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1. PURPOSE

The purpose of this analysis is to size and conceptually design the structures, systems, and components (SSCs) in the Canister Transfer System, which is one of the four primary waste handling systems in the Waste Handling Building (WHB). The waste handling systems in the WHB also include the Carrier/Cask Handling System, the Assembly Transfer System, and the Disposal Container (DC) Handling System. The configuration and relationship of these four waste handling systems in the WHB are based on the analysis documented in the *Waste Handling Systems Configuration Analysis* (WHSCA), Reference 5.1, and are shown in Figure 1-1.

Separate design analyses will be prepared for each of the four waste handling systems. The analyses will also develop and update the recommended waste handling system design configuration presented in the WHSCA. The objective of this analysis is to establish an equipment sizing basis for an updated WHB configuration and layout. This work will support the Viability Assessment design and cost estimates for the SSCs in the WHB.

2. QUALITY ASSURANCE

An activity evaluation has been performed in accordance with QAP-2-0 and has determined that the QA program is applicable to this analysis. The classification of permanent items described in QAP-2-3 *Classification of Permanent Items* has not been performed for the waste handling systems and facilities. However, waste handling systems and facilities are identified as "Q" in the project *Q-List* (Reference 5.2) by direct inclusion. Therefore, items addressed in this analysis are to be considered "Q" items, and are subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) (Reference 5.3). Therefore, as specified in NLP-3-18, this analysis shall be documented as being subject to QA controls.

Although the results from this analysis will define the space requirements and equipment sizes for the waste handling systems in the WHB, they are considered preliminary and will not be used directly for procurement, fabrication or construction. Therefore, the formal TBV and TBD tracking system described in NLP-3-15, To Be Verified (TBV) and To Be Determined (TBD) Monitoring System, is not applicable. Any data from this analysis that is used as design input must be treated as unconfirmed (TBV) and tracked per NLP-3-15 prior to inclusion in documents supporting fabrication, procurement, or construction.

3. METHOD

The method used to perform this analysis follows the approach used for facility conceptual design. This approach includes equipment sizing assumptions, preliminary design descriptions for major waste handling equipment, figures, material handling dimensional outlines, and preliminary equipment layout drawings of each of the major pieces of equipment used to transfer canisters in the WHB. Major pieces of equipment are those which are required to perform system waste

Figure 1-1. Waste Handling Systems in the WHB

handling, maintenance, and recovery operations, or which have a significant impact on the building arrangement and space. The design methodology employed is described in sections 3.1, 3.2, and 3.3.

3.1 CANISTER TRANSFER SYSTEM DESCRIPTION

The Canister Transfer System description in Section 7.1.3 is based on the functions, operations, activities, and major equipment items identified in the WHSCA (Reference 5.1); recommended maintenance and recovery equipment defined in the *Waste Handling Facilities Recovery Analysis* (Reference 5.4); new design inputs (see Section 4); and configuration changes developed in this analysis. The affected WHB operating areas, hot cells, maintenance bays, staging areas, airlocks, doors, and hatches are identified for layout purposes.

3.2 MAJOR EQUIPMENT DESIGN

For each major equipment item developed from Section 3.1, the key dimensions, capacities, and sizes are estimated using available design inputs (i.e., project reference documents and assumptions). Plan and elevation figures of each of the major equipment items are prepared to 1) illustrate the conceptual design and maximum equipment envelopes (sizes) required to perform system waste handling, maintenance, and recovery operations, and 2) estimate the space requirements. Tables are prepared to summarize key dimensions, capacities, and ratings for the major system equipment. Selected support equipment (e.g., tools, grapples, etc.) are sized and figures provided, as required, to ensure that significant space drivers and handling interfaces have been considered.

3.3 EQUIPMENT ARRANGEMENT AND SPACE ALLOCATION

For each system operational area, the space (length, width, and height) required to house the system and major equipment is developed. Plan and section figures are prepared to illustrate the arrangement of the equipment in the waste handling areas, hot cells, and transfer lines. These figures include space for airlocks, waste ingress and egress paths, doors, maintenance bays, and support equipment. Additional space allowances for in-process storage, equipment laydown, staging, and waste handling aisles are provided.

4. DESIGN INPUTS

Additional design inputs were developed from sources such as the waste package development organization, available cask manufacturer license application documentation, equipment supplier literature/data, technical papers, and engineering experience on prior nuclear facility design projects. These design input sources are identified as design parameters, criteria, assumptions, or codes/standards in this section. References are listed in Section 5.

4.1 DESIGN PARAMETERS

This data is TBV; consequently, the use of any data from this analysis for input into documents supporting procurement, fabrication, or construction is required to be controlled and tracked as TBV or TBD in accordance with NLP-3-15 or other appropriate procedures.

4.1.1 The specific weight of steel is 490 lb/ft³ (Reference 5.16).

4.2 CRITERIA

The following design criteria, which are applicable to this analysis, were developed to respond to requirements found in the *Repository Design Requirements Document* (RDRD) (Reference 5.6).

- 4.2.1 The waste handling system layout shall support the ability to limit radiation exposures and releases of radioactive materials to unrestricted areas (RDRD 3.2.1.2.C, 3.2.1.3, 3.2.1.4.A, 3.2.1.4.C, 3.2.2.1.C, 3.2.3.1.3.I, 3.2.4.5.2).
- 4.2.2 The waste handling system layout shall permit the control of radioactive waste and radioactive effluents at any time (including during normal operations, anticipated occurrences and under accident conditions) and permit prompt termination of operations and evacuation of personnel during an emergency (RDRD 3.2.1.7.B, RDRD 3.2.2.1.D.1 (TBR), RDRD 3.2.2.1.D.2 (TBV)).
- 4.2.3 The waste handling system layout shall permit the control of concentrations of radioactive material in air through the use of process or other engineering controls (e.g., containment or ventilation) (RDRD 3.2.2.3.A).
- 4.2.4 The layout of the waste handling systems for processing, transporting, handling, storing, and retrieving radioactive waste shall provide the ability to prevent the occurrence of a criticality accident unless two unlikely independent and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety (RDRD 3.2.2.5.A and 3.2.3.2.2.A.10).
- 4.2.5 The waste handling system facilities shall provide the capability to inspect and verify the description of the waste received (RDRD 3.2.3.1.1.B, 3.2.3.1.2.E).
- 4.2.6 The waste handling system facilities shall be capable of receiving and handling standard, failed, and nonstandard canistered defense high-level waste (DHLW) and large disposable canisters (RDRD 3.2.3.1.2.A, 3.2.3.1.2.B, 3.2.1.2.C.2 (TBV)).
- 4.2.7 The waste handling system facilities shall be capable of handling Nuclear Regulatory Commission (NRC)-licensed transportation cask systems (RDRD 3.2.3.1.3.H, Table 3-5) (TBR). The WHB is designed to interface with specific casks identified by MGDS systems analysis.
- 4.2.8 The waste handling system materials shall be physically and chemically compatible with the canistered waste forms (RDRD 3.2.3.2.2.A.9.c).

- 4.2.9** The waste handling system layout shall provide controlled access to areas where high and very high radiation levels exist (RDRD 3.2.4.3.2.A).
- 4.2.10** The waste handling system shall provide for continuous management, handling, transfer, and staging of the waste and canisters in a safe manner that optimally protects the health, safety, and the environment under normal and anticipated off-normal operating conditions or as a result of retrieval (RDRD 3.2.5.1, 3.7.4.1.A.1).
- 4.2.11** The waste handling system layout shall allow for periodic inspection, maintenance and testing as necessary to ensure continued functioning and readiness (RDRD 3.2.5.2.1, RDRD 3.2.5.2.2.B, RDRD 3.2.5.2.6).
- 4.2.12** The waste handling system facilities shall provide lifting devices when a capability greater than the limits for human portability is required (RDRD 3.2.5.2.4.B).
- 4.2.13** The waste handling system shall be designed so as not to preclude the expansion of its basic mission (e.g., increased storage area or increased disposal capacity) (RDRD 3.2.8).
- 4.2.14** The waste handling system layout shall provide viewing and monitoring capability for all remotely operated cranes, manipulators, and other equipment used for handling high-level wastes (RDRD 3.7.4.1.A.6).
- 4.2.15** The waste handling system layout shall provide temporary storage capacity equivalent to waste receipts (RDRD 3.7.4.1.A.2) (TBD).
- 4.2.16** The waste handling system layout shall have the capability to handle and store waste as received from offsite as well as the prepared WPs onsite (RDRD 3.7.4.1.A.3)(TBD).
- 4.2.17** The waste handling system layout shall provide retrievability (RDRD 3.7.1.4.A, RDRD 3.7.4.1.A.1, RDRD 3.7.4.1.A.4).

4.3 ASSUMPTIONS

Assumptions 4.3.1 through 4.3.5 have been used throughout the document.

- 4.3.1** The following assumptions are based on information found in the CDA (Reference 5.5).
- 4.3.1.1** Repository waste handling baseline design will not have canistered spent nuclear fuel burnup or thermal measurement capability. This is based on Assumption Identifier: Key 057, Subject: Burnup or Thermal Management.
- 4.3.1.2** The waste handling system layout will provide buffer or holding areas at certain locations within the operation areas. This is based on Assumption Identifier: RDRD 3.7.4.1.A.3 (TBD), Subject: Waste Handling Storage Areas.

- 4.3.2** DC loading, handling, and closure operations shall ensure that waste packages shall not contain liquid water in an amount that could compromise repository performance objectives. This is based on Assumption Identifier: EBDRD 3.7.1.2.D, Subject: Container to Limit Liquid Water Contact.(TBV).
- 4.3.3** Cask preparation and staging activities will be done using robotic and remote handling equipment in a shielded area consistent with DOE as low as reasonably achievable (ALARA) practices. Readily available remote/robotic technology will be used. It should be noted that although existing utility nuclear power plant cask preparation and decontamination operations are performed manually consistent with reactor site ALARA practices, this facility will handle significantly higher quantities of waste and experience higher radiation exposure times.
- 4.3.4** Adequate tools, spares, maintenance personnel, storage area, and equipment must be readily available to immediately repair failed system equipment. Since the WHB is used continuously, the system must be continuously maintained over its operating life.
- 4.3.5** DOE SNF will be received in a shipping cask similar to the large multi-purpose canister (MPC) cask (*Multi-Purpose Canister (MPC) Implementation Program Conceptual Design Phase Report*, Vol. II.B: Transportation Cask Conceptual Design Report (Reference 5.7)). DOE SNF canisters are assumed to be the same diameter as defense high-level waste (DHLW) canisters and will be 10 to 15 feet in height.
- 4.3.6** The mechanical design characteristics of the casks, canisters, and DC , including the different waste forms, waste content, maximum diameter, maximum height, and loaded weights used in this analysis, are provided in Table 4.3-1. The characteristics are based on the current cask, canister, and DC design data contained in the *Multi-Purpose Canister (MPC) Implementation Program Conceptual Design Phase Report*, Vol. II.B (Reference 5.7), the *Multi-Purpose*

Table 4.3-1. Mechanical Design Characteristics of the Casks, Canisters, and DC

Waste Form	Diameter*	Height	Loaded Weight	Basis
Cask (DHLW canister)	7'-3"* (2.21 m)	12'-6" (3.81 m)	154,900 lb (70,200 kg)	126,000 lb unloaded cask (large MPC Ref. 5.7) + 5 DHLW canisters
Cask (DOE SNF canister)	6'-1"* (1.85 m)	17'-4.25" (5.29 m)	202,800 lb (92,000 kg)	126,000 lb unloaded cask (large MPC Ref. 5.7) + 4 DOE SNF canisters
Cask (Small MPC canister)	5'-1"* (1.55 m)	17'-1" (5.21 m)	150,000 lb (68,000 kg)	Ref. 5.7, Figure 4.1.2-1
Cask (Large MPC canister)	6'-1"* (1.85 m)	17'-4.25" (5.29 m)	250,000 lb (113,400 kg)	Ref. 5.7, Figure 4.1.1-1
Canister (DHLW)	2'-0" (0.61 m)	9'-10" (3.0 m)	5,700 lb (2,600 kg)	Ref. 5.10
Canister (DOE SNF) (Hanford Long)	2'-0" (0.61 m)	13'-9" (4.19 m)	19,100 lb (8,700 kg)	Ref. 5.11
Canister (Small MPC)	4'-1.62" (1.26 m)	15'-11.625" (4.87 m)	64,000 lb (29,000 kg)	Ref. 5.8, Figure 4.2.2.1-4
Canister (Large MPC)	5'-0.25" (1.53 m)	16'-1" (4.90 m)	124,000 lb (56,200 kg)	Ref. 5.8, Figure 4.2.1.1-3
DC 5 DHLW/ 1 DOE SNF (SRS/WVDP)	6'-5.56" (1.97 m)	12'-5.22" (3.79 m)	83,800 lb (38,000 kg)	Ref. 5.9 and Assumption 4.3.6
DC 5 DHLW/ 1 DOE SNF (Hanford Long)	6'-6.74" (2.00 m)	17'-7.42" (5.37 m)	127,900 lb (58,000 kg)	Ref. 5.9 and Assumption 4.3.6
DC Commercial Canister Fuel 44 BWR (Large MPC)	6'-4.77" (1.95 m)	18'-6.83" (5.66 m)	152,100 lb (69,000 kg)	Ref. 5.9 and Assumption 4.3.6

* The diameter is measured within 1 foot of the bottom of the cask, below the trunnions.

SRS: Savannah River Project

WVDP: West Valley Demonstration Project

BWR: boiling water reactor

Canister (MPC) Implementation Program Conceptual Design Phase Report, Vol. II.A (Reference 5.8), the *Preliminary List of Waste Package Designs for VA* (Reference 5.9), the ACD (Reference 5.10), and the *Specification for the Spent Nuclear Fuel Multi-Canister Overpack* (Reference 5.11). The following specific design characteristic assumptions are used:

- The diameters, lengths, heights, and weights of Canister Transfer System casks, canisters, and disposal containers are based on best available data.
- The staging rack capacity for the DHLW/DOE SNF (8 canisters) is based on the WHSCA (Reference 5.1), with an additional capacity of 12 positions to store DOE SNF canisters or any new waste forms that may be introduced (TBV).

This assumption has been used in Table 4.3-1 and Sections 7.1.5.2, 7.1.5.3, 7.1.5.4, 7.1.5.5, 7.1.5.10, 7.1.5.11, and 7.3.2.2.

4.3.7 The standard design guidelines (*Design Guides for Radioactive Material Handling Facilities and Equipment*, Reference 5.12) were used for equipment clearance and space required for waste handling equipment. The dimensions were developed using mechanical engineering judgement, and experience in DOE and commercial nuclear facilities design.

This assumption has been used in Sections 7.1.5.3, 7.1.5.4, 7.1.5.5, 7.1.5.6, 7.1.5.10, 7.1.5.11, and 7.3.1.2.

4.3.8 The space required for waste handling equipment is developed using industry data, vendor information, and mechanical engineering judgement based on design experience with DOE and commercial nuclear facilities. The following specific equipment design assumptions are used:

- Empty disposal containers enter the Canister Transfer System ready to be loaded and handled using standardized lifting and base collars (handling fixtures).
- Standard industrial crane data was used for designing the transfer cell bridge crane.
- Standard industrial electro-mechanical manipulator data was used for designing the cask preparation and DC loading manipulators.
- The cask and DC cart designs were based on modification of the cart design in the ACD (Reference 5.10, Vol. II, pages 7-119 and 7-124).

This assumption has been used in Sections 7.1.5.1, 7.1.5.2, 7.1.5.4, 7.1.5.5, 7.1.5.6, 7.1.5.7, 7.1.5.8, and 7.1.5.9.

4.4 CODES AND STANDARDS

There are no codes or standards applicable to this design analysis.

5. REFERENCES

- 5.1 *Waste Handling Systems Configuration Analysis* (WHSCA), M&O Document Identifier BCBD00000-01717-0200-00001, REV 00.
- 5.2 *Q-List*, U.S. Department of Energy, YMP/90-55Q, REV 4.
- 5.3 *Quality Assurance Requirements and Description* (QARD), U. S. Department of Energy, DOE/RW-0333P, REV 7.
- 5.4 *Waste Handling Facilities Recovery Analysis*, M&O Document Identifier BCBD00000-01717-0200-00003, REV 00.
- 5.5 *Controlled Design Assumptions Document* (CDA), M&O Document Identifier B00000000-01717-4600-00032, REV 04, ICN 2.
- 5.6 *Repository Design Requirements Document* (RDRD), Yucca Mountain Site Characterization Project, YMP/CM-0023, REV 0, ICN 1.
- 5.7 *Multi-Purpose Canister (MPC) Implementation Program Conceptual Design Phase Report*, Vol. II.B: *Transportation Cask Conceptual Design Report*, M&O Document Identifier A20000000-00811-5705-00003, REV 00.
- 5.8 *Multi-Purpose Canister (MPC) Implementation Program Conceptual Design Phase Report*, Vol. II.A: *MPC Conceptual Design Report*, M&O Document Identifier A20000000-00811-5705-00002, REV 00.
- 5.9 *Preliminary List of Waste Package Designs for VA*, M&O Document Identifier: BBA000000-01717-3300-00008, REV 00.
- 5.10 *Mined Geological Disposal System, Advanced Conceptual Design Report* (ACD), M&O Document Identifier B00000000-01717-5705-00027, REV 00.
- 5.11 *Specification for the Spent Nuclear Fuel Multi-Canister Overpack*, Duke Engineering & Services Hanford, Inc., HNF-S-0426, Rev. 3, February 1997.
- 5.12 *Design Guides for Radioactive Material Handling Facilities and Equipment*, American Nuclear Society, Remote Systems Technology Division, 1988.

- 5.13 *Repository Surface Design Mechanical Flow Diagrams*, M&O Document Identifier BCBD00000-01717-2700-67000 through -67014, Rev. 00.
- 5.14 *Waste Package Design Basis Events*, M&O Document Identifier: BBA000000-01717-0200-00037, REV 00.
- 5.15 *Radiological Safety Design Analyses*, M&O Document Identifier: BCBD00000-01717-0200-00011, REV 00B (TBV).
- 5.16 *Vector Mechanics for Engineers, Statics*, Third Edition, Beer, Ferdinand P. and E. Russell Johnston, Jr., McGraw-Hill Book Company, 1977.
- 5.17 *Characteristics of Potential Repository Wastes*, U. S. Department of Energy, DOE/RW-0184-R1, Volumes 1 and 2, July 1992.

6. USE OF COMPUTER SOFTWARE

No design or scientific software was used for this analysis.

7. DESIGN ANALYSIS

The WHSCA (Reference 5.1) considered alternative handling configurations, systems, available technologies, and major equipment required to receive, unload, load, package, and deliver high-level waste to the subsurface repository, and to recover from off-normal operating conditions (Reference 5.4). This analysis defines the design of the waste handling systems, develops major equipment sizes based on Section 3.2, and determines space needs for the Canister Transfer System in the WHB. The analysis considers design inputs such as different waste types, forms, sizes, loads to be handled, and key dimensions. The system equipment used to perform the operations establishes the basis for the preliminary layouts, dimensional outlines, and equipment arrangement in the WHB. The equipment dimensional outlines are based on maximum equipment capacity ratings and minimum equipment envelopes (See Section 7.2.2) needed to meet the waste handling requirements. The maximum equipment envelopes are used to establish the space required to house the system.

Space is allocated for equipment operation and waste material handling, including allowances for waste storage, equipment maintenance, and staging of lifting yokes, fixtures, tools, and grapples. The minimum feasible equipment envelope for each system was determined based on conceptual designs of system equipment (See Section 7.1.4).

This Canister Transfer System design analysis for the WHB must consider several custom-designed, remotely operated equipment items. However, new research, technology surveys, or equipment design studies will not be performed at this stage of the design development.

7.1 DESCRIPTION OF SYSTEM

Section 7.1.1 describes updates to the configuration of the Canister Transfer System that have occurred since the WHSCA was issued. Section 7.1.2 discusses the alternative CTS configurations that were considered, the advantages/disadvantages of each, and identifies the preferred CTS configuration, which is described in Section 7.1.3. Sections 7.1.4 and 7.1.5 list and describe the equipment items, their functions, and the key design dimensions as they relate to space and size of CTS.

7.1.1 Updates to the System Configuration

The Canister Transfer System in the WHSCA (Reference 5.1) was based on a concept developed in the ACD (Reference 5.10) in which a load port is used above the cask to unload a canister and transfer it to another hot cell. The floors and walls of the hot cell shield one cell from the other, thus eliminating shielded hatches between cells. This presents a canister handling problem in that a DHLW or DOE SNF canister must be lifted through the port regardless of its height, yet the port height is sized for the tallest cask/canister. Another problem is access to the hot cell. The canister is loaded into a DC, which rides on a remotely operated transfer cart. The cart is located inside the DC cell and cannot be easily removed for maintenance since the load port cell wall and floor prevent its exit; therefore, cart maintenance is only possible by entering the DC cell after removing any DC. Thus, the WHSCA concept would require entry to the DC cell.

Manned entry into the DC cell is undesirable. In the updated configuration, a shield door between the canister transfer cell and the DC cell is a feasible solution to the above problems. Canisters are transferred directly to a DC or to canister staging without going through a port or over a wall. With this approach, the cask and DC are in the transfer cell together without a separating floor/port, thus avoiding the need to lift a canister higher than necessary and decreasing the canister potential drop heights. Also, the shield doors can be closed to the DC cell and manned entry to the transfer cell can be made for cart maintenance (assuming that all canisters are transferred to the DC cell). A maintenance bay is provided for the crane/manipulator.

The updated design configuration standardizes DC handling fixtures and lifting attachments for the different DC sizes and handling operations (see Assumption 4.3.8). The concept uses a standard set of DC lifting collars and base collars. The lifting collars are attached to the upper skirt of the DC and provide the means for lifting and handling the DC using the DC cell crane and the DC lifting yoke. The base collars are attached to the lower skirt of the DC and provide the means for securing the DC to the transfer carts and staging fixtures. The base collars also support the DC and protect them against tip-over.

7.1.2 Alternative Configurations

This section discusses the alternative Canister Transfer System configurations that were considered in selecting the preferred configuration.

7.1.2.1 Canister Transfer System Alternative Configurations

Three possible Canister Transfer System configurations are shown in Figure 7.1-1 and briefly described in this section. The DHLW and DOE SNF canisters are staged in staging racks. These racks are enclosed by shield walls 24' high by 5' wide. The purpose of the shield walls is to reduce the radiation exposure in case of manned entry. A bridge crane and a manipulator are located in the canister handling hot cell to support the operation. A maintenance bay in the canister handling hot cell is used for maintenance of the manipulator or crane.

Configuration 1 is the preferred configuration (Figure 7.1-1a) described in Section 7.1.3.

The Canister Transfer System includes two independent lines. Each line consists of two primary areas: a cask preparation and decontamination area, and a canister handling hot cell. There is a wall between line one and line two, two storage stations for the canisters, and a maintenance bay above.

Configuration 2 (Figure 7.1-1b) is the same as Configuration 1, with the exception that there is no wall between line one and line two and there is only one storage station needed for the canisters, rather than two. This configuration uses only one crane and one manipulator.

Configuration 3 (Figure 7.1-1c) assumes a single Canister Transfer System line is used, but there are three cask preparation stations and one decontamination station in the cask preparation area, and there is only one storage station for the DHLW and DOE SNF canisters. This configuration also uses one crane and one manipulator.

Figure 7.1-1. Canister Transfer System Alternative Configurations

7.1.2.2 Advantages and Disadvantages

The advantages and disadvantages of each alternative Canister Transfer System configurations are listed in Table 7.1-1.

Table 7.1-1. Canister Transfer System Alternative Configuration Advantages and Disadvantages

Configuration	Advantage	Disadvantage
1 Reference configuration	Independent lines/cells Better availability Redundant lines Narrow crane span	Wider space/increased cell size Two cranes/manipulators Increased cost
2 Two lines with shared space	More flexible cell with crossover Shared crane and manipulator Decreased cost Smaller WHB /cell size	Wide crane span Lower availability Cell entry more difficult
3 One line with expanded cask preparation area	One canister line/crane Multiple cask preparation stations Narrow crane span Decreased cost/cell size	Lower availability No redundancy More handling in series

7.1.2.3 Preferred Configuration

Configuration 1, as shown in Figure 7.1-1a, is similar to the configuration that was modeled in the WHSCA. The model showed that the WHSCA configuration met throughput requirements for the system; therefore, Configuration 1 will meet these throughput requirements. In addition, Configuration 1 has two independent lines so that if one line is inoperable, the other line will continue to operate. At this point, there is no proof that Configurations 2 and 3 will meet the throughput requirements. Based on current information and comparison data provided (See Table 7.1-1), the preferred configuration is Configuration 1.

The equipment arrangement and space allocation (sizing) in this analysis are based on the preferred configuration.

7.1.3 Canister Transfer System

The Canister Transfer System receives casks on a cart from the Carrier/Cask Handling System (through an airlock), and empty DC on a cart from the DC Handling System for large MPC canisters, small MPC canisters, DHLW canisters, and DOE SNF canisters. The system delivers empty casks to the Carrier/Cask Handling System, and loaded DC to the DC Handling System. The Canister Transfer System includes two independent lines. Each line consists of two primary areas: a cask preparation and decontamination area, and a canister handling hot cell.

The cask preparation and decontamination area consists of a cask preparation station and a cask decontamination station. In the cask preparation operation, flex hoses are attached to the cask; the

cask is sampled, vented, and purged; and the lid bolts are detensioned and removed. The lid bolter is positioned above the cask and the cask lid is unbolted. The cask lid lifting fixture is moved into position over the cask (by the manipulator hoist), lifting bolt holes in the cask lid are engaged, and the lid is lifted off the cask.

For small and large MPC canisters, the canister lifting fixture is then attached in the cask preparation area after the lid is removed. The canister lifting fixture is moved into position over the cask (by the manipulator hoist) and engages the lifting bolt holes in the canister lid. The cask with the canister lifting fixture attached is then transferred into the canister handling hot cell. For the DHLW and DOE SNF canisters, the cask lid lifting fixture remains attached to the cask lid until it has been transferred to the canister handling hot cell where the lid is lifted off the cask.

The empty cask decontamination operation consists of manual decontamination of the cask after it has been returned, unloaded, from the canister handling hot cell and before it is transferred to the Carrier/Cask Handling System.

The canister handling hot cell consists of a transfer station and a DC loading station. In the transfer operation, for the large and small MPC canisters, the bridge crane main hook remotely engages the canister lifting fixture, lifts the canister, and transfers it directly into the DC. For the DHLW and DOE SNF canisters, the auxiliary hook lifts the DHLW/DOE SNF lifting fixture (grapple) over the canister, remotely attaches the lifting fixture, and transfers the canister to the DC loading station.

In the DC loading station, the canister is placed in the DC, and the DC is transported to the DC Handling System. If the space in the DC will not accommodate all of the DHLW or DOE SNF canisters from the incoming cask, the canisters are placed in a staging rack for subsequent loading in the next available DC.

7.1.4 System Equipment

The equipment items and their functions shown in Table 7.1-2 are required for the Canister Transfer System and its handling operations. The equipment items and identifiers used are taken from the *Repository Surface Design Mechanical Flow Diagrams* (Reference 5.13). Items that are identified on the MFDs, but which do not affect the WHB space allocation, were not included in this analysis (e.g., PC-PV-110, vent & purge manifold; PC-DC-110 cask decontamination device).

Table 7.1-2. System Equipment and Functions

Equipment Item, Identifier	Function
Canister Cell Bridge Crane, PC-CN-110	Lift and transfer canisters from cask to DC
Cask Lid Lifting Fixture, PC-FX-110	Lift attachment for the cask lid
Large Canister Lifting Fixture, PC-FX-111	Lift attachment for large canisters
DHLW/DOE SNF Canister Lifting Fixture, PC-FX-112	Lift attachment for the DHLW and DOE SNF canister

DHLW/DOE SNF Canister Staging Rack, PC-SR-110	Hold DHLW or DOE SNF canisters prior to loading into a DC
Cask Preparation Manipulator, PC-EM-110	Provide remote handling capability during cask preparation
Canister Transfer Manipulator, PC-EM-111	Provide remote handling capability during canister transfer
Cask Transfer Cart, PC-CR-110	Transport cask to/from Canister Transfer System
DC Transfer Cart, PC-CR-111	Transport DC to/from Canister Transfer System
DC Lifting Collar, PD-FX-117	Lift attachment for the DC
DC Base Collar, PD-FX-118	Secure the DC to the DC transfer cart

7.1.5 Equipment Descriptions

This section provides a physical description of the 11 major pieces of equipment in the Canister Transfer System, an explanation of their functions, and key design dimensions as they relate to space and size requirements.

7.1.5.1 Canister Cell Bridge Crane, PC-CN-110

The canister cell bridge crane, PC-CN-110, is shown in Figure 7.1-2. The canister cell bridge crane, shown in Figure 7.3-4, is mounted on the overhead rails in the canister handling hot cell. It is used to transfer large, small, DHLW, and DOE SNF canisters from a cask to the DC, and to place extra DHLW or DOE SNF canisters in the staging rack. The crane consists of a double girder bridge, a rail-mounted trolley, a main hook, an auxiliary hook, and two bridge end-trucks. The crane's main hook can be used to lift either of the two MPC canister sizes once the appropriate lifting fixture (PC-FX-111) has been attached in the cask preparation area. The crane's auxiliary hook can be used to lift any of the DHLW/DOE SNF canister sizes once the appropriate lifting fixture (PC-FX-112) has been attached. The DHLW/DOE SNF lifting fixture (PC-FX-112) is used for DHLW and DOE SNF canisters, and is attached in the canister handling hot cell. The bridge end trucks and bridge girders are supported by the bridge rails, and the trolley is supported by the trolley rails. The crane trolley moves in a rectangular (x-y coordinate) pattern on the bridge inside the canister handling hot cell, and the main/auxiliary hooks move in a vertical (z coordinate) motion. The canister cell bridge crane capacity is based on the maximum main hook load. The maximum load is the large canister weight plus the weight of the lifting fixture (See Section 7.2.2). The crane bridge span is based on the canister cell width (see Section 7.3). Based on a review of vendor supplied information, the main hook approaches are 4' and 9' (see Assumption 4.3.8). The auxiliary hook approaches are 5' and 8', based on vendor information (see Assumption 4.3.8). The hook approaches indicate how closely the hooks can approach the walls. The end truck provides 12' crane bridge limits for the main hook from the center of the 23' bridge end-truck to either side.

The 15' main hook height, 11' bridge-rail-to-top-of- trolley distance, 19' trolley length, and 23' bridge end-truck length are also based on Assumption 4.3.8.

7.1.5.2 Cask Lid Lifting Fixture, PC-FX-110

The cask lid lifting fixture, PC-FX-110, is attached to the cask lid in the cask preparation area, and is shown in Figure 7.1-3. The cask lid lifting fixture provides the means to lift an unbolted cask lid off a loaded shipping cask or to lower a cask lid onto an unloaded shipping cask. The cask lid lifting fixture, which is staged in the cask preparation area (see Section 7.3), is lifted by the cask preparation manipulator hoist (see Section 7.1.5.6) using a hook, bail, and bail pin mechanism. The fixture is positioned over the cask and manually aligned with the guide pins that aid correct alignment with the lid.

The cask lid lifting fixture consists of a plate with three holes for bolts, a round cylindrical structure, three web supports, a lifting bail with a lifting bail pin, bolts, and guide pins. The lifting bail is mounted on the cylindrical structure. The webs are used for structural support of the round cylinder and the plate.

The equipment diameter is sized based on the 68" cask lid diameter shown in the configuration in Figure 4.1.1-1 of Reference 5.7. The 58" plate dimension on the drawing is based on Assumption 4.3.6. The 26" and 32" heights of the lifting fixture are based on Assumption 4.3.8.

7.1.5.3 Large Canister Lifting Fixture, PC-FX-111

The large canister lifting fixture, PC-FX-111, is shown in Figure 7.1-4. The large canister lifting fixture provides the means to lift a large canister from a shipping cask and lower it into a DC. The large canister lifting fixture consists of a round plate with three holes for bolts, a round cylindrical structure, three web supports, a lifting bail with a lifting bail pin, bolts, and guide pins. The lifting bail is housed on the round cylinder. The webs are used for structural support of the round cylinder and the plate.

The large canister lifting fixture, which is staged in the cask preparation area (see Section 7.3), is lifted by the cask preparation manipulator hoist (see Section 7.1.5.6), which slides into the lifting bail and engages the lifting bail pin. The lifting fixture is positioned above the cask, then lowered for manual alignment to the canister with the aid of two guide pins. Once in place, the bolts are tensioned with an impact wrench. The cask, canister, and lifting fixture are transferred to the canister handling hot cell. Once the large canister is in the canister handling hot cell, the bridge crane main hook slides into the lifting bail, engages the lifting bail pin, removes the large canister from the cask, and transfers it directly into the DC.

The lifting bail and lifting bail pin are sized to accommodate the bridge crane main hook. The 56" diameter of the lifting fixture is based on Assumptions 4.3.6 and 4.3.7. The 38" and 46" heights are based on Assumptions 4.3.6 and 4.3.7. The 58" outer diameter of the large MPC canister lid is based on Reference 5.7. The same concept is used for small MPC canisters, since the large and small MPC canisters are the same shape, and differ only in diameter.

Figure 7.1-3. Cask Lid Lifting Fixture, PC-FX-110

Figure 7.1-4. Large Canister Lifting Fixture, PC-FX-111

7.1.5.4 DHLW/DOE SNF Canister Lifting Fixture, PC-FX-112

The DHLW/DOE SNF canister lifting fixture, PC-FX-112, is shown in Figure 7.1-5. The DHLW/DOE SNF canister lifting fixture provides the means to remotely grapple and lift a DHLW canister or DOE SNF canister from a shipping cask and lower it into a DC or place it in a staging rack. The DHLW/DOE SNF canister lifting fixture consists of a round cylindrical grapple assembly which houses a lifting bail with a lifting bail pin, power and instrumentation cable, three grippers, and the grapple mechanism. The bridge crane auxiliary hook slides into the lifting bail, engages the lifting bail pin, raises the lifting fixture, and then positions it over the canister. The lifting fixture grapple is opened to allow engagement of the DHLW or DOE SNF canister's lifting pintle. After the pintle has been engaged, the bridge crane auxiliary hook raises the canister from the cask and transfers it into the DC or to the staging rack. The DHLW/DOE SNF canister staging rack is sized so that the top of the canisters extend beyond the top of the rack.

The lifting bail and lifting bail pin are sized to accommodate the bridge crane auxiliary hook. The 1'-6" diameter for the lifting fixture is based on Assumption 4.3.8 and the 1'-10" height is based on Assumption 4.3.7. The 6.63" and 9.12" dimensions appearing in the figure are based on Reference 5.17, while the 1' gripper opening is based on Assumption 4.3.8.

7.1.5.5 DHLW/DOE SNF Canister Staging Rack, PC-SR-110

The DHLW/DOE SNF canister staging rack, PC-SR-110, is shown in Figure 7.1-6. The DHLW/DOE SNF canister staging rack may be used to store DHLW or DOE SNF canisters until they are loaded into a DC. The rack consists of a metal frame sized for four canisters; five racks are needed to accommodate 20 canisters (based on Assumption 4.3.6). The rack is designed to be attached to the hot cell wall and floor for structural support. The vertical and horizontal dimensions of 8'-0" and 4'-10", respectively, are based on Assumptions 4.3.6, 4.3.7, and 4.3.8.

The 29" center-to-center dimension for canisters enables the canisters to fit into the staging rack with a 5" clearance for handling, rack framework, and canister alignment guides.

7.1.5.6 Cask Preparation Manipulator, PC-EM-110

The cask preparation manipulator, PC-EM-110, is shown in Figure 7.1-7. The cask preparation manipulator is used for all remote connections and to assist in the cask preparation operation (e.g., detorque the bolts on the cask lid). The cask preparation manipulator consists of a telescoping mast mounted on the overhead bridge crane and trolley. The bridge and trolley are used to support the manipulator arm and the mast. The bridge and trolley are used to position the manipulator in an x-y location within the cell. The mast is used for vertical positioning of the manipulator. The manipulator can be equipped with a wide variety of tools and accessories for assisting in cask preparation. A small hoist (part of the cask preparation manipulator) is mounted on the trolley to hold the impact wrench that is used to detorque the bolts on the cask. The hoist hook is also used to lift the cask lid lifting fixture, canister lifting fixture, and cask lid (see Sections 7.1.5.2 and 7.1.5.3). The hoist is operated independently from the manipulator.

Figure 7.1-5. DHLW/DOE SNF Canister Lifting Fixture, PC-FX-112

Figure 7.1-6. DHLW/DOE SNF Canister Staging Rack PC-SR-110

Assumption 4.3.8 was used to size the overhead bridge crane, the trolley, the manipulator, the mast, and the hoist maximum envelope size. The 37' and 45' dimensions are based on the cell dimensions (see Figure 7.3-1 in Section 7.3). The 27' maximum reach (upper limit to lower limit) distance is based on the DC plus DC cart height (see Figure 7.3-2). The 27' maximum reach is provided to service the carts. The bridge and trolley clearances are based on Assumptions 4.3.7 and 4.3.8. A 5' manipulator arm clearance, 7'-9" distance, and high hook clearance are based on standard manipulator/crane data (Assumption 4.3.8).

7.1.5.7 Canister Transfer Manipulator, PC-EM-111

The canister transfer manipulator, PC-EM-111, is shown in Figure 7.1-8. The canister transfer manipulator is used to assist in loading the canister into the DC. The canister transfer manipulator consists of a telescoping mast mounted on an overhead bridge crane and trolley. The bridge crane and trolley are used to support the manipulator and the mast. The bridge and trolley are used to set the manipulator in the x-y location of the cell. The mast is used for vertical positioning of the manipulator. The manipulator can be equipped with a wide variety of tools and accessories for assisting in loading and unloading operations. A hoist is provided. The hoist hook is also used to lift the cask lid lifting fixture and the cask lid (see Sections 7.1.5.2 and 7.1.5.3). The hoist is operated independently from the manipulator.

Assumption 4.3.8 was used to size the overhead bridge crane, the trolley, the manipulator, the mast, and the hoist maximum envelope size. The 33' and 92' dimensions are based on the cell size (see Figure 7.3-4 in Section 7.3). The 31' maximum reach (upper limit to lower limit) is provided to service the carts. The height of the manipulator (11'; 7' above rail, 4' below) is based on Assumption 4.3.8. A 5' manipulator arm clearance, 8'-2" distance, and 3' high hook clearance are based on standard manipulator/crane data (Assumption 4.3.8).

7.1.5.8 Cask Transfer Cart, PC-CR-110

The cask transfer cart, PC-CR-110, is shown in Figure 7.1-9. The rail-mounted cask transfer cart is used to transfer casks, in a vertical orientation, between the Carrier/Cask Handling System and the two canister transfer lines which make up the Canister Transfer System. The casks remain on the transfer cart during Canister Transfer System operations prior to their return to the Carrier/Cask Handling System for empty cask shipping operations. Each of the two canister transfer lines requires an individual cask transfer cart.

The cask transfer cart is equipped with adjustable chucks, which engage the various casks for cask alignment. The cask transfer cart is driven along the rails by means of an electro-mechanical drive system with power provided to the cart by an umbilical system or a conductor bar system. Sensors/limit switches and locking pins facilitate positioning of the cask cart at the transfer stations.

Figure 7.1-8. Canister Transfer Manipulator, PC-EM-111

Figure 7.1-9. Cask Transfer Cart, PC-CR-110

The overall length, width, and height of the transfer cart, including guide height, are based on the ACD (Reference 5.10, Vol. II page 7-119), with modifications based on industry data and engineering judgement (Assumption 4.3.8). The 15'-0" x 11'-0" length and width are based on a reasonable envelope to accommodate the 6'-1" maximum cask outer diameter, and the transfer cart drive system (motor, gear reducer, drive components, etc.). The 2'-0" height of the cart is based on the estimated structure and wheel size to accommodate the maximum cask weight (See Table 4.3-1). The 4'-0" height of cart with the adjustable chucks is based on the need to guide and align the cask as the cask is lowered onto the cart surface.

7.1.5.9 DC Transfer Cart, PC-CR-111

The DC transfer cart, PC-CR-111, is shown in Figure 7.1-10. The rail-mounted DC transfer cart is used to transfer an empty DC, in a vertical orientation, between the DC cell and one of the two canister transfer lines in the Canister Transfer System. The DC remains on the transfer cart during Canister Transfer System operations prior to its return to the DC cell for DC Handling System operations. Each of the two canister transfer lines requires an individual DC transfer cart.

The DC transfer cart is equipped with guides, which engage the DC base collars for DC alignment, and with support saddles which mate with the DC base collar trunnions. The common outer diameter on the various DC base collars allows the transfer cart guide and saddle spacing to be fixed. The trunnion support saddles are equipped with electromechanical devices which will secure the DC base collar trunnions to the cart to prevent DC tip-over. The DC transfer cart/rail system also provides features to prevent cart or DC tip-over. The DC transfer cart is driven along the rails by means of an electromechanical drive system, with power provided to the cart by an umbilical system or a conductor bar system. Sensors/limit switches and locking pins facilitate positioning of the DC cart at the transfer stations.

The 8'-2" spacing between the guides and the trunnion support saddle configurations and locations are based on the configurations of the DC base collars as described in Section 7.1.5.11.

The overall length, width, and height of the transfer cart, including guide height, are based on industry data and engineering judgement (Assumption 4.3.8). The 11'-0" x 11'-0" length and width are based on a reasonable envelope to accommodate the DC base collar 8'-2" outer diameter, the trunnion support saddles, and the transfer cart drive system (motor, gear reducer, drive components, etc.). The 2'-0" height of the cart is based on the estimated structure and wheel size needed to accommodate the maximum DC weight. The 4'-0" height of cart with the guides is based on the need to guide and align the DC and base collar as the DC is lowered onto the cart surface and the trunnion support saddles engage the trunnions.

Figure 7.1-10. DC Transfer Cart, PC-CR-111

7.1.5.10 DC Lifting Collar, PD-FX-117

The DC lifting collar, PD-FX-117, is shown in Figure 7.1-11. The DC lifting collar provides the means for lifting and handling the DC during DC Handling System operations in the DC cell. The lifting collar is equipped with guides to align the collar with the DC and three locking pins which engage the three holes provided in the DC upper skirt. Trunnions are provided on the outer diameter of the collar for engagement by the DC lifting yoke. This collar accommodates DC with outside diameters ranging from 6'-4.77" (1.95 m) to 6'-6.74" (2.0 m).

The inner diameter of the lifting collar is based on the DC outer diameter and skirt thickness (See Assumption 4.3.6). The number and configuration of the locking pins is based on the handling holes provided in the DC upper skirt (Reference 5.14, p. I-3). The outer diameter and height of the collar and the sizes of the trunnions are based on Assumption 4.3.7.

7.1.5.11 DC Base Collar, PD-FX-118

The DC base collar, PD-FX-118, is shown in Figure 7.1-12. The DC base collars provide the means for securing the DC to the transfer carts during DC loading operations. The base collar is equipped with guides to align the collar with the DC lower skirt and three remotely operated locking pins, similar to those in the DC lifting collar, which engage the three holes in the DC lower skirt. Trunnions are provided on the outer diameter of the collar for engagement by the DC cart and trunnion locking devices. The lower surface of the base collar provides a protective interface between the DC and various surfaces when the DC is supported vertically, thereby preventing potential damage to the DC lower skirt.

The inner diameter of the base collar is based on the DC outer diameter and skirt thickness (See Assumption 4.3.6). The number and configuration of the locking pins are based on the handling holes provided in the DC lower skirt (Reference 5.14, p. I-3). The outer diameter and the heights of the collars and the sizes of the trunnions are based on Assumption 4.3.7.

Figure 7.1-11. DC Lifting Collar, PD-FX-117

Figure 7.1-12. DC Base Collar, PD-FX-118

7.2 EQUIPMENT ALTERNATIVES, CAPACITIES, AND SIZES

This section contains a discussion of the alternatives for the equipment in the Canister Transfer System, where applicable, and a summary of estimated equipment capacities, sizes, and maximum dimensional envelopes.

7.2.1 Equipment Alternative Configurations Considered

The following alternative configurations for the equipment in the Canister Transfer System were considered before arriving at the equipment preferred configuration presented in this analysis.

7.2.1.1 Cask Lid Lifting Fixture, PC-FX-110

The cask lid lifting fixture (PC-FX-110) preferred in this analysis is a plate with three holes for bolts, a round cylindrical structure, three web supports, a lifting bail with a lifting bail pin, bolts, and guide pins. The lifting bail is mounted on the cylinder. The webs are used for structural support of the round cylinder and the plate. This fixture is manually or remotely attached in the cask preparation area.

Alternatives configuration considered included:

- 1) A cask lid fixture that was used for removing a cask lid in the ACD (Reference 5.10, Vol. II, page 7-120). The cask lid remover is a remotely operated fixture that lifts a loosened cask lid. The lid remover is mounted to the ceiling of the canistered waste cask room. The lid remover uses pneumatic nut-runners that engage the lifting bolt holes on a shipping cask lid. The lid remover can be pre-programmed for different cask lid bolt patterns.
- 2) Remote/manual installation of three eye bolts used for symmetrical three-point lifting. A wire rope sling or lift beam is used to lift the cask lid. The minimum lifting angle between a horizontal plane and the lifting cable attached to the eye bolts is assumed to be 45 degrees.

The preferred cask lid lifting fixture configuration was selected for the following reasons:

- 1) No programming is necessary to accommodate the different bolt patterns. The recommended configuration employs multiple fixtures designed for each cask type, possibly increasing reliability and cost effectiveness.
- 2) Remote eyebolts installation and rigging of the lifting sling would be very difficult. Therefore, higher reliance on manual installation would be required. Manual installation would result in higher radiation dose exposure to operators.

7.2.1.2 Large Canister Lifting Fixture, PC-FX-111

The large canister lifting fixture (PC-FX-111) preferred in this analysis is a lifting fixture that provides the means for lifting a large canister from the cask to the DC (see Section 7.1.5.3).

The large canister lifting fixture consists of a round plate with three holes for bolts, a round cylindrical structure, three web supports, a lifting bail with a lifting bail pin, bolts, and guide pins. The lifting bail is housed on the round cylinder. The webs are used for structural support of the round cylinder and the plate.

Alternatives configuration considered included:

- 1) An automatic-center-of-gravity lifting fixture that adjusts the center of gravity of the canister to eliminate the vertical misalignment. The automatic-center-of-gravity lifting fixture includes two rotating weights on top that rotate until the misalignment is eliminated (see ACD, Reference 5.10, Vol. II, page 7-121).
- 2) Remote/manual installation of three eyebolts used for symmetrical three-point lifting. A wire rope sling or lift beam is used to lift the cask lid. The minimum lifting angle between a horizontal plane and the lifting cable attached to the eyebolts is assumed to be 45 degrees.

The preferred large canister lifting fixture configuration was selected for the following reasons:

- 1) The automatic center-of-gravity lifting fixture is more complex and is less reliable. The recommended configuration would employ multiple lifting fixtures designed for each canister type. This reduces the level of complexity during installation and operation and the size of the lifting fixture.
- 2) Remote eyebolts installation and rigging the lifting sling would be very difficult. Therefore, higher reliance on manual installation is required. Manual installation will result in higher radiation dose exposure to operators.

7.2.1.3 DC Transfer Cart, PC-CR-111

The DC transfer cart preferred in this analysis is 11'-0" x 11'-0" and is equipped with guides to engage the DC base collars (the outer diameter of the base collars are identical for all sizes of DC). Support saddles with locking mechanisms are provided on the cart to engage the DC base collar trunnions for prevention of DC tip-over.

Alternatives configuration considered included:

- 1) A 15'-0" x 15'-0" DC cart that was used for DC transfer in the ACD (Reference 5.10, Vol. II, page 7-124) and the WHSCA (Reference 5.1). The cart provides three adjustable chucks to guide and secure DC of various diameters to the cart. The

adjustable chucks are mounted on the turntable, which rotates the DC for loading and lid welding operations.

- 2) A DC transfer cart with adjustable chucks which are equipped with trunnions/pins that engage the three handling holes in the DC lower skirt. By engaging the DC lower skirt handling holes with the transfer cart chucks, a lower DC handling collar will not be required.
- 3) A transfer cart with a fixed circular structural frame that encloses the vertical DC near its center of gravity to prevent DC tip-over. This configuration requires the DC to be lifted over this frame in order to be positioned on the cart.

The preferred DC transfer cart configuration was selected for the following reasons:

- 1) By using DC base collars with a fixed outer diameter on the bottom of all DC, fixed guides can be used for positioning a DC on the cart. This fixed diameter and elimination of the turntable do away with the complex adjustable chucks.
- 2) By eliminating the transfer cart turntable and adjustable chuck, the basic length and width of the cart can be reduced from 15'-0" x 15'-0" to 11'-0" x 11'-0". This smaller cart size results in narrower shield and isolation doors and smaller rooms for waste handling.
- 3) The cart with a fixed circular frame requires the DC to be lifted higher than 6'-6.74" (2 m) to place the DC on the cart. This is very undesirable from a heavy-lift safety perspective.

7.2.2 Equipment List, Capacities, and Sizes

The equipment identifier, description, capacity, and maximum dimensional envelope (sizes) for the Canister Transfer System equipment are shown in Table 7.2-1. The capacities shown are calculated using the maximum load for the equipment and the figures provided in this analysis. A reference is provided to the figure depicting the equipment. Attachment I provides the calculations and estimated capacity of each equipment item.

Table 7.2-1. Major Equipment in the Canister Transfer System

Equipment Identifier (Ref. 5.13)	Description	Capacity*	Max Envelopes (x,y,z)	Reference
PC-CN-110	Canister Cell Bridge Crane	65 ton	span 33'-0" width 23'-0" height 15'-0"	Figure 7.1-2
PC-FX-110	Cask Lid Lifting Fixture	5 ton	diameter 4'-10" height 2'-8"	Figure 7.1-3
PC-FX-111	Large Canister Lifting Fixture	65 ton	diameter 4'-8" height 3'-10"	Figure 7.1-4
PC-FX-112	DHLW/DOE SNF Canister Lifting Fixture	4/10 ton	diameter 1'-6" height 2'-10"	Figure 7.1-5
PC-SR-110	DHLW/DOE SNF Canister Staging Rack	4 DHLW or DOE SNF canisters	length 4'-10" width 4'-10" height 8'-0"	Figure 7.1-6
PC-EM-110	Cask Preparation Manipulator	150 lb 6 ton (hoist)	span 37'-0" width 7'-9" height 11'-0"	Figure 7.1-7
PC-EM-111	Canister Transfer Manipulator	150 lb 6 ton (hoist)	span 33'-0" width 8'-2" height 11'-0"	Figure 7.1-8
PC-CR-110	Cask Transfer Cart	125 ton	length 15'-0" width 11'-0" height 4'-0"	Figure 7.1-9
PC-CR-111	DC Transfer Cart	83 ton	length 11'-0" width 11'-0" height 4'-0"	Figure 7.1-10
PD-FX-117	DC Lifting Collar	83 ton	length 9'-6" diameter 8'-2" height 1'-2"	Figure 7.1-11
PD-FX-118	DC Base Collar	83 ton	length 9'-6" diameter 8'-2" height 1'-2"	Figure 7.1-12

* Estimated capacity calculations are provided in Attachment I.

7.3 EQUIPMENT ARRANGEMENT AND SPACE ALLOCATION

For this analysis, only one canister transfer line is discussed, since both transfer lines are identical. This preferred configuration consists of two areas: the cask preparation/decontamination area (plus airlock) and the canister handling hot cell. Waste movement is from the cask preparation/decontamination area through the canister handling hot cell. This section describes each area and discusses the equipment arrangement and space allocated for that area, as well as the major factors that determined the size.

7.3.1 Cask Preparation/Decontamination Area (Plus Airlock)

The cask preparation/decontamination area includes an airlock, a cask preparation station, and a cask decontamination station (Figures 7.1-1, 7.3-1, and 7.3-2). The airlocks are provided to maintain the facilities confinement pressure. The airlock accommodates one loaded cask on a cart either entering or exiting. The cask preparation station accommodates one loaded cask for preparation. The cask decontamination station accommodates one cask (after the cask has been unloaded in the canister handling hot cell). The cask preparation/decontamination area measures 45'(l) x 38'(w) x 40'(h). The airlock area measures 39'-6"(l) x 23'(w) x 27'(h).

7.3.1.1 Equipment Arrangement

The primary equipment in the cask preparation/decontamination area is the cask preparation manipulator (PC-EM-110). The large/DOE SNF and small cask lid lifting fixture (PC-FX-110), the large canister lifting fixture (PC-FX-111), and small canister lifting fixture, the DHLW cask lid lifting fixture, the cask on the cart, the airlock/preparation isolation door (PC-DO-111), the airlock isolation door (PC-DO-110), and the transfer shield door (PC-DO-112) were also considered for equipment arrangement and space allocation. This analysis uses the large canister lifting fixture for space allocation, since the small lifting fixtures require less room. Detailed descriptions of the equipment are in Section 7.1-5. The equipment arrangements and their spatial relationship are shown in Figures 7.3-1 and 7.3-2. The three shield doors are located on the inside of the room for cask entrance and exit, and the cask is on a cart with a total height of 19'-6". The casks are positioned at the appropriate station for preparation or decontamination operations.

7.3.1.2 Space Allocation

The equipment layout and space allocation are shown in Figures 7.3-1 and 7.3-2 in a plan view and a sectional view. The plan view is used to allocate space in x-y (length-width) directions, and the sectional view is used to allocate space in the z (height) direction.

The 38' cask preparation/decontamination area width shown in Figure 7.3-1 is based on door size. The conceptual design of the facility relies on an 11' x 15' cart to move the cask from one area to another. The shielded door width of 17' is based on the 11' cart width plus a 1' clearance on each side plus a 2' overlap of the door with the wall on each side of the door.

Figure 7.3-1. Cask Preparation/Decontamination Area (Plus Airlock) (Plan View)

Figure 7.3-2. Cask Preparation/Decontamination Area (Plus Airlock) (Section View)

The 45' cask preparation/decontamination area length shown in Figure 7.3-1 is based on two stations in the cask preparation/decontamination area with an assumed 3' clearance between the cart and the door at either end of the cell and an allowance for a 1' thick airlock door (PC-DO-111) and a 5' thick shield door (PC-DO-112).

The 40' cask preparation/decontamination area height shown in Figure 7.3-2 is based on a 2' cart height, plus 17'-6" for the large canister cask height (Assumption 4.3.7), plus a 7'-6" cask-to-manipulator clearance, plus an 11' manipulator height, plus a 2' clearance from the manipulator to the ceiling. The 27' maximum reach for the manipulator is from the manipulator shoulder to the floor. The door opening height of 21' is based on the 19'-6" cask-on-the-cart height plus a 1'-6" clearance.

The 39'-6" airlock width shown in Figure 7.3-1 is based on the same 17' door size (PC-DO-110) as the cask preparation/decontamination area.

The 23' airlock length shown in Figure 7.3-1 is based on accommodating one cask on the cart plus a 4' clearance to the wall on either side of the cask.

The 27' airlock height shown in Figure 7.3-2 is based on maintaining the same ceiling height as the adjacent cell, which is preferred from a structural design standpoint. This allows a 2' cart height, plus a 17'-6" cask plus a 7'-6" clearance from the cask to ceiling.

7.3.2 Canister Handling Hot Cell

The canister handling hot cell includes a transfer station, a DC loading station, a DHLW/DOE SNF canister staging station, and a maintenance bay area to perform crane and manipulator maintenance (see Figures 7.3-3 and 7.3-4). The transfer station accommodates one loaded cask and cart for unloading, and the DC loading station accommodates one DC and cart for loading canisters. The canister handling hot cell is fully enclosed by thick concrete walls, floors, and ceiling on all sides. The canister handling hot cell is 92'(l) x 34'(w) x 64'(h).

7.3.2.1 Equipment Arrangement

The equipment located in the canister handling hot cell includes: the canister cell bridge crane (PC-CN-110), the canister transfer manipulator (PC-EM-111), the DC transfer cart (PC-CR-111), and the DHLW/DOE SNF canister staging rack (PC-SR-110). The cask on the cart, the DC, the DC base collar (PD-FX-118), the lifting collar (PC-FX-117), the DHLW/DOE SNF canister lifting fixture (PC-FX-112), the canister, the DC cell shield door (PC-DO-113), and the transfer cell shield door (PC-DO-112) were also considered for equipment arrangement and space allocation. Detailed descriptions of the equipment are provided in Section 7.1.5. The equipment arrangements and their spatial relationships are shown in Figure 7.3-3 and 7.3-4. The DHLW/DOE SNF canister staging area is in one corner. The crane hook is able to reach each canister. The transfer station and DC loading station are set next to each other with a 1' clearance for easy handling between them. One shield door is located inside the cell to allow the entrance and exit of a DC on a cart. The transfer shield cell shield door is located outside the cell.

Figure 7.3-3. Canister Handling Hot Cell (Plan View)

Figure 7.3-4. Canister Handling Hot Cell (Section View)

7.3.2.2 Space Allocation

The equipment layout and space allocation for the canister handling hot cell are shown in Figures 7.3-3 and 7.3-4. The plan view is used to allocate space in an x-y (length-width) direction as shown in Figure 7.3-3, and the sectional view is used to allocate space in the z (height) direction as shown in Figure 7.3-4.

The 32' maintenance bay width is based on the 23' bridge crane end truck (Figure 7.1-2) plus 4'-6" on either side of the crane for operator platform and operation activity. The 36' maintenance bay height (Figure 7.3-4) is based on a 2' clearance (maintenance bay floor to manipulator) plus an 11' manipulator height plus a 21' bridge crane height plus a 2' bridge crane clearance.

The 34' canister handling hot cell width shown in Figure 7.3-3 is based on door size. The conceptual design of the facility relies on an 11' wide cart to move the cask or DC from one area to another. The shielded door width of 17' is based on the 11' cart width plus a 1' clearance on each side plus a 2' overlap on each side of the door. The open door measures 13', there is a 1' clearance between the open door and the cell wall, and a 3' clearance from the doorway to the wall. The 34' total width is also based adding the 11' width of the DHLW canister staging station, the 5' wide concert shield wall (Reference 5.15, page 34), the 17' shield door, and the 1' door clearance to the cell wall.

The 92' canister handling hot cell length as shown in Figure 7.3-3 was determined by the need to accommodate a 15' long cask cart station and an 11' long DC cart station with a 1' clearance between them, a 37' long canister staging station (24'-2", 5 rack, plus 12' bridge crane and 10" clearance), a 5' concrete wall (Assumption 4.3.6), the 32' long maintenance bay (where the crane and manipulator are pulled in for maintenance), and an 18' clearance between the waste staging area DHLW/DOE SNF station and maintenance bay (lifting fixture staging and operation activity).

The 64' height of the canister handling hot cell, as shown in Figure 7.3-4, is based on the 24' high shield door (PC-DO-113), the 4' distance (2' from the door to the maintenance bay plus a 2' maintenance floor thickness), and the 36' maintenance bay height.

The 22' door opening height is based on a 19' (18"-6.83" DC height was rounded to 19') DC plus 2' cart height plus a 1' clearance. The manipulator (PC-EM-111) height of 32' (31' max reach plus 1' gap) is based on the need for the manipulator to be able to reach around the DC bottom and top (21' above the floor) and to also be able to pull inside the maintenance bay.

8. CONCLUSIONS

Due to the unqualified/unconfirmed input data used in this analysis, the output/conclusions from this analysis cannot be used as input into documents supporting procurement, fabrication, or construction unless they are controlled and tracked as TBV or TBD in accordance with NLP-3-15.

The system design methodology for performing this analysis was established in Section 3.0. In Section 4.0, the design inputs were identified and assumptions were established for undocumented design inputs or unknown sets of data.

Section 7.0 describes updates to the configuration of the CTS since issuance of the WHSCA (Section 7.1.1), and discusses CTS alternatives considered and the CTS configuration selected to be used for this analysis (Section 7.1.2). The preferred configuration is similar to the configuration that was modeled in the WHSCA, which was shown to meet the required throughput. No simulations have been run for the other configurations, and until further simulations have been completed, the adequacy of the other alternatives is undetermined. Therefore, the CTS configuration selected in Section 7.1.2 is the current preferred CTS configuration.

Using the preferred CTS configuration, an equipment arrangement and space allocation was performed for the two primary areas of the CTS: the cask preparation/ decontamination area and the canister handling hot cell. The analysis briefly describes the CTS (Section 7.1.3), identifies system equipment (Section 7.1.4), and describes each piece of equipment used in the CTS (Section 7.1.5). A list of the equipment and its arrangement in each area is provided. Each area is sized with respect to that equipment. Overall space allocation dimensions are provided for each area, including length, width, and height (see Section 7.3). Based on the calculation shown in Table 8-1, the total net floor space required for the Canister Transfer System is 11,494 sq ft.

Table 8-1. Canister Transfer System Net Floor Space

Area	Dimensions (in feet)	Area sq ft (One line)	x 2 Lines	Total Area sq ft (Both lines)
Airlock	39.5 x 23	909	x2	1,818
Cask Preparation Area	38 x 45	1,710	x2	3,420
Canister Handling Hot Cell	34 x 92	3,128	x2	6,256
Total		5,747	x2	11,494

Note: The results in this table are based on TBV inputs and are not for construction or procurement.

The scope of this design analysis did not include the following activities, which should be conducted prior to license application :

- a. Research into new technologies or consideration of unproven design concepts
- b. Detailed trade-off evaluations of alternative design concepts (i.e., Kepner-Tregoe (K-T) analyses)
- c. Surveys or formal data requests with nuclear industry suppliers and manufacturers

- d. Extensive analyses of waste forms, types, and configurations handled [including Department of Energy (DOE) special nuclear fuel (SNF)]
- e. Major departures from the waste handling operations assumed in the WHSCA
- f. Development of equipment databases, data sheets, and cost estimates
- g. WHB configuration optimization, simulation of revised operations, or re-examination of WHSCA conclusions
- h. West Valley Demonstration Project HLW canister lifting fixture.

Several of these activities are important elements of a complete design. Although these activities are not underway at present, they should be conducted at a later date when qualified data replaces the assumptions in the WHSCA (Reference 5.1) and the CDA (Reference 5.5).

9. ATTACHMENTS

ATTACHMENT	DESCRIPTION
I	Major Equipment Estimated Capacity Calculations

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

The mechanical design characteristics used as the basis for the equipment estimated capacity calculations included in this attachment are found in Table 4.3-1 of the main analysis, in References 5.7, 5.8, 5.9, 5.10, or 5.11, or in Assumption 4.3.6. All equipment capacities are rated to the nearest number. The weights are based on approximation of the equipment size. The specific weight of steel = 490 lb/ft³ (Reference 5.16).

Capacity (C) in tons (except where indicated) of the:

1. Canister Cell Bridge Crane, PC-CN-110

$C_{PC-CN-110}$ = large MPC canister (Table 4.3-1) + large canister lifting fixture (weight estimate on page I-3)

$$C_{PC-CN-110} = 62 + 2.12 = 64.12 \text{ tons} \approx \mathbf{65 \text{ ton rating}}$$

2. Cask Lid Lifting Fixture, PC-FX-110

$C_{PC-FX-110}$ = cask lid lifting fixture (weight estimate on page I-4) + cask lid (Reference 5.7)

$$C_{PC-FX-110} = 1.4 + 3.2 = 4.6 \approx \mathbf{5 \text{ ton rating}}$$

3. Large Canister Lifting Fixture, PC-FX-111

$C_{PC-FX-111}$ = large canister lifting fixture (weight estimate on page I-3) + large canister MPC (Table 4.3-1)

$$C_{PC-FX-111} = 2.1 + 62 = 64.1 \approx \mathbf{65 \text{ ton rating}}$$

4. DHLW Canister Lifting Fixture, PC-FX-112

$C_{PC-FX-112/DOE \text{ SNF}}$ = DHLW/DOE SNF canister lifting fixture (weight estimate on page I-5) + DHLW/DOE SNF canister (Table 4.3-1)

$$C_{PC-FX-112} = .38 + 2.85 = 3.23 \approx \mathbf{4 \text{ ton rating}}$$

$$C_{DOE \text{ SNF}} = .38 + 9.55 = 9.93 \approx \mathbf{10 \text{ ton rating}}$$

5. DHLW Canister Staging Rack, PC-SR-110

$C_{PC-SR-110}$ = 4 DHLW canisters (Table 7.2-1)

$$C_{PC-SR-110} = \mathbf{4 \text{ DHLW canisters}}$$

6. Cask Preparation Manipulator, PC-EM-110

$C_{PC-EM-110}$ = cask preparation manipulator (Assumption 4.3.8)

$$C (\text{Manipulator}) = 150 \approx \mathbf{150 \text{ lb}}$$

$$C (\text{Manipulator hoist}) = \text{Manipulator hoist (Assumption 4.3.8)}$$

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

C (Manipulator hoist) $\approx$ **6 ton**

7. Canister Transfer Manipulator, PC-EM-111

C = canister transfer manipulator (industry based - Assumption 4.3.8)

C_{PC-EM-111} (Manipulator) = 150 $\approx$ **150 lb**

C (Manipulator hoist) = Manipulator hoist (industry based - Assumption 4.3.8)

C_{PC-EM-111} (Manipulator hoist) = **6 ton rating**

8. DC Transfer Cart, PC-CR-111

C_{PC-CR-111} = DC, large MPC (Table 4.3-1) + DC lifting collar (weight estimate on pages I-6 and I-7)
+ DC base collar (weight estimate pages I-8 and I-9)

C_{PC-CR-111} = 76.05 + 3.2 + 3.2 = **82.45 $\approx$ 83 ton rating**

9. DC Lifting Collar, PD-FX-117

C_{PD-FX-117} = DC, large MPC (Table 4.3-1) + DC lifting collar (weight estimate on pages I-6 and I-7)
+ DC base collar (weight estimate pages I-8 and I-9)

C_{PD-FX-117} = 76.05 + 3.2 + 3.2 = **82.45 $\approx$ 83 ton rating**

10. DC Base Collar, PD-FX-118

C_{PD-FX-118} = DC, large MPC (Table 4.3-1) + DC lifting collar (weight estimate on pages I-6 and I-7)
+ DC base collar (weight estimate pages I-8 and I-9)

C_{PD-FX-118} = 76.05 + 3.2 + 3.2 = **82.45 $\approx$ 83 ton rating**

11. Cask Transfer Cart, PC-CR-110

C_{PC-CR-110} = Cask, large MPC (Table 4.3-1)

C_{PC-CR-110} = 125 $\approx$ **125 ton rating**

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: Large Canister Lifting Fixture (PC-FX-111)

1- Lifting bail

$$V_1 = (1.33')(2')(25')(2)$$

$$V_1 = 1.33 \text{ ft}^3$$

2- Lifting Pin

$$V_2 = (3.14)(.21')^2(.5')$$

$$V_2 = .07 \text{ ft}^3$$

3- Web

$$V_3 = (.5)(1.33')(1')(.33')(3)$$

$$V_3 = .66 \text{ ft}^3$$

4- Cylindrical Structure

$$V_4 = (3.14)(.83')^2(1.67')$$

$$V_4 = 3.61 \text{ ft}^3$$

5- Pin

$$V_{5a} = (.785)(.21')^2(.17')$$

$$V_{5a} = .006 \text{ ft}^3$$

$$V_{5b} = (.785)(.15')^2(.4')$$

$$V_{5b} = .007 \text{ ft}^3$$

$$3 V_5 = (3)(.006 + .007) = .04 \text{ ft}^3$$

6- Plate

$$V_6 = (.785)(4.7')^2(.17')$$

$$V_6 = 2.95 \text{ ft}^3$$

$$V_T = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 = 8.67 \text{ ft}^3$$

$$W = (490 \text{ lb/ft}^3)(8.67 \text{ ft}^3) = 4,248.3 \text{ lb}$$

$$W = 2.12 \text{ ton}$$

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: Cask Lid Lifting Fixture (PC-FX-110)

1- Lifting bail

$$V_1 = (1')(1.33')(0.17') = .23 \text{ ft}^3$$

$$2V_1 = 2(.23) = .46 \text{ ft}^3$$

2- Lifting Pin

$$V_2 = (3.14)(.125')^2(.33')$$

$$V_2 = .02 \text{ ft}^3$$

3- Web

$$V_3 = (.5)(1')(1.33')(0.25')(3)$$

$$V_3 = .5 \text{ ft}^3$$

4- Cylindrical Structure

$$V_4 = (3.14)(.67')^2(1.17')$$

$$V_4 = 1.65 \text{ ft}^3$$

5- Pin

$$V_{5a} = (.785)(.21')^2(.17')$$

$$V_{5a} = .006 \text{ ft}^3$$

$$V_{5b} = (.785)(.15')^2(.4')$$

$$V_{5b} = .007 \text{ ft}^3$$

$$3 V_5 = (3)(.006 + .007) = .04 \text{ ft}^3$$

6- Plate

$$V_6 = (.785)(4.83')^2(.17')$$

$$V_6 = 3.11 \text{ ft}^3$$

$$V_T = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 = 5.8 \text{ ft}^3$$

$$W = (490 \text{ lb/ft}^3)(5.8 \text{ ft}^3) = 2,842 \text{ lb}$$

$$W = 1.42 \text{ ton} \approx 1.4 \text{ ton rating}$$

6

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: DHLW/DOE SNF Canister Lifting Fixture (PC-FX-112)

1- Lifting bail

$$V_1 = (.54')(.54')(.042') + (.63')(.83')(.042')$$

$$V_1 = .012 + .022 = .034 \text{ ft}^3$$

$$2V_1 = .07 \text{ ft}^3$$

2- Lifting Pin

$$V_2 = (3.14)(.071')^2(.33')$$

$$V_2 = .01 \text{ ft}^3$$

3- Cylindrical Structure

$$V_3 = (3.14)(.583')^2(1.25')$$

$$V_3 = 1.33 \text{ ft}^3$$

4- Gripper

$$V_4 = .583'((.29')(.583') - (.125')(.42'))$$

$$V_4 \approx .07 \text{ ft}^3$$

$$2V_4 = 2(.07) = .14 \text{ ft}^3$$

$$V_T = V_1 + V_2 + V_3 + 3V_4 = 1.55 \text{ ft}^3$$

$$W = (490 \text{ lb/ft}^3)(1.55 \text{ ft}^3) \approx 760 \text{ lb}$$

$$W \approx .38 \text{ ton}$$

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: DC Lifting Collar (PD-FX-117)

$$(1) \text{ TOP } \frac{\pi}{4} (8.17^2 - 6.0^2) (.17') = 4.10 \text{ FT}^3 = 4.10 \text{ FT}^3$$

$$(2) \text{ OUTER RING } \frac{\pi}{4} (8.17^2 - 7.83^2) (1) = 4.27 \text{ FT}^3 = 4.27 \text{ FT}^3$$

2" THICK

$$(3) \text{ TRUNNIONS } \frac{\pi}{4} (.5)^2 (.542') = .106 \text{ FT}^3$$

$$\frac{\pi}{4} (.67)^2 (.125) = .044 \text{ FT}^3$$

$$\text{TOTAL} = .150 \text{ FT}^3$$

$$2 \text{ TRUNNIONS} =$$

$$2 \times .150 = .30 \text{ FT}^3$$

(4) PINS

$$\frac{\pi}{4} (.23)^2 \left(\frac{12.25}{12} \right) = .0424 \text{ FT}^3$$

$$\frac{\pi}{4} (.75)^2 (.125) = .0550 \text{ FT}^3$$

$$.0974 \times 3 \text{ PINS}$$

$$= .29 \text{ FT}^3$$

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: DC Lifting Collar (PD-FX-117), continued

(5) GUIDES (THREE)

7.375" = .615'

6" THICK

$$[(.615)(1) - (.5)(.115)(.167)] \cdot 5 = .303 \text{ FT}^3$$

$$3 \text{ GUIDES} = .303 \times 3 = \underline{.909 \text{ FT}^3}$$

7.375 - 6.00 = 1.375" = .115'

2" = .167'

(6) WEBS (TWO)

2" THICK

$$(1)(.33)(.17) = .056 \times 2 \text{ WEBS} = \underline{.112 \text{ FT}^3}$$

(7) WEBS (FOUR)

1" THICK

$$(1)(.33)(.08) = .0264 \times 4 \text{ WEBS} = \underline{.106 \text{ FT}^3}$$

(8) INNER RING

$$\text{O.D.} = 7'-2" = 7.17' \quad \frac{\pi}{4} (7.17'^2 - 6.92'^2)(1) = 2.77 \quad \underline{2.77 \text{ FT}^3}$$

DEPTH = 1'

THICKNESS = 1.5"

$$\text{TOTAL VOLUME} = \underline{12.86 \text{ FT}^3}$$

$$\text{TOTAL WT. LIFTING COLLAR} = 12.86 \text{ FT}^3 \times 490 \text{ LB/FT}^3 = \underline{6301 \text{ LB}}$$

$$\text{USE } \underline{6400 \text{ LB}} = \underline{3.2 \text{ TONS}}$$

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: DC Base Collar (PD-FX-118)

MAJOR EQUIPMENT ESTIMATED CAPACITY CALCULATIONS

Weight Estimate: DC Base Collar (PD-FX-118), continued

(5) GUIDES (THREE)

7.375" = .615'

6" THICK

$$\left[(.615)(1) - (.5)(.115)(.167) \right] \cdot 5 = .303 \text{ FT}^3$$

$$3 \text{ GUIDES} = .303 \times 3 = \underline{.909 \text{ FT}^3}$$

7.375 - 6.00 = 1.375" = .115'

2" = .167'

(6) WEBS (TWO)

2" THICK

$$(1)(.33)(.17) = .056 \times 2 \text{ WEBS} = \underline{.112 \text{ FT}^3}$$

(7) WEBS (FOUR)

1" THICK

$$(1)(.33)(.08) = .0264 \times 4 \text{ WEBS} = \underline{.106 \text{ FT}^3}$$

(8) INNER RING

$$\text{O.D.} = 7'-2" = 7.17' \quad \frac{\pi}{4} (7.17'^2 - 6.92'^2)(1) = 2.77 \quad \underline{2.77 \text{ FT}^3}$$

DEPTH = 1'

THICKNESS = 1.5"

TOTAL VOLUME = 12.86 FT³

TOTAL WT. LIFTING COLLAR = $12.86 \text{ FT}^3 \times 490 \text{ LB/FT}^3 = \underline{6301 \text{ LB}}$

USE 6400 LB = 3.2 TONS