buildings, below-grade vaults, and underground mined cavities. In this appendix, only storage in buildings is addressed. As before, three cases are considered — storage of 100%, 50%, and 25% of the depleted uranium metal that was produced from the conversion of depleted UF_6 generated by DOE prior to July 1993.

This appendix has the same structure as the main body of the report, except that sections, tables, and figures relating to storage in vaults or mined cavities have been deleted. The headings of sections that are unchanged are retained, and the numbering of remaining tables are the same as in the main body of this report. In sections that contain changes, the revised material is indicated by bold type.

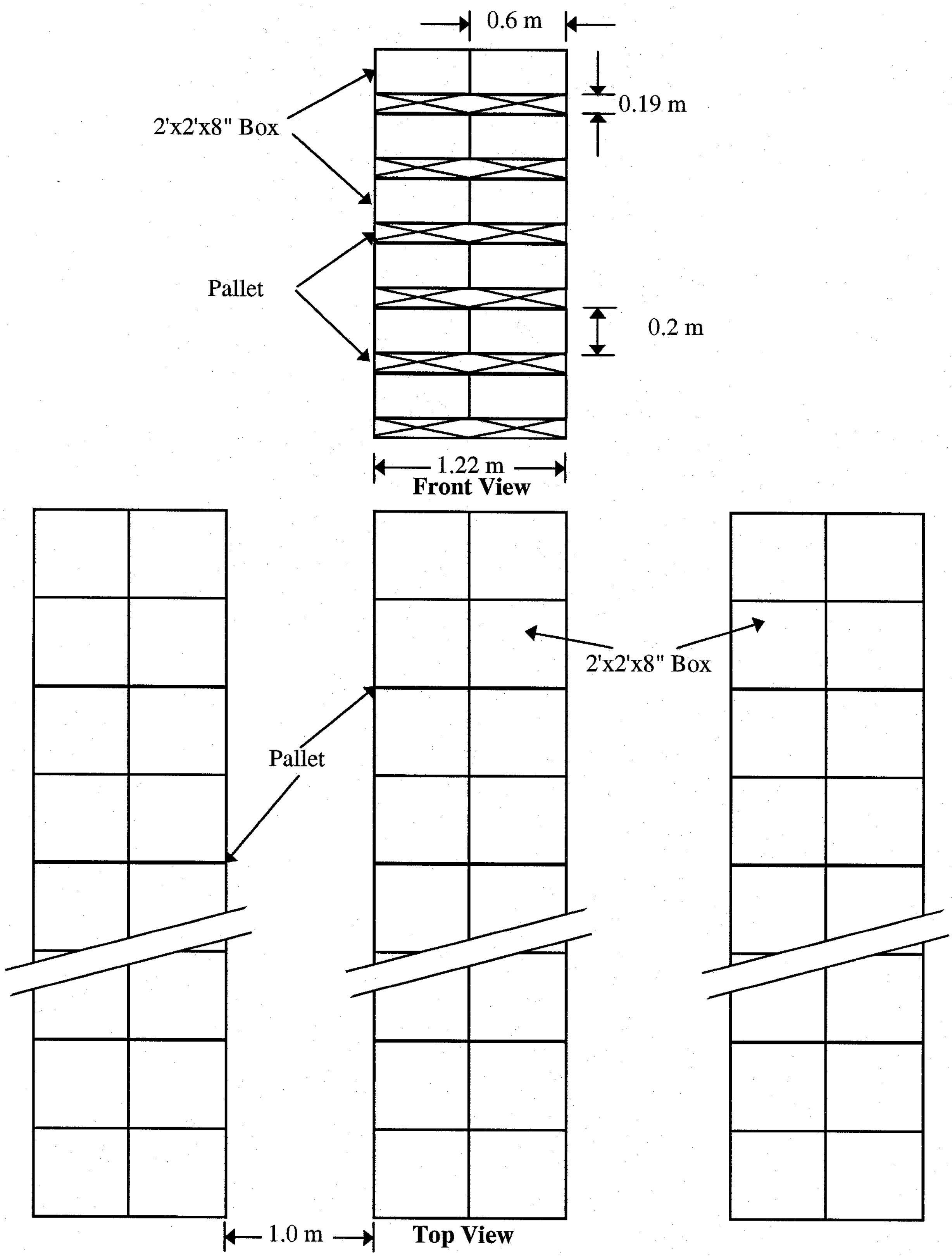

Figure D.1.1 Revised Storage Configuration for Uranium Metal

D.2 DESCRIPTION OF THE FACILITY

This whole section is unchanged.

D.2.1 General Design Criteria

This whole section is unchanged.

D.2.2 Support Buildings

This whole section is unchanged.

D.2.2.1 Receiving Warehouse and Repackaging Building

The storage facility would have a building for temporary storage and inspection of boxes containing uranium metal received at the storage facility. The building would also house a facility for repackaging uranium billets in damaged boxes. This building will be referred to as the receiving warehouse and repackaging building. The entire building would be high-efficiency-particulate-air (HEPA) filtered and served by two overhead cranes. The receiving warehouse is designed to store pallets that would be delivered in **6.4** weeks, when approximately **132** pallets would be delivered each week for the 100% Case, **66** for the 50% Case, and **33** for the 25% Case. Boxes would be stored on pallets, four boxes per pallet, one high. Each pallet is assumed to be 4 ft wide by 4 ft long. Each pallet would have a 1-m clearance to allow detailed inspection of all sides. Table **D.2.2** shows the dimensions, storage configuration, and capacity of the receiving warehouse when the storage facility receives 100%, 50%, and 25% of the depleted uranium needed to be stored. Figures 2.1a through 2.1c contain plan views for the receiving warehouse for these three cases. Undamaged boxes would be moved to a loading bay for removal to a storage enclosure. Damaged boxes would be moved to the repackaging facility for transfer of their contents to new boxes.

The repackaging facility would be an enclosure within the receiving warehouse building that is kept at a slightly lower pressure than the receiving warehouse. Therefore, ingress and egress would be through air locks. The repackaging facility would contain a billet packaging station for transferring billets from damaged boxes to new boxes. A storage area with empty new boxes and 55-gal drums would hold damaged boxes that are assumed to be LLW, pending shipment to an off-site disposal facility. Boxes would be moved in the receiving warehouse by bridge crane and to or from trucks or railcars by davit crane. A forklift would be used to transfer damaged boxes from the receiving warehouse to the repackaging facility.

TABLE D.2.2 Revised Dimensions, Storage Configuration, and Capacity of the Receiving Warehouse

Percent received	Length (m)	Width (m)	Number of rows	Containers per row	Containers, bldg. capacity	Storage capacity, (weeks)
100%	83	75	28	120	3,360	**6.4**
50%	83	44	14	120	1,680	**6.4**
25%	83	28	7	120	840	**6.4**

The receiving warehouse and repackaging building would be a standard warehouse-type building with sheet steel used for exterior walls, spread footings, and a 30-cm (1 ft) concrete floor. The exterior walls would have steel pillars, as needed, to provide additional support for crane rails. There would be no interior pillars. Steel trestles would support a standard flat roof. Heating, ventilation, and air conditioning (HVAC) would control temperature and humidity to comfortable working levels. Once-through air flow and single filtration of exhaust air through HEPA filters would also be provided.

D.2.2.2 Workshop

This whole section is unchanged.

D.2.2.3 Administration Building

This whole section is unchanged.

D.2.3 Storage Buildings

The length of a storage building was chosen such that a storage building would contain the same number of depleted uranium billets with the revised box design and stacking as with the original box design and stacking, while maintaining the same building width. With the original box design, 1,431,232 billets (75,328 boxes with 19 billets per box) would be stored in a storage building if there were eight buildings for the 100% Case. They would be stored in 22 rows, 214 stacks in a row, with 16 boxes per stack. With the new box design, with 21 billets per box, this same number of billets would be stored in 68,154 boxes. With 22 rows of pallets stored in a building as before, and with 24 boxes per stack, a row would have to contain 129 stacks. A building with a length of 168 m could accommodate

129 stacks when the clearance between the end of a row and the end of the storage building is 5 m.

Stacking pallets and boxes four high conforms with the Occupational Safety and Health Administration (OSHA) requirement that containers stored in tiers shall be stacked, blocked, interlocked, and limited in height so that they are stable and secure against sliding or collapse (29 CFR 1910.176(b)). The height of a stack of **6** pallets and **24** boxes, with a pallet having a height of 0.19 m is **2.36** m. Assuming that a pallet weighs 25 kg and a box weighs **33.5** lb, the corresponding loading is **11,879** kg/m^2. These heights and loadings are **compared with those for** the other chemical forms in Table **D.2.3.**

Boxes of depleted uranium would be brought to a storage building, one pallet at a time, and subsequently be moved to its storage location one pallet (four boxes) at a time. When a storage building is filled with its complement of 75,328 boxes, it would be difficult for a handling machine to maneuver because the building would be tightly packed. All boxes must be readily removable in the event that a box might fail and it is necessary to repackage its contents. As discussed in the Engineering Analysis Report, a forklift would not have room to maneuver, and an overhead crane could cause damage to the stored boxes should the roof collapse in the event of natural phenomenon disaster. Therefore, a straddle carrier was chosen to be the best machine for handling pallets of boxes in a storage building. A straddle carrier is a mini-crane on wheels, capable of lifting a loaded pallet and moving it around.

A storage building would be a standard warehouse-type (“Butler”) building. It would have spread footings and a 30-cm- (1-ft)-thick floor. Its exterior walls would be 0.3-cm-thick sheet steel. There would be no interior pillars; rather, steel trestles would support a truss-supported flat roof. The HVAC would avoid temperature and humidity extremes that could cause deterioration of wood boxes and enhance corrosion of the depleted uranium billets. The ventilation system would utilize once-through flow of air to prevent recirculation of contaminants, accommodate single filtration of exhaust through HEPA filters, and control pressure to assure air flow from areas of low hazard to areas of high hazard. Each building would have a bay for shipping or receiving boxes at each end. Figure D.2.2a shows a plan view of a storage building with storage configuration, and Figure D.2.2b shows an elevation view of a storage building with storage configuration.

TABLE D.2.3 Comparison of Containers in Storage Configuration

Chemical form	Description	Height (m)	Loading (kg/m^2)
Uranium metal	2' × 2' × **8**" box , 4-box pallet, **6** layers	**2.36**	**11,879**
UF_6	Type 48 cylinder, on supports	2.52	4,425
UO_2	30-gal drum, 4 drum pallet, 2 layers	1.86	8,565
U_3O_8	55-gal drum, 4 drum pallet, 2 layers	2.15	4,121

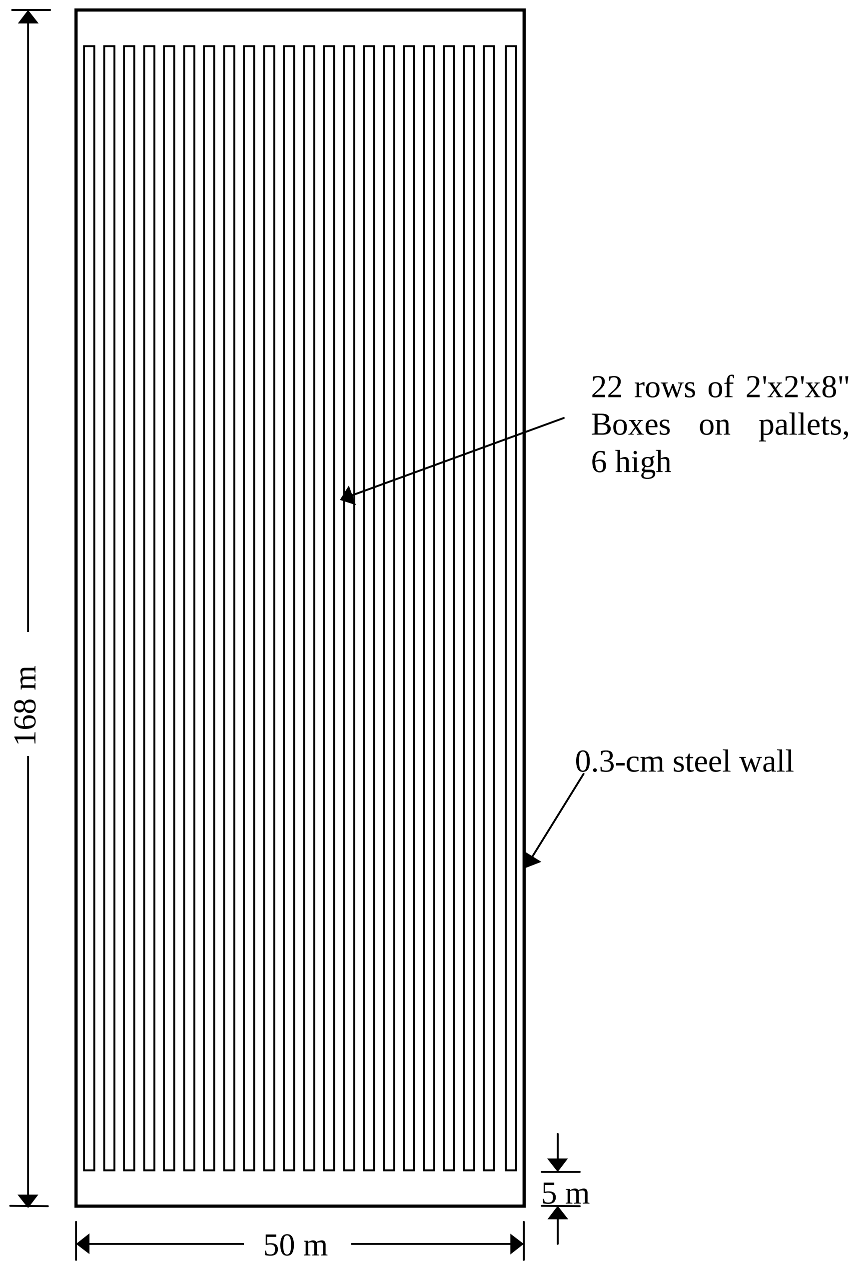

FIGURE D.2.2a Plan View of a Storage Building with Storage Configuration

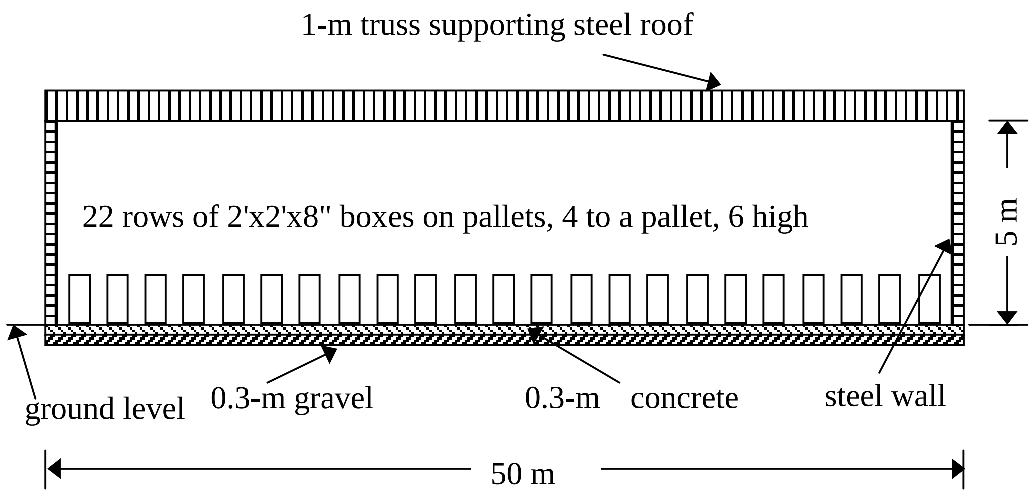

FIGURE D.2.2b Elevation View of a Storage Building with Storage Configuration

D.3 STORAGE SITE MAP AND USAGE REQUIREMENTS

Storage site maps were developed to be consistent with those shown for the other three chemical forms of depleted uranium presented in Section 6.12.3 of the Engineering Analysis Report. Site maps were developed from consideration of the operations that would take place at the storage facility; that is, unloading containers from rail cars and trucks, storing and inspecting containers in the receiving warehouse, moving inspected boxes to storage enclosures, and repackaging damaged containers. Additional considerations discussed in the Engineering Analysis Report include restricted access to the site by road to promote security and the need for open ground for rainwater infiltration. The advantages of minimizing site area were balanced against the need for storm water control. In general, impervious areas (paving and buildings) were restricted to less than 50% of the site area.

Construction sequences for a building storage facility are indicated with reference to Figures **D.3.1a** through **D.3.1c** for the 100% Case, 50% Case, and 25% Case, respectively. Construction would begin with the administration building, proceed with the receiving warehouse and repackaging building, and then continue with the workshop building. Storage buildings would be constructed near the receiving warehouse and 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 and then move away from the centroid as new storage buildings are constructed.

Because boxes containing depleted uranium would be received over a 20-year period, it would not be necessary to build all the storage buildings at once. Clearing and grubbing of the site would be performed for the area where construction would begin in that year. It would not be reasonable to clear and grub the entire site at the beginning of construction because substantial regrowth could occur over 20 years, and it would be necessary to clear and regrub the site for storage buildings constructed in later years.

Between two and eight storage buildings would be needed, depending on the percentage of depleted uranium received at this storage facility. These storage buildings would be laid out in two rows of between two and four buildings, as shown in Figures **D.3.1a** and **D.3.1b** for the 100% Case and the 50% Case. For the 25% Case, there would be one row of two storage buildings, as shown in Figure **D.3.1c**. The area between buildings in a row would be open area for rainwater infiltration.

The complex would have road access from one end of the site and rail access through the center. This configuration should prevent conflicts between road traffic and rail traffic and minimize the travel time and distance required to move boxes from the receiving warehouse and repackaging building to the storage buildings. It should be noted that the estimated construction area is based on a generic site and would require adjustments for the actual site selected. Land area for a building storage facility is given in Table **D.3.1.**

TABLE D.3.1 Site Land Area Requirements for the Building Storage Facility

Land Area, hectares (ha)	100%	50%	25%
Total site area	**1.90E+1**	**1.05E+1**	**7.32**
Total disturbed area	**8.64**	**4.66**	**2.65**
Total paved area	1.17	8.10E-1	6.10E-1

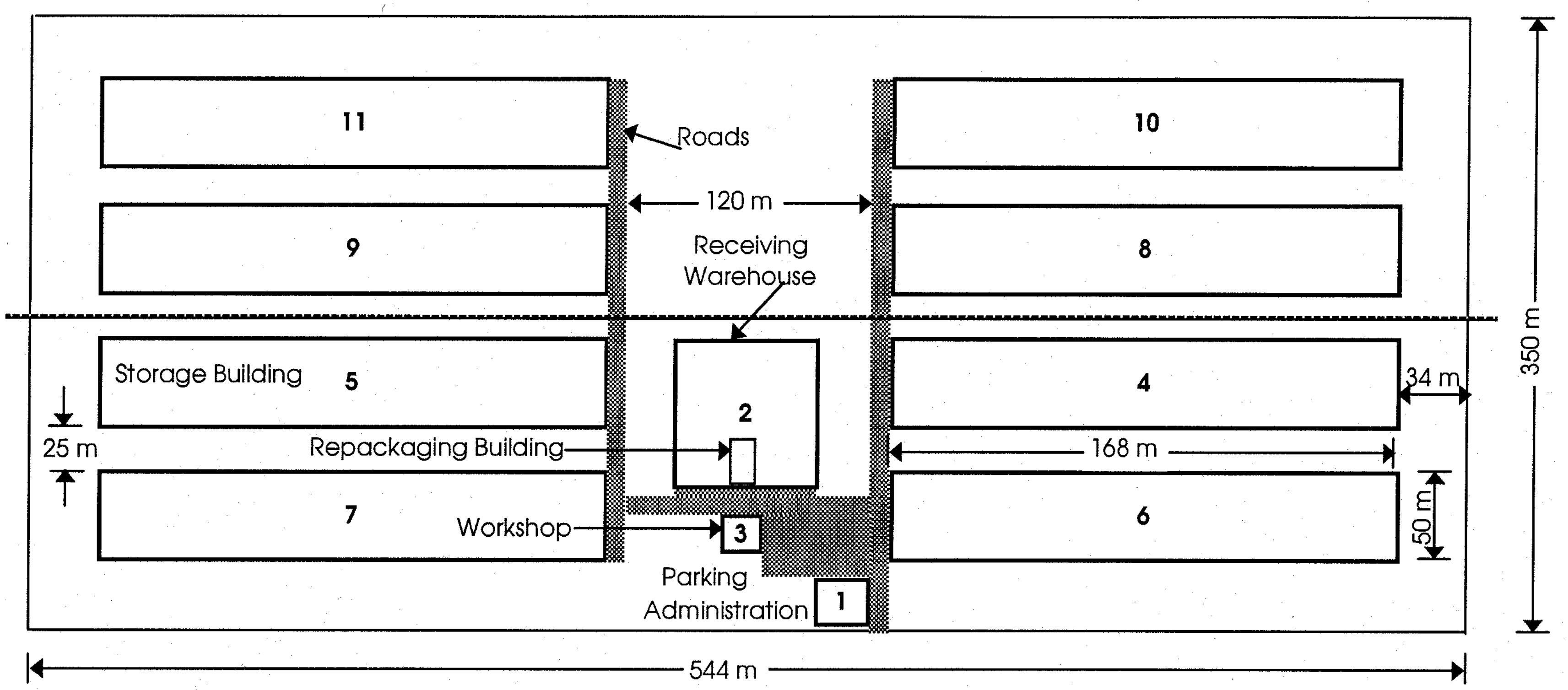

FIGURE D.3.1a Site Layout of the Building Storage Facility — Uranium Metal, Base (100%) Case

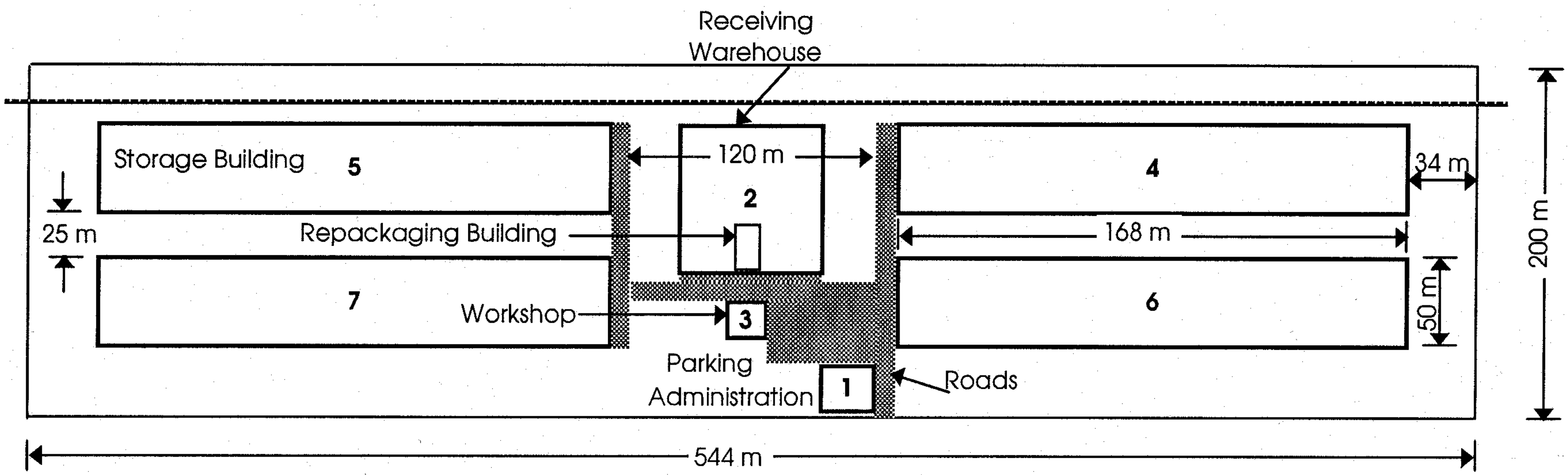

FIGURE D.3.1b Site Layout of the Building Storage Facility — Uranium Metal, 50% Case

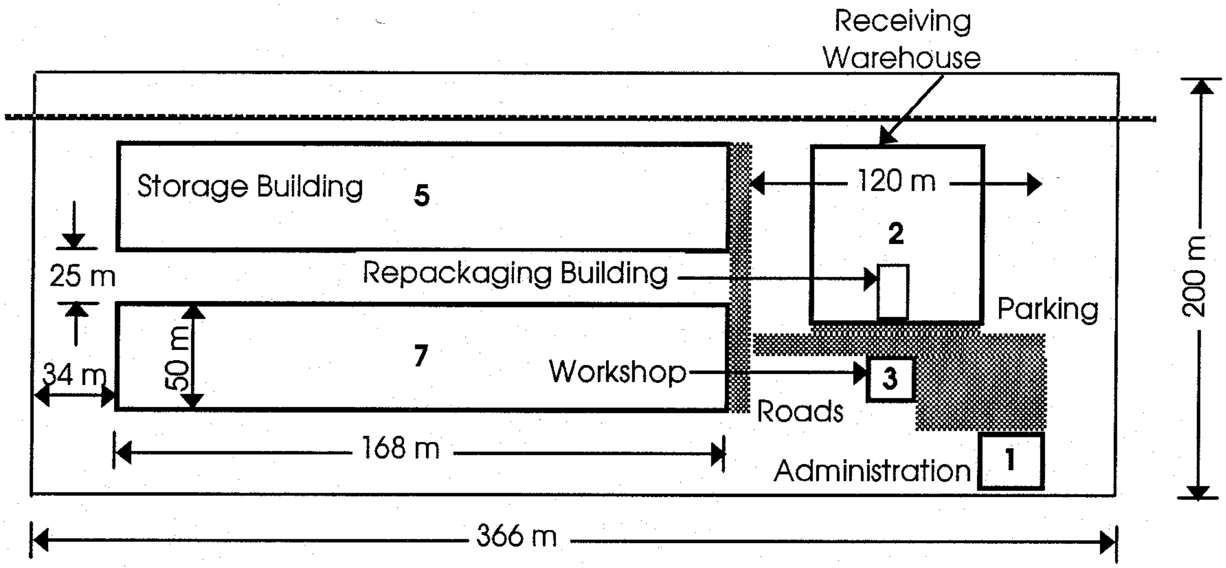

FIGURE D.3.1c Site Layout of the Building Storage Facility — Uranium Metal, 25% Case

D.4 RESOURCE NEEDS

Resources for the storage facility are required for two stages — the construction stage and the operational stages. The operational stage, in turn, is divided into two phases. Phase I, or the emplacement phase, is the first 20 years of operations, during which the storage facility would receive boxes of depleted uranium as well as store and maintain boxes that have already been received. Phase II is the second 20 years of operation. During Phase II, or the maintenance phase, all depleted uranium destined for the storage facility would have been received, and all building construction would have been completed. During Phase II, the operational activities would be to monitor and, if necessary, repackage stored boxes. Phase I would have additional operational activities, namely to receive, repackage (if necessary), and transport boxes to the storage buildings. Also, storage enclosures would be constructed during Phase I.

Construction of the receiving warehouse and repackaging building, the administration building, and the workshop building would occur first. Storage enclosures would be constructed over the 20-year period when the storage facility would be receiving boxes of depleted uranium. The enumerated support buildings would be much smaller than the storage enclosure and, therefore, a small part of the total construction activity. Hence, it is assumed that an equal amount of material would be used for construction each year during the construction stage. However, the amount of materials and resources cited in the tables in this section are for the entire 20-year construction stage, not per year. Exceptions to this rule are the tables with natural gas and electricity usage for year 20 of the emplacement phase or any year of the monitoring phase.

A small percentage of the boxes in which the depleted uranium billets are shipped to the storage facility can be expected to be damaged. Also, monitoring during storage would reveal a few damaged boxes that were not found during inspection prior to storage. Therefore, it would be necessary to transfer billets from the damaged boxes to new boxes, which would be independent of the shipment schedule. It is assumed that damaged wooden boxes would be considered as LLW because of potential surface contamination. These damaged boxes would be broken up and packed in 55-gal drums, **4.41** boxes per drum (refer to Section **D.6.2**). It is assumed that 0.1 percent of the boxes arriving at the storage facility would be damaged during shipment. The damaged boxes arriving at the receiving warehouse would be detected during inspection and repackaged. Boxes arriving at the storage facility would be subject to six operations before being stored. It is assumed that 0.1 percent of the boxes would be damaged in each operation; thus, 0.6 percent of the boxes would be damaged before storage. Ninety percent of these would be detected and repackaged prior to storage. Of the remaining damaged boxes, half would be detected and repackaged during Phase I operations and the remaining half during Phase II.

For the 100% Case (**544,667** boxes arriving at the storage facility over 20 years), **545** boxes would arrive damaged and, on the average, **3,268** would be damaged prior to storage. Of these, **2,942** boxes would be repackaged prior to storage, and **163** boxes would be detected as damaged during Phase I and be repackaged. Then, **3,651** boxes would be disposed of as LLW during Phase I, requiring **828** 55-gal drums during the 20-year duration of Phase I. For the 100% Case, **163** damaged boxes would be detected and repackaged from inspections in Phase II. Annual usage of drums and boxes was obtained by dividing totals by 20 and could be considered as annual averages.

Table **D.4.1** presents the materials that would be used in constructing the building storage facility for the three cases. Materials requirements during construction for cement, gravel, macadam, and steel were estimated from the physical dimensions of the buildings and the types of materials used for floors, walls, and roofs. No allowance was made for internal rooms in the administration building and workshop building. Trucks, cranes, and generators would use diesel fuel during construction. Gasoline requirements were estimated on the basis of 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 because of the generic location of the site.

Table **D.4.1** presents the total construction requirements for one storage building, for all storage buildings (2, 4, or 8), and for all storage buildings and the support buildings (total facility). Commonly used materials (e.g., concrete and steel) would be used for construction. Specialty materials, such as Inconel, would not be required. Any process equipment would be purchased from equipment vendors.

TABLE D.4.1 Materials and Resources Used during Construction of the Building Storage Facility

One Storage Building			Total Storage Buildings			Total Storage Facility		
Material/ Resource	Units	Value	100% Case	50% Case	25% Case	100% Case	50% Case	25% Case
Concrete	m^3	**2.52E+3**	**2.02E+4**	**1.01E+4**	**5.04E+3**	**2.24E+4**	**1.16E+4**	**6.13E+3**
Cement	te	**1.01E+3**	**8.06E+3**	**4.03E+3**	**2.02E+3**	**8.97E+3**	**4.66E+3**	**2.48E+3**
Sand	te	**1.26E+3**	**1.01E+4**	**5.04E+3**	**2.52E+3**	**1.12E+4**	**5.78E+3**	**3.06E+3**
Gravel	te	**9.20E+3**	**7.36E+4**	**3.68E+4**	**1.84E+4**	**7.58E+4**	**3.83E+4**	**1.95E+4**
Steel	te	**1.03E+3**	**9.00E+3**	**4.88E+3**	**2.83E+3**	**9.94E+3**	**5.52E+3**	**3.30E+3**
Macadam	m^3					1.75E+3	1.21E+3	9.16E+2
Water	ML	**1.50**	**1.20E+1**	**6.00**	**3.00**	**1.32E+1**	**6.35**	**3.32**
Diesel fuel	ML					**4.41E-1**	**2.37E-1**	**1.34E-1**
Gasoline	KL					**1.68**	**6.70E-1**	**3.00E-1**
Electricity	MW-yr	**5.00E-1**	**4.00**	**2.00**	**1.00**	**4.48**	**2.32**	**1.24**
Excavation	m^3	**4.20E+3**	**3.36E+4**	**1.68E+4**	**8.40E+3**	**3.51E+4**	**1.78E+4**	**9.12E+3**

Estimates of annual natural gas consumption by building type and case are given in Table **D.4.2** for year 20 of the emplacement phase or any year of the monitoring phase. These estimates are based on usage of natural gas of 2.42E-09 million standard cubic meters (MSCM) per hour per square meter of building area and natural gas usage for half the time (4,380 h/yr) for space heating.

Tables **D.4.3** and **D.4.4** contain estimates of electricity usage for the last year of the emplacement phase (Phase I) and for any year of the monitoring phase (Phase II), respectively. Total annual consumption is displayed as well as consumption for cooling, lighting, air filtration (HEPA), and tools or equipment. In these tables, it is assumed that the electrical capacities needed for a square meter of building area are 0.0065 kW(e) for cooling, 0.0355 kW(e) for lighting, and 0.0079 kW(e) for air filtration, which is consistent with the Engineering Analysis Report. With regard to tools or equipment, it is assumed that the electrical capacity needed is 0.5 kW(e) per full-time equivalent (FTE), except in storage buildings. It is assumed that cooling will be needed half the time, and HEPA filtration will run continuously, but will be not be needed in the workshop and administration building. It is also assumed that lighting will operate continuously except in the storage buildings, where it will operate 5% of the time.

Finally, it is assumed that electric-driven 7.5-ton davit cranes and bridge cranes will be used in the receiving warehouse and repackaging building, and electric-driven 7.5-ton davit cranes will be used in the storage buildings. Annual electricity consumption by these cranes will depend on how many boxes and pallets are moved in a year, which in turn will depend on the number of boxes received at the storage facility (100% Case, 50% Case, or 25% Case) and on the operational phase (emplacement or maintenance).

With these assumptions, the differences in electricity consumption between Phase I and Phase II are the use of cranes and the number of FTEs in the receiving warehouse and repackaging building, the workshop, and the administration building. In the receiving warehouse and repackaging building, the numbers of FTEs for the three cases are **20, 8**, and 5, respectively, during Phase I and 7, **4**, and 3, respectively, during Phase II. Similarly, in the administration building, the numbers of FTEs for the three cases are 18, 16, and 16, respectively, during Phase I

TABLE D.4.2 Annual Natural Gas Consumption for Building Storage Facility Operations

Building	Area (m^2)			Usage	MSCM/yr		
Type	100%	50%	25%	(h/yr)	100%	50%	25%
Storage	**6.72E+04**	**3.36E+04**	**1.68E+04**	**4,380**	**7.11E-01**	**3.56E-01**	**1.78E-01**
Receiving Warehouse	6.22E+03	3.65E+03	2.32E+03	4,380	6.59E-02	3.86E-02	2.46E-02
Workshop	6.25E+02	6.25E+02	6.25E+02	4,380	6.60E-03	6.60E-03	6.60E-03
Admin.	6.75E+02	6.75E+02	6.75E+02	4,380	7.10E-03	7.10E-03	7.10E-03

TABLE D.4.3 Annual Electricity Consumption during Phase I for Building Storage

			Consumption (MWh/yr)		
Building	Application	Usage (h/yr)	100%	50%	25%
Storage	Cooling	4,380	**1.91E+03**	**9.56E+02**	**4.78E+02**
	Lighting	438	**1.04E+03**	**5.22E+02**	**2.61E+02**
	HEPA	8,760	**4.65E+03**	**2.32E+03**	**1.16E+03**
	Davit Crane	Variable[a]	**5.20E+01**	**2.61E+01**	**1.30E+01**
	Tools	None	0.0	0.0	0.0
	Subtotal		**7.65E+03**	**3.82E+03**	**1.91E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.61E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.52E+02	1.61E+02
	Bridge Crane	Variable[b]	**4.40**	**2.24**	**1.13**
	Davit Crane	Variable[c]	**1.03E+02**	**5.14E+01**	**2.57E+01**
	Tools	8,760	**8.74E+01**	**3.50E+01**	2.19E+01
	Subtotal		**2.74E+03**	**1.57E+03**	**9.99E+02**
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1.94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	3.07E+01	2.19E+01	1.75E+01
	Subtotal		2.42E+02	2.34E+02	2.29E+02
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	7.88E+01	7.01E+01	7.01E+01
	Subtotal		3.08E+02	2.99E+02	2.99E+02
ALL	**TOTAL**		**1.06E+04**	**5.92E+03**	**3.44E+03**

[a] Hours of operation: **3486** for the 100% Case; **1,560** for the 50% Case**; 872** for the 25% Case.

[b] Hours of operation: **295** for the 100% Case; **150** for the 50% Case; **76** for the 25% Case.

[c] Hours of operation: **6,886** for the 100% Case; **3,443** for the 50% Case; **1,722** for the 25% Case.

TABLE D.4.4 Annual Electricity Consumption during Phase II for Building Storage

Building	Application	Usage (h/yr)	Consumption (MWh/yr) 100%	50%	25%
Storage	Cooling	4,380	**1.91E+03**	**9.56E+02**	**4.78E+02**
	Lighting	438	**1.04E+03**	**5.22E+02**	**2.61E+02**
	HEPA	8,760	**4.65E+03**	**2.32E+03**	**1.16E+03**
	Davit Crane	Variable[a]	**1.35E-01**	**5.40E-02**	**2.70E-02**
	Tools	None	0.0	0.0	0.0
	Subtotal		**7.60E+03**	**3.79E+03**	**1.90E+03**
Receiving Warehouse and Repackaging Area	Cooling	4,380	1.77E+02	1.04E+02	6.61E+01
	Lighting	8,760	1.94E+03	1.14E+03	7.23E+02
	HEPA	8,760	4.31E+02	2.52E+02	1.61E+02
	Bridge Crane	Variable[a]	**1.35E-01**	**5.40E-02**	**2.70E-02**
	Davit Crane	Variable[a]	**1.35E-01**	**5.40E-02**	**2.70E-02**
	Tools	8,760	3.07E+01	**1.75E+01**	1.31E+01
	Subtotal		2.57E+03	1.51E+03	9.62E+02
Workshop	Cooling	4,380	1.78E+01	1.78E+01	1.78E+01
	Lighting	8,760	1.94E+02	1.94E+02	1.94E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	2.63E+01	2.19E+01	1.75E+01
	Subtotal		2.82E+02	2.77E+02	2.72E+02
Administration	Cooling	4,380	1.92E+01	1.92E+01	1.92E+01
	Lighting	8,760	2.10E+02	2.10E+02	2.10E+02
	HEPA	None	0.0	0.0	0.0
	Tools	8,760	**7.88E+01**	6.57E+01	5.26E+01
	Subtotal		3.08E+02	2.95E+02	2.82E+02
ALL	**TOTAL**		**1.08E+04**	**5.87E+03**	**3.42E+03**

[a] Hours of operation: **9** for the 100% Case; **3.6** for the 50% Case; **1.8** for the 25% Case.

and **18**, 15, and 12, respectively, during Phase II. In the workshop, the number of FTEs for the 100% Case is reduced from 7 for Phase I to 6 for Phase II (FTEs for the other two cases remain at 5 and 4, respectively).

It should be noted that the figures for electrical consumption noted in Tables **D.4.3** and **D.4.4** are higher than those shown in the Engineering Analysis Report for long-term storage of the other three chemical forms (i.e., UF_6, UO_2, and U_3O_8). To attenuate any potential airborne releases under normal (incident-free) and accident conditions, continuous operation of the HEPA filtration system was assumed in this report.

Table **D.4.5** gives the materials and resources used during Phase I operations of the building storage facility for the entire 20-year period. Water requirements were based on the

TABLE D.4.5 Materials and Resources Used during Phase I Operation of the Building Storage Facility

Material/ Resource	Units	Annual			Over 20 Years		
		100%	50%	25%	100%	50%	25%
Diesel	kL	4.09	3.01	2.0	8.16E+1	6.01E+1	3.99E+1
Gasoline	kL	**6.85**	**3.54**	**2.16**	**1.37E+2**	**7.08E+1**	**4.32E+1**
Electricity	MW-h	**1.08E+4**	**5.86E+3**	**3.40E+3**	**2.16E+5**	**1.17E+5**	**6.80E+4**
Natural Gas	MSCM	**7.90E-1**	**4.30E-1**	**2.20E-1**	**1.58E+1**	**8.16**	**4.32**
Water	ML	**5.07**	**3.47**	2.58	**1.01E+2**	**6.94E+1**	5.16E+1
55-gal drums	number	**41**	**21**	**10**	**828**	**414**	**207**
Boxes	number	**183**	**92**	**46**	**3,660**	**1,840**	**920**

operations and maintenance workforce at the facility. Gasoline consumption was estimated from the movement of operations and maintenance staff across the site, three times a day, in gasoline-powered vehicles. The gasoline consumed by the workers while traveling between home and the storage facility was not included in the estimate.

Materials and resources used during Phase II of operations of the building storage facility would be primarily related to the heating, cooling, and humidity control of the storage buildings, with a minor need for boxes and 55-gal drums from damaged boxes discovered during storage. Materials and resources used during Phase II operations are given in Table **D.4.6**. Total materials and resources used during the operational stages, both Phase I and Phase II, are given in Table **D.4.7**. Table **D.4-8** contains the total materials and resources used during operation and construction of the building storage facility.

TABLE D.4.6 Materials and Resources Used during Phase II Operation of the Building Storage Facility

Material/ Resource	Units	Annual			Over 20 Years		
		100%	50%	25%	100%	50%	25%
Diesel	kL	1.2E-3	9.00E-4	6.00E-4	2.40E-2	1.80E-3	1.20E-2
Gasoline	kL	**5.28**	**3.00**	**1.86**	**1.07E+2**	**5.99E+1**	**3.72E+1**
Electricity	MW-h	**1.07E+4**	**5.84E+3**	**3.38E+3**	**2.15E+5**	**1.17E+5**	**6.75E+4**
Natural Gas	MSCM	**7.90E-1**	**4.10E-1**	**2.20E-1**	**1.58E+1**	**8.16**	**4.32**
Water	ML	3.91	2.94	2.22	7.83E+1	5.87E+1	4.45E+1
55-gal drums	drums	**2**	**1**	**1**	**37**	**19**	**9**
Boxes	boxes	**8**	**4**	**2**	**163**	**82**	**41**

TABLE D.4.7 Materials and Resources Used over the 40-Year Operation of the Building Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	kL	8.18E+1	6.01E+1	3.99E+1
Gasoline	kL	**2.43E+2**	**1.31E+2**	**8.04E+1**
Electricity	MW-h	**4.30E+5**	**2.34E+5**	**1.36E+5**
Natural Gas	MSCM	**3.16E+1**	**1.63E+1**	**8.64**
Water	ML	**1.79E+2**	**1.28E+2**	9.61E+1
55-gal drums	drums	**865**	**432**	**216**
Boxes	boxes	**3,823**	**1,922**	**961**

[a] Does not include construction.

TABLE D.4.8 Materials and Resources Used over the Total Life Cycle of the Building Storage Facility[a]

Material/ Resource	Units	100% Case	50% Case	25% Case
Diesel	ML	**5.23E-1**	**2.97E-1**	**1.74E-1**
Gasoline	kL	**2.44E+2**	**1.31E+2**	**8.07E+1**
Electricity	MW-yr	**5.38E+1**	**2.91E+1**	**1.67E+1**
Natural Gas	MSCM	**3.16E+1**	**1.63E+1**	**8.60**
Water	ML	**1.92E+2**	**1.34E+2**	**9.93E+1**
55-gal drums	drums	**865**	**432**	**216**
Boxes	boxes	**3,823**	**1,922**	**961**

[a] Includes construction use of the materials and resources listed, but does not include construction material such as steel and concrete.

D.5 PERSONNEL STAFFING ESTIMATES

D.5.1 Construction Labor Force for All Facilities

It was assumed in estimating the construction labor force that construction would take place during the entire emplacement phase (Phase I) of 20 years. The support buildings (receiving warehouse and repackaging building, administration building, and workshop) would be built before the storage enclosures. Table **D.5.1** contains the estimated labor force for construction per year and aggregated over 20 years. In estimating the annual construction force, it was assumed that a storage area sufficient to store a year's receipt of depleted uranium would be constructed each year to arrive at annual average values.

TABLE D.5.1 Estimated Labor Force for Construction of the Storage Facilities

Enclosure Type	FTEs/yr			FTE-yr (over 20 yr)		
	100% Case	50% Case	25% Case	100% Case	50% Case	25% Case
Building	**21**	**11**	**6**	**420**	**220**	**120**

D.5.2 Operations Labor Force

The required labor force for Phase I (emplacement) and Phase II (maintenance) was estimated on the basis of the activities occurring in each type of storage structure, the number of workers needed for each operation, the time required for each operation, and the number of operations per year. Detailed time-operations tables for the three storage options are given in Appendix B **of the main text**. Some of the activities do not require full-time effort. Therefore, the summary of the required labor force (in FTEs) given in Table **D.5-2** is provided in terms of broad labor categories such as line supervisors, which includes supervisors for repackaging activity, storage activity and receipt activity. For Phase I, estimates are for year 20, when all support buildings and storage enclosures are in operation and depleted uranium is still being received.

In general, workers would not use respiratory or breathing equipment during normal operations. Respirators or air masks might be used during certain activities, such as repackaging billets or compacting damaged boxes, or during maintenance activities involving potentially contaminated equipment such as HEPA filtration units.

TABLE D.5.2 Estimated Labor Force (FTEs) for Operation of the Building Storage Facility

	Phase I			Phase II		
Labor Category	100%	50%	25%	100%	50%	25%
Officials and Managers	9	8	7	9	7	6
Professionals	6	5	4	6	5	4
Office and Clerical	3	3	2	3	3	2
Craft Workers (maintenance)	7	5	4	6	5	4
Operators/Technicians	**17**	**6**	4	5	3	2
Line Supervisors	**3**	2	1	2	1	1
Security	12	10	7	13	9	6
Total	**57**	**39**	29	44	33	25

D.6 FACILITY EMISSIONS AND WASTES

D.6.1 Estimate of Emissions and Wastes Generated during Construction of the Storage Facilities

Wastes generated during construction of the storage facility would be typical of large construction projects. Wastes would be primarily construction debris, including concrete fragments, and sanitary wastes from the labor force. Emissions would result primarily from the consumption of fuels used in construction, removal of construction debris, and disturbance of the land (dust). These estimates are entered in **Table D.6.1**. In this table, the amount of concrete waste was estimated with the assumption that two percent of the concrete usage would be spoilage. The other solid wastes, which would include construction debris and rock cuttings, are taken to be 8 times the volume of the concrete spoilage. These solid non-hazardous wastes would be disposed of in a municipal solid waste landfill. The amount of sanitary waste was estimated on the basis of the total construction workforce. Liquid (sanitary) non-hazardous wastes would be treated in a portable system or hauled to off-site facilities for treatment and disposal.

Criteria pollutant emissions generated during construction were based on the amount of fuel consumed by the trucks and cranes during construction, as indicated by standard U.S. Environmental Protection Agency (EPA) emission factors (EPA 1993). The emission factors used in this report are consistent with those used in the Engineering Analysis Report for depleted uranium management options, such as Conversion, Cylinder Treatment, Cylinder Transfer and so forth. However, the emission factors applied in the Engineering Analysis Report for the long-term storage option are anomalous with respect to the other depleted uranium management options. As such, the calculated emissions during construction shown in **Table D.6.1** are higher than those for long-term storage of the other chemical forms (UF_6, UO_2, and U_3O_8). Emissions were calculated from the total quantity of liquid fuel consumed (gasoline and diesel). Dust was estimated on the basis of the amount of disturbed land area and the duration that the disturbed area would be under construction.

D.6.2 Estimate of Emissions and Wastes Generated during the Operational Stage

Phase I operation of the storage facility would involve the receipt, inspection, and repackaging (if damaged) of the depleted uranium boxes and transfer of these boxes to the storage buildings. The major wastes and emissions generated during the operational stage would consist of sanitary wastes from the on-site labor force; empty, damaged boxes (considered to be radioactively contaminated) that must be repackaged; and criteria pollutant emissions from transport of the containers and from facility space heating. Emissions of criteria pollutants were calculated on the basis of the amount of diesel fuel, gasoline, and natural gas consumed annually. Under normal (incident-free) conditions, the amount of radioactive emissions would be insignificant. (Such emissions, primarily generated during repackaging of damaged wooden boxes, could be reduced through administrative procedures.)

TABLE D.6.1 Estimated Emissions and Wastes from Construction of the Building Storage Facility

	Units	100% Case	50% Case	25% Case
EMISSIONS				
Carbon monoxide	te	**1.33E+01**	**7.11**	**4.03**
Hydrocarbons	te	**5.30E-01**	**2.80E-01**	**1.60E-01**
NO_x	te	**1.99**	**1.07**	**6.00E-01**
SO_x	te	**1.30E-01**	**7.00E-02**	**4.00E-02**
Dust	te	**2.32E+01**	**1.25E+01**	**7.13**
PM-10	te	**2.97**	**1.59**	**9.00E-01**
WASTES				
Concrete	m^3	**4.48E+02**	**2.31E+02**	**1.22E+02**
Other solid waste	m^3	**3.59E+03**	**1.85E+03**	**9.80E+02**
Sanitary liquids	m^3	**3.82E+03**	**2.00E+03**	**1.10E+03**
Other liquids	m^3	**1.70E+03**	**8.90E+02**	**4.90E+02**

During Phase II operation, boxes in long-term storage would be inspected annually. Depleted uranium billets in damaged boxes would be replaced from storage, repackaged, and returned to storage. Waste and emissions generated during this phase would include the sanitary wastes from the on-site labor force; empty, damaged boxes (considered to be radioactively contaminated); and emissions of criteria pollutants from transport of the boxes and from facility space heating.

The boxes determined to be damaged, either upon receipt or during long-term storage, are assumed to be noncombustible, compatible solid LLW that would require disposal. It is assumed that these boxes would be only slightly contaminated by U^{238} and would be Class A waste under the U.S. Nuclear Regulatory Commission's (NRC) classification system. It is important for disposal that LLW have structural stability to preclude slumping, collapse, or failure of a disposal unit (10 CFR 61.56). Damaged boxes would not be stable when buried because they are empty (subject to compaction) and would deteriorate from moisture and microbial action. It is assumed that breaking down the boxes, which have a wood volume of 5/6 ft^3 per box, and packing them into 55-gal drums, would provide stability. (This activity would be performed within the airlock located in the repackaging area to minimize potential spread of airborne contamination.) It is reasonable to estimate that the boxes are packed in a drum would occupy approximately 50% of the volume (bulking factor of 2). Then, the wood equivalent of **4.41** damaged boxes would be packed in a 55-gal drum for disposal. There would be small volumes of wipes, personal protective equipment, and other slightly contaminated items that could be disposed of in the same drums to further reduce the void fraction. It is expected that administrative procedures would minimize the generation of LLW.

The amount of contamination that could adhere to a box is estimated as follows. The surface of a uranium metal billet would become tarnished (oxidized) to form a surface layer of UO_2, as discussed in Appendix C. It is assumed that this oxide layer is 100 microns thick. (A literature search did not indicate oxidation rates specific to the uranium metal-iron alloy considered for long-term storage. A 200-micron-thick layer of UO_2 oxide was assumed for heavily corroded N-reactor fuel assemblies [Cooper et al. 1996]. This analysis assumes 50% of the literature value because the corrosion of the depleted uranium metal billets is not expected to be as severe. This value is consistent with the Engineering Analysis Report, which assumed a 100-micron-thick oxide layer for handling of uranium metal under the Shielding option.)

If each of these billets had a layer of UO_2 this thick, with a surface area of 1,966 cm^2, **21** billets per box, and UO_2 density of 3 g/cm^3, there would be **1,239** g of UO_2 or **1,092** g of U^{238} available to contaminate the boxes, assuming that the entire surface layer is dislodged during repackaging and that it would contaminate the inner surfaces of the damaged box. With a specific activity of 3.36×10^{-7} Ci/g, the level of contamination of a damaged box could be **3.6** $\times 10^{-4}$ Ci. The packaged LLW would be surveyed prior to off-site transport and presumably shipped to a shallow land disposal facility.

Three types of non-hazardous wastes would be generated during operations. These wastes would consist of liquid sanitary waste released to a local sanitary system; municipal solid waste (office waste, domestic trash, and food waste) transported to an off-site municipal landfill for disposal; and recyclable waste (aluminum, steel, paper, and cardboard) picked up by recycling companies.

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 boxes. This gives a conservative estimate of emissions. Four tables detail the estimated emissions and wastes for the building storage facility. Table D.6.4 is for Phase I, Table D.6.5 is for Phase II, Table D.6.6 is for total wastes and emissions from Phase I and Phase II, and Table D.6.7 is for total wastes and emissions (i.e., from construction as well as from both phases of operations).

TABLE D.6.4 Estimated Emissions and Wastes from Phase I Operations of the Building Storage Facility

Parameter	Units	Annual 100%	Annual 50%	Annual 25%	Over 20 years 100%	Over 20 years 50%	Over 20 years 25%
EMISSIONS							
CO	kg	**8.34E+2**	**4.57E+2**	**2.62E+2**	**1.67E+4**	**9.15E+3**	**5.26E+3**
Hydrocarbons	kg	**3.46E+1**	**1.90E+1**	**1.09E+1**	**6.93E+2**	**3.79E+2**	**2.17E+2**
NO_x	kg	**1.07E+3**	**5.58E+2**	**2.99E+2**	**2.15E+4**	**1.12E+4**	**5.98E+3**
SO_x	kg	**1.09E+1**	**5.88**	**3.32**	**2.17E+2**	**1.18E+2**	**6.64E+1**
PM-10	kg	**1.11E+2**	**6.35E+1**	**3.83E+1**	**2.23E+3**	**1.27E+3**	**7.65E+2**
WASTES							
Non-haz solid	m^3	**1.09E+2**	7.45E+1	5.54E+1	**2.18E+3**	1.49E+3	1.11E+3
Recyclable solid	m^3	4.40E+1	3.00E+1	2.20E+1	8.80E+2	6.00E+2	4.40E+2
Sanitary liquid	m^3	**4.84E+3**	3.32E+3	2.46E+3	**9.68E+4**	6.63E+4	4.93E+4
LLW	te	**4.30**	**2.20**	**1.10**	**8.60E+1**	**4.40E+1**	**2.20E+1**

TABLE D.6.5 Estimated Emissions and Wastes from Phase II Operations of the Building Storage Facility

Parameter	Units	Annual 100%	Annual 50%	Annual 25%	Over 20 years 100%	Over 20 years 50%	Over 20 years 25%
EMISSIONS							
CO	kg	**6.65E+2**	**3.51E+2**	**1.94E+2**	**1.33E+4**	**7.02E+3**	**3.88E+3**
Hydrocarbons	kg	**2.79E+1**	**1.47E+1**	**8.11**	**5.57E+2**	**2.94E+2**	**1.62E+2**
NO_x	kg	**1.05E+3**	**5.42E+2**	**2.89E+2**	**2.10E+4**	**1.08E+4**	**5.77E+3**
SO_x	kg	**9.18**	**4.82**	**2.63**	**1.84E+2**	**9.63E+1**	**5.27E+1**
PM-10	kg	**7.34E+1**	**3.97E+1**	**2.29E+1**	**1.47E+3**	**7.94E+2**	**4.58E+2**
WASTES							
Non-haz solid	m^3	8.41E+1	6.31E+1	4.78E+1	1.68E+3	1.26E+3	9.56E+2
Recyclable solid	m^3	3.40E+1	2.50E+1	1.90E+1	6.80E+2	5.00E+2	3.80E+2
Sanitary liquid	m^3	3.74E+3	2.80E+3	2.12E+3	7.48E+4	5.60E+4	4.25E+4
LLW	te	**2.00E-1**	**1.00E-1**	**5.00E-2**	**4.00**	**2.00**	**1.00**

TABLE D.6.6 Estimated Emissions and Wastes over the 40-Year Operation of the Building Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	te	**3.00E+01**	**1.62E+01**	**19.14**
Hydrocarbons	te	**1.25**	**6.73E-01**	**3.80E-01**
NO_x	te	**4.25E+01**	**2.20E+01**	**1.17E+01**
SO_x	te	**4.01E-01**	**2.14E-01**	**1.19E-01**
PM-10	te	**3.70**	**2.06**	**1.22**
WASTES				
Non-haz solid	m^3	**3.86E+03**	**2.75E+03**	**2.07E+03**
Recyclable solid	m^3	**1.56E+03**	**1.10E+03**	**8.20E+02**
Sanitary liquid	m^3	**1.72E+05**	**1.22E+05**	**9.18E+04**
LLW	te	**9.0E+01**	**4.6E+01**	**2.3E+01**

TABLE D.6.7 Estimated Emissions and Wastes over the Total Life Cycle (Including Construction) of the Building Storage Facility

Parameter	Units	100%	50%	25%
EMISSIONS				
CO	**te**	**4.32E+01**	**2.33E+01**	**1.32E+01**
Hydrocarbons	**te**	**1.78**	**9.57E-01**	**5.41E-01**
NO_x	**te**	**4.45E+01**	**2.31E+01**	**1.24E+01**
SO_x	**te**	**5.34E-01**	**2.85E-01**	**1.59E-01**
PM-10	**te**	**6.67**	**3.66**	**2.12**
Dust	**te**	**2.32E+01**	**1.23E+01**	**7.13**
WASTES				
Concrete	m^3	**4.48E+02**	**2.31E+02**	**1.22E+02**
Other const. solid	m^3	**3.59E+03**	**1.85E+03**	**9.80E+02**
Non-haz solid	m^3	**3.86E+03**	**2.75E+03**	**2.07E+03**
Recyclable solid	m^3	**1.56E+03**	**1.10E+03**	**8.20E+02**
Sanitary liquid	m^3	**1.75E+05**	**1.24E+05**	**9.29E+04**
Other non-haz liquid	m^3	**1.70E+03**	**8.90E+02**	**4.90E+02**
LLW	te	**1.70E+03**	**8.90E+02**	**4.90E+02**

D.7 DESCRIPTION OF POTENTIAL ACCIDENTS

Accidents that could occur during long-term storage are analyzed in this section. Potential accidents could be initiated during facility operations or could be caused by external events, including natural phenomena (earthquake and wind). Reasonably foreseeable accidents have been screened to identify the accidents that have the greatest consequences to workers and the public. These are the "bounding" accidents that provide an envelope for the consequences of other potential accidents that would have less impact on workers and the public.

Four types of events were considered credible: a handling accident, a fire or explosion, an earthquake, and a tornado. A flood was considered to be incredible because it is assumed that the facility would be sited to preclude severe flooding. Figure **D.7.1** summarizes the results of the accident analysis and gives the accident scenario, a description of the accident, the frequency range, and information about the source term.

The source term, which is the amount of radioactive material released, is the product of four factors: the material at risk (MAR); the damage fraction (DF); the respirable airborne release fraction (RARF); and the fraction of respirable airborne material released to the environment, or leak path factor (LPF).

D.7.1 Handling Accidents

Mechanical upsets are events such as spills, forklift punctures, loss of filtration, and piping failures. In general, mechanical upset-initiated accidents would result in small releases to the atmosphere. Here it is assumed that a forklift in the receiving warehouse and repackaging building damages an entire pallet (4 boxes with **21** billets each). This causes the four boxes to fall to the floor, break, and release the UO_2 patina that had formed on the uranium metal billets. The MAR is the total radioactive material, uranium metal with oxide coating, in four boxes (**6,300** lb uranium metal or **7,146** lb with UO_2 coating). It is assumed that the damage fraction is unity, that all of the oxide becomes airborne and is in the respirable range, and that none of the metal becomes airborne. Then, the RARF would be 1.73×10^{-4}, as estimated for an oxide layer 100 microns thick, with a surface area of approximately **41,000** cm^2 for **21** billets per box and an oxide density of 3 g/cm^3 (refer to Section 6.2 for further details on the derivation of the RARF). As in the Engineering Analysis Report, it is assumed that the uranium dioxide release would be filtered as it passes through the HEPA filters with an efficiency of 99.9% (LPF = 0.001) as a puff. (The accident scenario would not result in failure of off-gas filters because of the absence of energetic processes.) The release is estimated to be **0.0013** lb (0.**58** g of uranium) or **1.9** $\times 10^{-7}$ Ci.

The frequency of this accident per year is the product of the number of pallets received per year, the number of operations per pallet, and the probability that a mishandling accident would cause damage to the boxes on a pallet and result in release of radioactive material per operation. It is assumed that the number of operations (six) and the mishandling accident probability (1.1×10^{-5}) are the same as for mishandling of drums in the Engineering Analysis Report. For the 100% Case, where **6,808** pallets would be handled per year, the frequency of this accident would be **0.45**/yr. For the 50% Case and the 25% Case, the frequency of this accident would be reduced proportionately. This accident is considered to be anticipated, because it has a frequency greater than 0.01/yr.

D.7.2 Fire or Explosion

Here it is assumed that a fire or explosion within the receiving warehouse would affect the contents of four boxes on a pallet. The absence of combustible materials or a fire source within the receiving warehouse would limit the material-at-risk to a single pallet. This accident scenario assumes that the fire is initiated by a fuel leak from the forklift, which could be ignited by a number of sources. Because a forklift is used only within the receiving warehouse, a comparable scenario within the storage facilities was not considered.

The fire or explosion would initiate burning of uranium metal to form U_3O_8 particulates (refer to Appendix C) that would be filtered through the HEPA filter (LPF = 0.001). The material at risk and damage fraction would be the same as for the mishandling accident. The RARF (0.001) is based on thermal stress (oxidation) of uranium (refer to DOE-HDBK-0013 [DOE 1994b] page 4-2). The frequency of this accident is assumed to be the same as in the Engineering Analysis Report for a fire or explosion accident (9.6×10^{-6}). It is estimated that **0.0074** lb of U_3O_8 particulates would be released with an activity of **9.6** $\times 10^{-7}$ Ci. The release would continue for 30 minutes, at which point appropriate measures would result in extinguishing the fire.

As noted in DOE-HDBK-1081-94 (DOE 1994c), metallic uranium handled in massive forms does not present a significant fire risk unless exposed to a severe and prolonged external fire, which would be highly unlikely because of the absence of combustible material necessary to support a fire of any significant magnitude. Unlike plutonium, uranium is difficult to ignite. The presence of an adherent, protective layer of hyperstoichiometric dioxide at the interface limits oxygen availability. At surface to mass ratios greater than 1.0 cm^2/g, the ignition temperature of bulk metallic uranium exceeds 500 ^oC and increases rapidly, indicating that large pieces of uranium are very difficult to ignite because large amounts of external heat must be supplied and serious heat loss prevented (Mishima et al. 1985). Therefore, this accident is considered to be extremely unlikely; that is, it has a frequency of between 10^{-6}/yr and 10^{-4}/yr.

An accident scenario that has been examined in a number of environmental studies concerns a diesel fire in an underground disposal facility (DOE 1980; DOE 1990) and its potential to affect the entire facility. This accident scenario was projected to be risk-dominant compared with other plausible scenarios for disposal of transuranic waste at the Waste Isolation Pilot Plant (DOE 1990). However, because of concerns about air quality in the drifts and aisleways of the mined-cavity storage facility, it was decided to use electric-driven straddle carriers in this study. Consequently, it was deemed incredible that a sufficient quantity of combustible material would accumulate in the mined cavities to initiate a significant accident. Thus, this accident scenario was not considered further in this analysis.

D.7.3 Earthquake

Here, the receiving warehouse and repackaging building would be damaged in a design basis earthquake. Review of the on-site structures indicated that this building had the greatest potential for a significant airborne release due to the potential for the overhead crane to fall during the event, resulting in crushing of the wooden boxes located underneath with subsequent atmospheric release. (Although the storage buildings contain a higher inventory of uranium metal, the storage buildings do not contain an overhead crane, so it is difficult to postulate a scenario that results in a significant airborne release. An accident scenario in which more than one building would collapse simultaneously was considered so unlikely that it is not reasonably foreseeable.)

The material at risk would be the entire amount of depleted uranium metal in storage at the receiving warehouse and repackaging building; that is, material received during a **6.3**-week period (**5,272,000** lb of uranium metal, or **5,827,000** lb if all metal is converted to UO_2). The damage fraction is taken as 10%. The RARF would be the same as for the mishandling accident. The seismic event is assumed to cause failure of the building structure and its confinement system so that 10% of the oxide released from the boxes would be released from the building, resulting in a ground-level unfiltered release of **10.4** lb of UO_2 (**1.4** $\times 10^{-3}$ Ci). (A damage fraction of 10% is reasonable given the cross section of the overhead crane; refer to Figure 2.2.) The release is assumed to continue for a 30-minute period. The frequency of this event (5×10^{-4}/yr), as well as the LPF, DF, and release duration, are assumed to be the same as for the earthquake event in the Engineering Analysis Report. DOE hazard category 2 buildings are constructed such that earthquakes (and tornadoes as well) could cause failure of the building structure and confinement at this annual frequency.

Although it might appear intuitively that the potential consequences of an earthquake on an underground facility would be more severe than on a surface facility, that does not appear to be the case. Available data on the effects of earthquakes in underground mines and tunnels indicate that they are significantly less susceptible to damage from earthquakes than are surface facilities (DOE 1980). Investigations measuring earthquake acceleration underground and at the surface indicated that underground motion was four to six times less than at the surface. A study of the Alaskan earthquake of 1964 by the U.S. Geological Survey reported no significant damage to underground facilities, such as mines and tunnels, although some rocks were shaken loose in places. Therefore, it is expected that damage to mined cavities would be much less than for aboveground facilities, such as the receiving warehouse and repackaging building. Thus, the scenario considered in Table **D.7.1** could be considered the bounding earthquake event for a mined-cavity storage facility.

D.7.4 Tornado — Warehouse and Repackaging Building

Here, the warehouse and repackaging building would be damaged when a major tornado and associated tornado missiles sweep across the building in 30 seconds. The material at risk would be the material received during a **6.3**-week period (**5,272,000** lb of uranium metal, or **5,827,000** lb if all metal is converted to UO_2), and the fraction damaged is taken as 10%. The RARF would be the same as for the mishandling accident and the earthquake event. There would be failure of the building structure and its confinement system so that 10% of the oxide released from the boxes would be released from the building, resulting in ground-level unfiltered release of **10.4** lb of UO_2 (**1.4** $\times 10^{-3}$ Ci). The released powder would be highly dispersed because of tornado wind conditions. The release is assumed to continue for a 30-second period. The frequency of this event (5×10^{-4}/yr), as well as the LPF, DF, and release duration, are assumed to be the same as for the earthquake event in the Engineering Analysis Report.

D.7.5 Tornado — Single Storage Building

This whole section is unchanged.

FIGURE D.7.1 Assessment of Accidents for the 100% Case

Accident Scenario	Accident Description	Frequency Range	Release (Source Term) Chemical Form	Amount (lb)	Duration (minutes)	Release Level
Mishandling or drop of drum or billet inside building	An entire pallet of uranium metal billets is damaged by a forklift and spills its contents onto the ground inside the receiving warehouse and repackaging building.	>10E-2/yr	UO_2	**1.3E-03**	Puff	Stack
Fire or explosion within the warehouse and repackaging building	A fire or explosion within the receiving warehouse and repackaging building affects the contents of a single pallet of 4 wooden boxes.	10E-6/yr - 10E-4/yr	U_3O_8	**7.4E-3**	30	Stack
Earthquake	The receiving warehouse and repackaging building is assumed to be damaged during a design basis earthquake with resulting failure of the structure and confinement occurring.	10E-4/yr - 10E-2/yr	UO_2	**10.4**	30	Ground
Tornado	A major tornado and associated tornado missiles results in failure of the receiving warehouse and repackaging building structure and confinement systems.	10E-4/yr - 10E-2/yr	UO_2	**10.4**	0.5	Ground
Flood	It is assumed that the facility would be sited to preclude severe flooding.	<10E-6/yr	No Release	NA	NA	NA
Tornado – Single Storage building	A major tornado and associated tornado missiles results in failure of a single storage building structure and confinement systems.	10E-4/yr – 10E-2/yr	UO_2	1.92E+1	0.5	Ground

D.8 TRANSPORTATION

This section primarily addresses on-site transportation of depleted uranium. In addition, off-site shipments of LLW for disposal are discussed.

Operation of a storage facility requires the following types of on-site transportation of depleted uranium: movement of the depleted uranium in boxes from the site boundary to the receiving warehouse by rail or truck, movement within the receiving warehouse and repackaging facility by overhead crane, movement from the receiving warehouse and repackaging building to storage enclosures by truck, and movement within storage enclosures by straddle carrier. Except for 55-gal drums containing damaged boxes to be disposed of as LLW, wooden boxes would be the only other major stream that would be transported on-site. These wooden boxes would, for the most part, contain **21** billets of depleted uranium, although some empty boxes would be needed for repackaging of billets in damaged boxes. Table **D.8.1** contains on-site transportation requirements.

TABLE D.8.1 On-Site Transportation

Parameter	100% Case	50% Case	25% Case
Physical form	Solid, metal	Solid, metal	Solid, metal
Container type	2'×2'×**8"** wood box	2'×2'×**8"** wood box	2'×2'×**8"** wood box
Weight per container, gross	**731** kg	**731** kg	**731** kg
Annual quantity, mass of billets	19,455 te	9,727 te	4,864 te
Annual quantity, number of containers	**27,240**	**13,620**	**6,810**
Annual quantity, number of pallets	**6,810**	**3,405**	**1,703**
Transportation mode (from site boundary)	Rail	Rail	Rail
Containers per railcar	80	80	80
Annual number of railcar shipments,12 railcars per shipment	**28**	**14**	**7**
Transportation mode (from site boundary)	Truck	Truck	Truck
Containers per truck	**24**	**24**	**24**
Annual number of truck trips	**1,135**	**568**	**284**
Transportation mode (receiving warehouse to storage)	Truck	Truck	Truck
Containers per truck trailer	6 pallets	6 pallets	6 pallets
Annual number of truck trips	**1,135**	**568**	**284**
Transportation mode (within storage building)	Straddle carrier	Straddle carrier	Straddle carrier
Containers per lift	1 pallet	1 pallet	1 pallet
Annual number of lifts	**7,945**	**3,976**	**1,988**

As discussed earlier, boxes contaminated with UO_2 and small amounts of other radiologically contaminated solids (e.g., wipes and protective clothing) will be placed in 55-gal drums and transported to an off-site LLW disposal facility. The 55-gal drums will serve as transportation packages and disposal containers. It is assumed that these drums will be transported to an LLW disposal facility by truck, and the truck has a capacity of 28 drums. It is also assumed that a shipment does not occur until 28 drums have accumulated. With these assumptions, and the quantities of LLW shown in Tables **D.6.4** and **D.6.5,** the off-site transportation of LLW would be as shown in Table **D.8.2** for the emplacement phase (Phase I) and in Table **D.8.3** for the maintenance phase (Phase II).

TABLE D.8.2 Off-Site Transportation of Low-Level Radioactive Waste, Emplacement Phase (Phase I)

Transported Materials	100% Case	50% Case	25% Case
Type	Low-level rad waste	Low-level rad waste	Low-level rad waste
LLW type	Noncombustible, compactible solid	Noncombustible, compactible solid	Noncombustible, compactible solid
Physical form	Solid	Solid	Solid
Chemical composition	Wood & UO_2	Wood & UO_2	Wood & UO_2
Temperature and pressure	Ambient	Ambient	Ambient
Packaging			
Type	55-gal drum	55-gal drum	55-gal drum
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (kg)	23	23	23
Material weight (kg)	108	108	108
Contamination content (wt%)	3.8%	3.8%	3.8%
Contaminant	UO_2	UO_2	UO_2
Shipments			
Average volume (m^3) per year	**4.3**	**2.2**	**1.1**
Packages per year	**41.4**	**20.7**	**10.3**
Packages during Phase I	**828**	**414**	**207**
Packages per shipment	**28**	**28**	**28**
Shipments per year	**1.48**	**0.74**	**0.37**
Shipments during Phase I	**30**	**15**	**8**
Form of Transportation/Routing			
Form of transportation	Truck	Truck	Truck
Destination	LLW disposal facility	LLW disposal facility	LLW disposal facility

TABLE D.8.3 Off-Site Transportation of Low-Level Radioactive Waste, Maintenance Phase (Phase II)

Transported Materials	100% Case	50% Case	25% Case
Type	Low-level rad waste	Low-level rad waste	Low-level rad waste
LLW type	Noncombustible, compactible solid	Noncombustible, compactible solid	Noncombustible, compactible solid
Physical form	Solid	Solid	Solid
Chemical composition	Wood & UO_2	Wood & UO_2	Wood & UO_2
Temperature and pressure	Ambient	Ambient	Ambient
Packaging			
Type	55-gal drum	55-gal drum	55-gal drum
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (kg)	23	23	23
Material weight (kg)	108	108	108
Contamination content (wt%)	3.8%	3.8%	3.8%
Contaminant	UO_2	UO_2	UO_2
Shipments			
Average volume (m^3) per year	**0.19**	**0.10**	**0.05**
Packages per year	**1.85**	**0.93**	**0.46**
Packages during Phase II	**37.1**	**18.5**	**9.3**
Packages per shipment	**28**	**28**	**28**
Shipments per year	**0.07**	**0.03**	**0.02**
Shipments during Phase II	**2**	**1**	**1**
Form of Transportation/Routing			
Form of transportation	Truck	Truck	Truck
Destination	LLW disposal facility	LLW disposal facility	LLW disposal facility

D.9 PERMITTING AND REGULATORY COMPLIANCE

This whole section is unchanged.

D.10 PRELIMINARY SCHEDULE ESTIMATES

This whole section is unchanged.

APPENDIX E:

URANIUM METAL PACKAGING DESIGN

APPENDIX E:

URANIUM METAL PACKAGING DESIGN

This appendix provides information concerning the packaging design that was used in the previous chapters of this report and advances another design that would reduce the amount of void space, and thereby the total area, required for storage. It should be noted that the packaging arrangement shown in this appendix has not been optimized, and other arrangements may exist that would further reduce the total area required for long-term storage of depleted uranium metal.

The Engineering Analysis Report (LLNL 1997) assumed that the depleted uranium metal billets would be contained within a wooden box with dimensions of 2 ft long by 2 ft wide and a height of 1 ft. The box would be constructed of 0.75-in. plywood that has been treated to limit its flammability. Taking into account the thickness of the wooden sides, the total volume of a single wooden box available for storage would be on the order of 3.08 ft^3.

The Engineering Analysis Report indicates that a single wooden box would contain a total of 19 uranium metal billets, each 3 in. wide by 2 in. tall, with a length of 20 in. The total volume associated with 19 billets is on the order of 1.32 ft^3, which would be only 43% of the total wooden box volume of about 3.08 ft^3. Thus, a large proportion of the wooden box volume would not be used effectively for storage purposes.

A figure was not provided in the Engineering Analysis Report to indicate how the 19 uranium metal billets would be stacked within the 2-ft by 2-ft by 1-ft wooden box. This analysis had assumed a configuration in which the first row laying on the bottom of the wooden box would contain a total of four billets. Four billets would then be placed perpendicular to the four billets. This procedure would be continued until the wooden box would contain a total of five rows, of which four rows would each contain four billets, with the fifth (top) row containing only three billets (refer to Figure E.1). The total height of stacked arrangement would be about 10 in., which allows for a 0.5-in. clearance with the inside of the box top (i.e., 12 in. – 0.75 in. [bottom thickness] – 0.75 in. [top thickness] = 10.5 in.).

In this manner, the overall height of the billets stacked in the wooden box would be on the order of 1 ft, which is the height of the wooden box. The engineering team believed that this configuration would provide the necessary structural support so that stacking of one wooden box on another could be implemented without failure of the box. However, this stacking arrangement could be subject to shifting of the depleted uranium billets during transportation and handling that could contribute to enhanced (inward) damage of the wooden box. It may be necessary to place spacers or similar devices between the billets to prevent shifting. However, the Engineering Analysis Report does not indicate the presence of such devices.

The arrangement of stacked billets in the Engineering Analysis Report would not provide the optimal storage design because of the existence of a large voidage that increases the area required for long-term storage. As an alternative, this analysis considers another arrangement for stacking the individual depleted uranium metal billets, as shown in Figure E.2, which involves placing a total of 21 billets within a wooden box. Comparison of the stacking arrangement between the Engineering Analysis Report and this sensitivity analysis is provided in Table E.1.

The total number of depleted uranium metal billets increases from 19 to 21 for the new stacking arrangement. As shown in Figure E.2, the new stacking arrangement assumes three rows of billets, each row containing a total of seven billets. The height of the wooden box decreases from 12 in. to 8 in., with the sides of the wooden box maintained at 2 ft by 2 ft, similar to the design in the Engineering Analysis Report (refer to Figure E.3). For this arrangement, the percent of total available volume is 77%, which may not be considered optimal.

The new arrangement provides a clearance of 1.5 in. in the horizontal direction (24 in. – 0.75 in. [side thickness] – 0.75 in. [side thickness] – 21 in. [7 billets × 3 in.]), which should be sufficient for placing the billets within the box using a bin packaging station. The total height of stacked arrangement would be about 6 in., which allows for a 0.5-in. clearance with the inside of the box top (i.e., 8 in. – 0.75 in. [bottom thickness] – 0.75 in. [top thickness] = 6.5 in.). This should be sufficient to allow variation in the size of the depleted uranium billets.

One important feature that must be considered within the design of a storage facility is the dead load of the wooden boxes stacked within a storage building. Dead loads are loads that remain permanently in place. They include the weights of all permanent materials and equipment. This analysis assumes four wooden boxes per pallet, with approximate dimensions of 4 ft long by 4 ft wide by 7.5 in. tall. Conservatively assuming a weight of 50 lb per box, the total weight of the four boxes and their contents on a single pallet is approximately 6,500 lb. The dead load of six pallets, each containing four boxes, stacked on top of each other is about 2,440 lb per ft^2 (psf), neglecting the weight of the pallets. The compressive strength of the 12-in. concrete foundation for the storage buildings is 3,000 lb per $in.^2$ (psi) (equivalent to 432,000 psf), indicating that a total of six pallets stacked on top of each other could be borne safely by the concrete foundation.

TABLE E.1 Comparison of Stacking Arrangements between the Engineering Analysis Report and the Sensitivity Analysis

Variable	Engineering Analysis Report	Sensitivity Analysis
Number of Billets per Storage Box	19	21
Total Weight of Billets in Box	1,425 lb	1,575 lb
Height of Wooden Box	12-in.	8-in.
Percent of Total Volume of Wooden Box Used	43%	77%

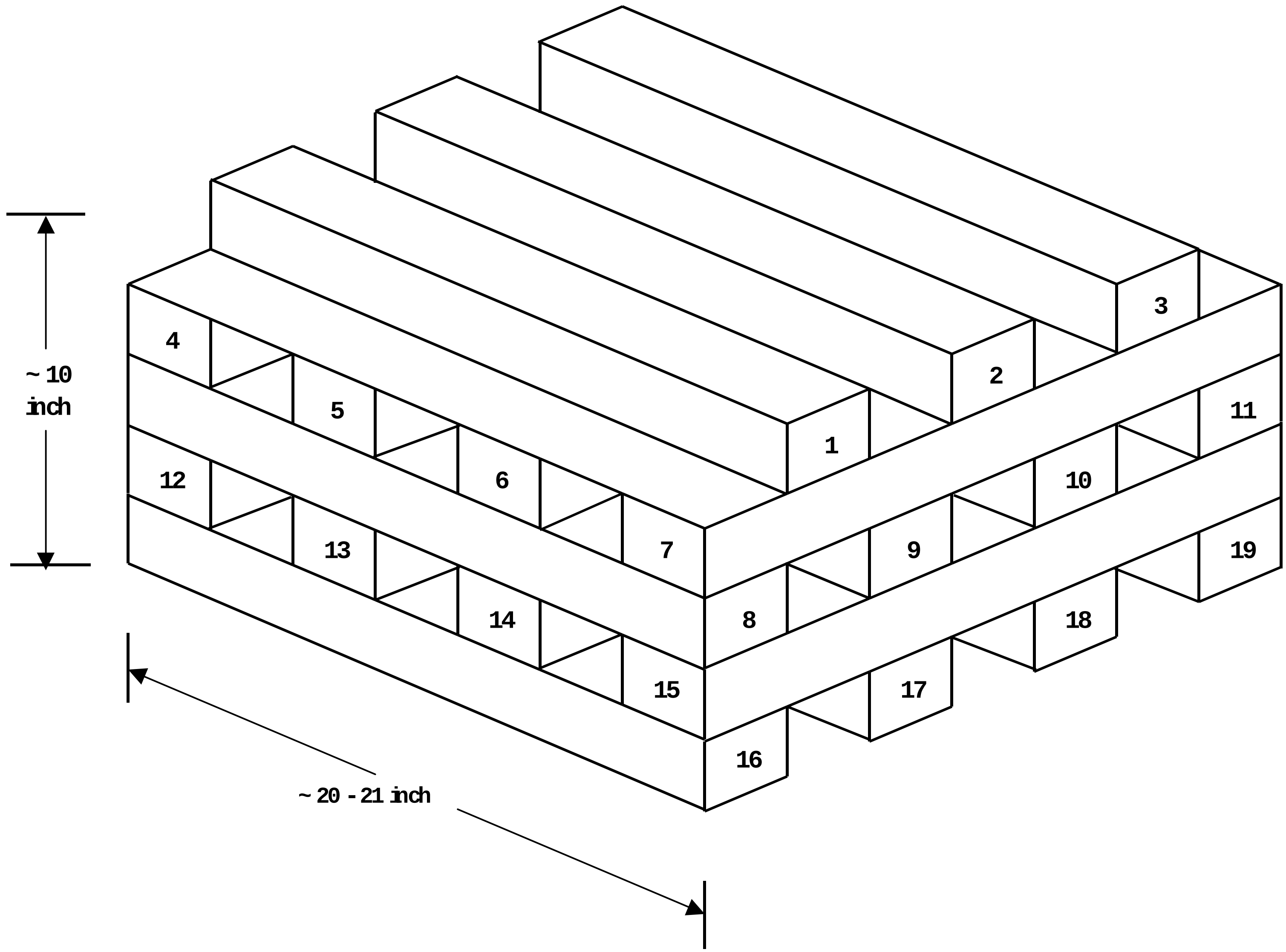

FIGURE E.1 Stacking Arrangement of Depleted Uranium Metal Billets Presumably Used in the Engineering Analysis Report

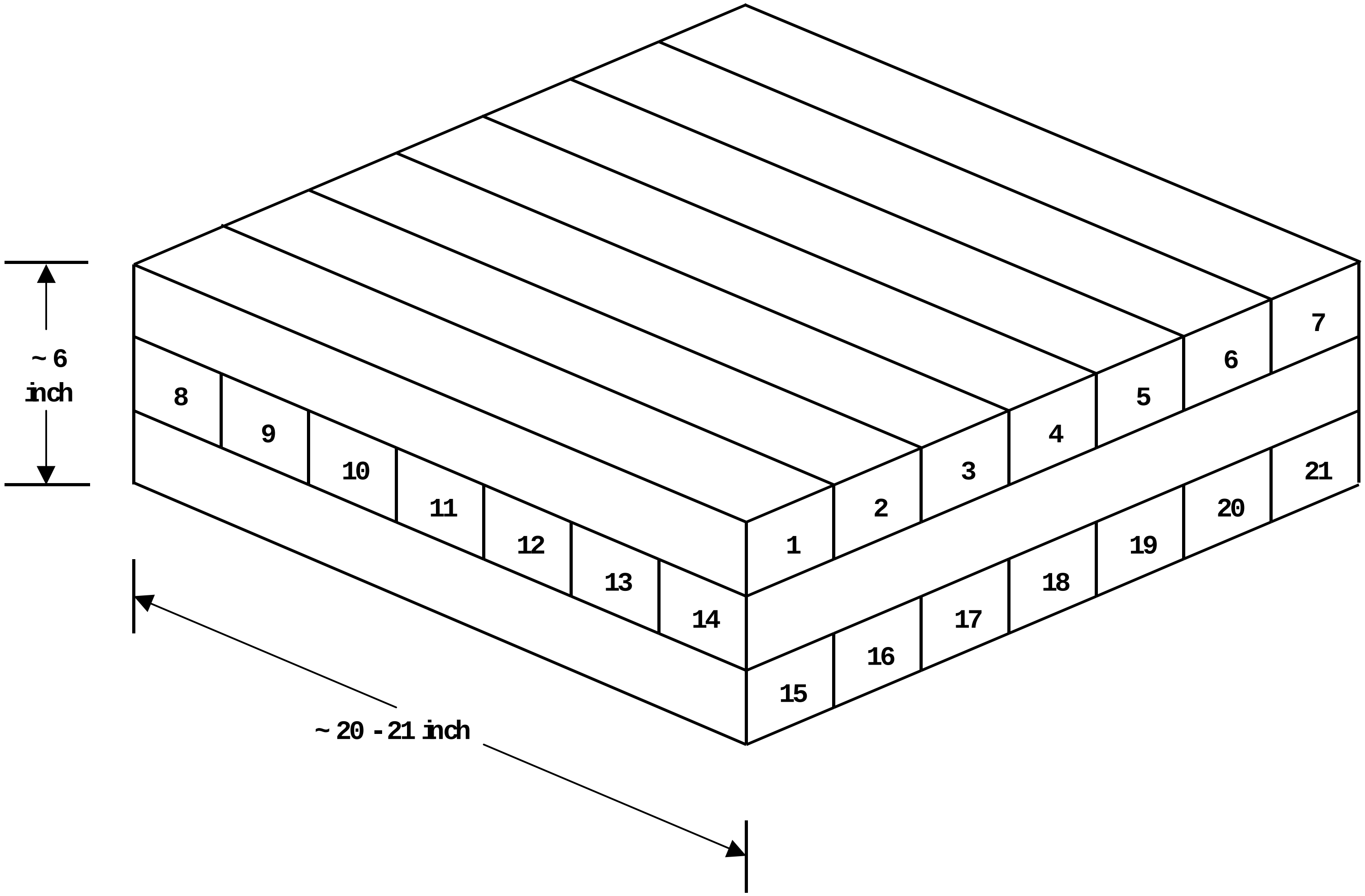

FIGURE E.2 Stacking Arrangement of Depleted Uranium Metal Billets Proposed in Appendix D

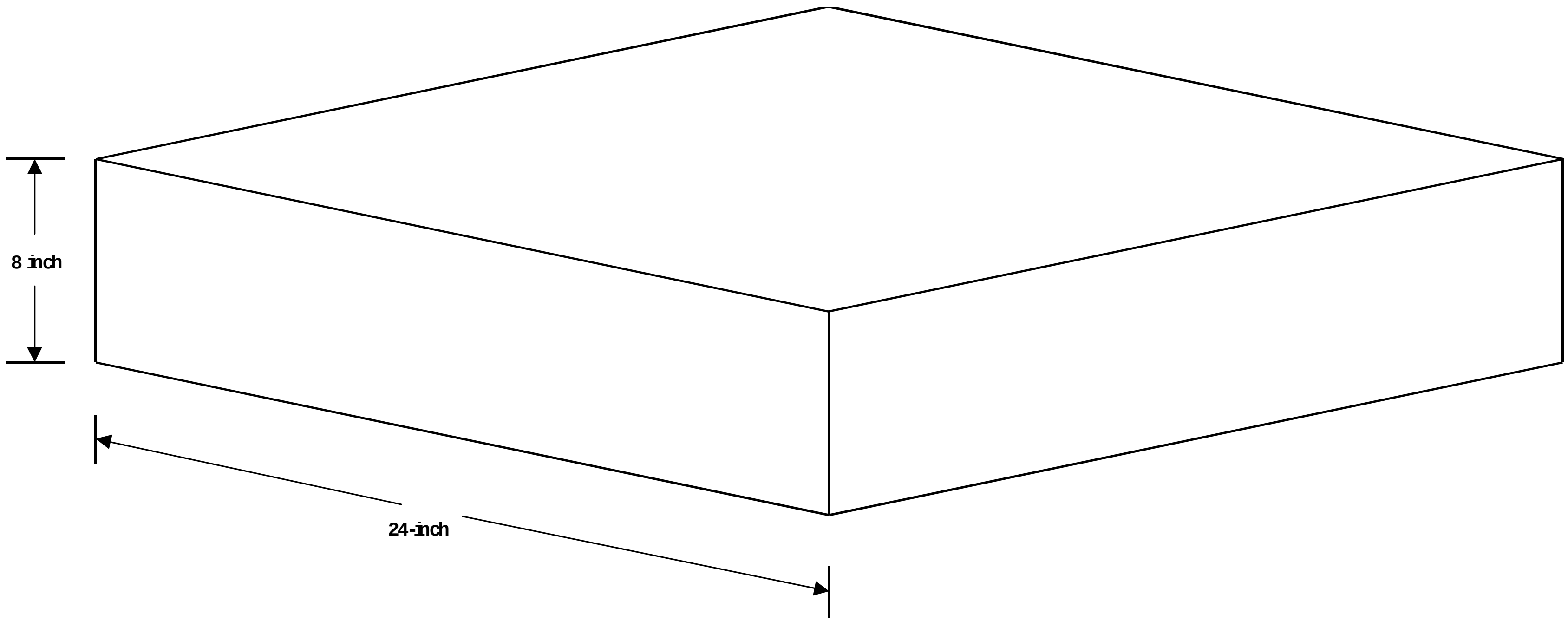

FIGURE E.3 Proposed Dimensions of the Wooden Box for Storage of Depleted Uranium Metal Billets in the New Stacking Arrangement