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APPENDIX B
INTERIM STORAGE AND STAGING

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CONTENTS

ATTACHMENTS

FIGURES

TABLES

LIST OF TERMS

CSB	Canister Storage Building
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
HEPA	high-efficiency particulate air
HSF	Hanford Shipping Facility
HVAC	heating, ventilation, and air conditioning
IHLW	immobilized high-level waste
MCO	multi-canister overpack
MGR	monitored geologic repository
SCT	shielded canister transporter
SNF	spent nuclear fuel
SRS	Savannah River Site
WTP	Waste Treatment Plant

B1.0 PROBLEM STATEMENT

This appendix evaluates several interim storage and staging functional requirements alternatives for the Hanford Shipping Facility (HSF) and answers the following question:

> What is the preferred technically feasible and cost-effective method to provide storage of 2,000 immobilized high-level waste (IHLW) canisters and provide staging of IHLW, multi-canister overpacks (MCOs), and U.S. Department of Energy (DOE) standard canisters as required to support HSF operations, Waste Treatment Plant (WTP) delivery rate, and Monitored Geologic Repository (MGR) acceptance rate?

B2.0 DECISION ANALYSIS SUMMARY

Several alternatives for the storage and staging functions are evaluated in this appendix. The storage alternatives fall into four basic concepts, as defined in the following list.

A. **Open rack vault concept** – Used in facilities in the U.K. and used on a smaller scale for staging in the U.S. The following four alternatives are evaluated:

   1. One open vault with a one layer of canisters in a rack
   2. One open vault with canisters stacked two high in a rack
   3. Two open vaults with a one layer of canisters in a rack
   4. Two open vaults with canisters stacked two high in a rack.

B. **Closed tube vault concept** – Used in the existing Canister Storage Building (CSB) at Hanford. The following four alternatives are evaluated:

   1. One vault with an array of canister storage tubes and with one canister in each storage tube
   2. One vault with an array of canister storage tubes with two canisters stacked in each storage tube
   3. Two vaults with arrays of canister storage tubes and with one canister in each storage tube
   4. Two vaults with arrays of canister storage tubes and with two canisters stacked in each storage tube.

C. **Savannah river vault concept** – A variation of the CSB concept using a wheeled shielded canister transporter (SCT). The following two alternatives are evaluated:

   1. One vault with an array of access ports to a rack for one layer of canisters

2. One vault with an array of access ports to a rack for stacking canisters two high.

D. **Dry cask storage concept** – Used in the U.S. for temporary storage of spent nuclear fuel (SNF). The following two alternatives are evaluated:

1. One canister capacity storage cask with horizontal loading and storage

2. Five canister capacity storage cask with vertical loading and storage.

Arrangements were developed for each of the storage alternatives. Basic layouts were developed for each storage alternative and alternatives for the staging function were also analyzed. Capital cost estimates for discriminating cost elements and construction quantities were developed for comparison.

B3.0 CONSTRAINTS, ASSUMPTIONS, AND RISKS

This section identifies the constraints and assumptions used in the evaluation and any associated uncertainty or risk. The following are constraints and assumptions used in this evaluation:

- The storage and staging alternatives shall comply with all relevant requirements in *Hanford Shipping Facility System Specification* (RPP-20270).
- The HSF throughput shall be based on a just-in-time philosophy that will receive IHLW at the WTP production rate for immediate shipment to the MGR (RPP-20270).
- The HSF shall be designed to receive 2 IHLW canisters per day in accordance with *ICD 14 – Interface Control Document for Immobilized High-Level Waste* (24590-WTP-ICD-MG-01-014) to prevent impact to WTP operations (RPP-20270). WTP has a canister storage area for 45 IHLW canisters, and the WTP nominal production rate is 480 canisters per year.
- The staging area shall be designed for two IHLW canisters per day receipt rate and the projected HSF availability and MGR cask availability. However, the size of the staging area could be decreased if the WTP storage area (or a portion thereof) could be specified for use during periods of HSF outage.
- The storage area shall be sized for interim storage of up to 2,000 IHLW canisters ("Solicitation No. 109427 For Hanford Shipping Facility (W-QQQ) Feasibility Study, Statement of Work" [CHG 2004]). Based on this constraint it is assumed that storage will not be provided for MCOs and DOE standard canisters and that only staging will be provided.
- The staging area shall include staging for IHLW, MCO, and DOE standard canisters (CHG 2004).

- Peak HSF throughput rates will be accommodated by additional shift operations. Based on initial time and motion studies, the assumption is that normal operations will be based on two 8-hour shifts, 5 days per week, and operational for 240 days per year.

- 9,400 IHLW canisters, 418 MCOs and 71 DOE standard canisters are to be processed through the HSF (CHG 2004). The facility shall be designed for this total throughput.

- The allowable shipment rates of canisters from the Hanford Site to the MGR are 655 IHLW canisters per year concurrent with either 78 MCOs or 36 DOE standard canisters (RPP-20270). Based on this and the driving receipt rate from the Hanford facilities, MGR shipment constraints are not impacted as the MGR can accept at a greater average rate than the HSF can process (i.e., 480 IHLW canisters per year maximum will be available for HSF processing).

- Receipt rate of SNF canisters is 78 MCOs per year or 36 DOE standard canisters per year. Based on the small percentage of these canisters, the assumption is that they will be 'worked in' to the overall shipping operations or will be accommodated by additional operating shifts. The flexibility to campaign these canister types has clear benefits, especially as the requirement is that the facility is 'just-in-time' and only staging (no storage) provisions are required for SNF canisters.

- The staging function is given priority over the storage function from a layout perspective and is therefore close to the load-in/load-out area.

- Staging and storage concepts, when integrated into the facility design, must be feasible with respect to the preferred sites identified in Appendix A. This means that the concepts cannot be developed in isolation to the other facility functions and facility siting constraints.

- The design shall allow for expansion for storage of IHLW canisters without negatively affecting the ability of the HSF to receive, store, and ship canisters (RPP-20270). The assumption is that the storage, staging, and load-in/load-out areas shall include provision for a shielded route for IHLW canisters to an adjacent storage module of the same capacity as the interim storage area (i.e., 2,000 canisters).

- The functional requirements for storage and staging are defined as 'interim'; however, the assumption is that the HSF storage and staging equipment is designed for a 40-year operational life.

- The canisters will maintain containment [redacted]

- Implementation of the following security constraints is assumed to be similar among the facility configuration alternatives.

  - A facility may not possess, receive, process, transport, or store special nuclear material until the facility has been cleared in accordance with *Safeguards and Security Program* (DOE O 470.1)

- A security requirements analysis risk assessment must be completed to ensure any additional protection measures are incorporated into the design of the facility.

- A security concept and design criteria document will be completed for integration of the physical security, protective force, operations security requirements, and administrative controls for the HSF.

- Category I and II quantities of special nuclear material must be protected by an integrated physical security protection system.

B4.0 ALTERNATIVES CONSIDERED

This section describes the alternates considered for the storage and staging functions of the HSF.

B4.1 STORAGE ALTERNATIVES

Alternatives for storage options were developed by analyzing proven concepts used in the U.S. and U.K. for storage of packaged high-level waste forms. There are four arrangements that have been proven to be effective:

- **Open rack vault** – The canistered waste is stored in steel racks in an open-bay vault, which has reinforced-concrete walls, floor, and roof to provide radiation shielding and containment. Canisters are loaded into the racks remotely, using an in-cell high-integrity electric overhead traveling crane that operates over the racks. A crane maintenance area is provided at one end of the vault, segregated from the main storage area by a steel shield door. This concept is used on a smaller scale at West Valley Nuclear Site Vitrification Plant, and at the Hanford WTP (currently under construction) and is in operation as the preferred concept for new waste storage facilities at the BNFL Encapsulated Waste Product Store in the U.K.

- **Closed tube vault** – The canistered waste is stored in an array of steel tubes below a reinforced-concrete 'charge floor' that provides radiation shielding and containment for the charge floor operating area. The waste is loaded into the tubes remotely using a bottom-opening cask mounted on a gantry crane, which traverses the vault operating area above the charge floor. The cask is similar to a reactor charge machine and has hoisting mechanisms to remotely remove a steel shield plug in the top of each storage tube, retain it temporarily to facilitate loading of the canister into the tube, and then replace the shield plug. The cask provides radiation shielding during canister loading and unloading operations. This concept is used effectively in the CSB at Hanford and at the BNFL vitrification plant in the U.K.

- **Savannah River Site (SRS) vault** – A variation of that used in the Hanford CSB. Canisters are stored, single-stacked in racks below a reinforced-concrete 'charge floor' that provides radiation shielding and containment for the charge floor operating area. The canisters are loaded into the racks remotely using a bottom–opening cask mounted on a modified wheel tractor unit (called the SCT) that traverses the vault operating area above the charge floor. The cask is similar to a reactor charge machine and has hoisting mechanisms to remotely remove a shield plug in the top of each storage tube, retain it temporarily to facilitate loading of the canister into the rack, and then replace the shield plug. The cask provides radiation shielding during canister loading and unloading operations. A wheeled unit is provided, as opposed to a crane because the storage building is physically separated from the processing building (i.e., Defense Waste Processing Facility).

- **Dry cask storage overpack** – Uses a concrete/steel cask to provide storage and containment of the canistered waste form, thus precluding the need for a facility-based vault arrangement. It is used in the U.S. at commercial nuclear power utilities for temporary storage of SNF. In this concept, the canisters are loaded into an overpack at the load-in/load-out cell in the HSF, and the overpack is then transported from the facility to a external concrete storage pad for storage, until required to be transported back into the HSF for loading into an MGR cask. The cask can be designed to contain different quantities of IHLW canisters. Two concepts are analyzed; the first being an overpack designed for horizontally loading a single canister and storage in the horizontal. The second is for vertical loading of five IHLW canisters in an overpack that is stored vertically.

For each of the above concepts a number of alternate configurations were developed, as listed in Table B.1. Other configurations (e.g., stacking more than three high, wider vaults) were not evaluated because of physical constraints as described in Section B4.3.3.

Table B.1. Storage Alternatives

Storage Alternative ID	Storage Concept	Storage Configuration
A1	Open rack vault	Single vault – single stack
A2	Open rack vault	Single vault – double stack
A3	Open rack vault	Dual vault – single stack
A4	Open rack vault	Dual vault – double stack
B1	Closed tube vault	Single vault arrays – single stack
B2	Closed tube vault	Single vault arrays – double stack
B3	Closed tube vault	Dual vault arrays – single stack
B4	Closed tube vault	Dual vault arrays – double stack
C1	Savannah river vault	Single vault arrays – single stack
C2	Savannah river vault	Single vault arrays – double stack
D1	Dry cask storage	Single canister overpack – horizontal loading/storage
D2	Dry cask storage	Five-canister overpack – vertical loading/storage

B4.2 OPEN RACK VAULT ALTERNATIVES

B4.2.1 Alternative A1 – Open Rack Vault, Single Vault Single Stack

In Alternative A1, canisters are single-stacked in one large open vault with a single 6-ton overhead crane operating over the racks. The canisters are arrayed 20 wide by 100 long at 36-inch centers, providing a rectangular storage configuration. A clear center corridor is provided down the center of the vault to enable greater flexibility for rack loading, and to reduce the crane lift height such that the canister will clear the rack structure (approximately half the height of a canister), but not clear a stored canister. It should be noted here that the canister centers are driven by providing a 28-inch ID guide sleeve with a flare to aid canister positioning and allowance for structural framing between canisters. The rack design will be optimized during conceptual design to provide the simplest, robust, seismic and structurally compliant cost-effective support structure that will promote heat dissipation. A conservative approach is taken here, using the WTP rack design as a basis and reducing the centers slightly (WTP uses 37 inches in one direction and 44 inches in the other direction). It is thought that rack centers could be optimized to between 32 and 36 inches. The rack supports the canister just above its center of gravity.

There is a separate crane maintenance area at one end of the vault, separated by a shield door.

The load-in/load-out equipment, including staging racks, is located in a cell adjacent to the vault, with a bogie (or transfer cart) transfer between the load-in/load-out cell and the storage vault. A separate crane is provided for the load-in/load-out cell. The storage transfer bogie tunnel extends to the perimeter of the structure to enable future connection to an additional adjacent storage vault. This concept is proven and used in operating facilities at Sellafield, U.K., as a standard method to facilitate expansion.

An active ventilation system is assumed to be required for this concept and high-efficiency particulate air (HEPA) filters, fans, and a single stack will be located in rooms adjacent to the storage vault and load-in/load-out cell crane maintenance areas, to minimize duct length between the ventilated areas and filters.

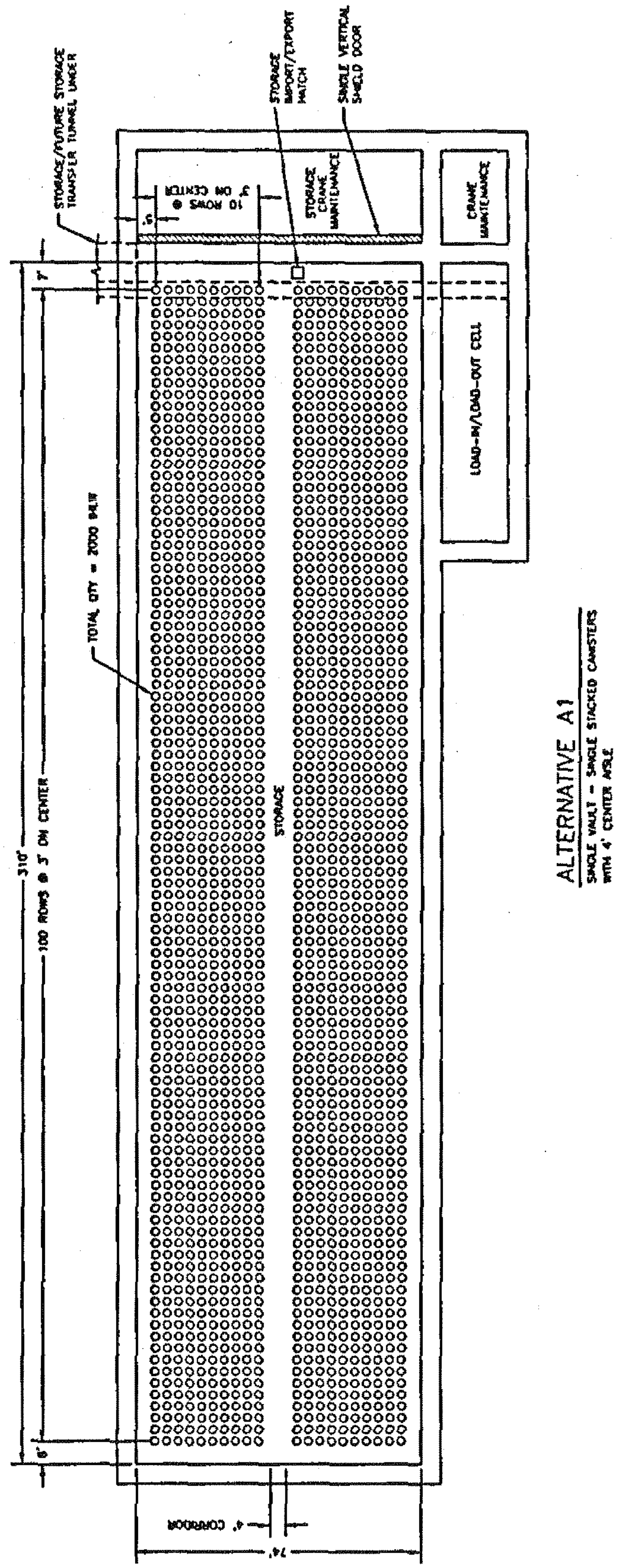
Figure B.1 shows the Alternative A1 plan configuration.

B4.2.2 Alternative A2 – Open Rack Vault, Single Vault Double Stack

In Alternative A2, canisters are double-stacked in one large open vault, with a single 6-ton overhead crane operating over the racks. The canisters are arrayed 16 wide by 63 long by 2 high at 36 inch centers, providing a rectangular storage configuration. A clear center corridor is provided down the center of the vault to enable greater flexibility for rack loading as the crane lift height is minimized to enable the canister to clear the rack structure, but not clear a stored canister.

The crane has a separate crane maintenance area at one end of the vault adjacent to the load-in/load-out cell, separated by a shield door.

Figure B.1. Alternative A1 – Open Rack Vault, Single Vault Single Stack



The load-in/load-out equipment, including staging racks, is located in a cell adjacent to the vault, with a bogie transfer between the load-in/load-out cell and the storage vault. A separate crane is provided for the load-in/load-out cell. The storage transfer bogie tunnel extends to the perimeter of the structure to enable future connection to an additional adjacent storage vault.

An active ventilation system is assumed to be required for this concept and HEPA filters, fans, and a single stack will be located in rooms adjacent to the storage vault and load-in/load-out cell crane maintenance areas to minimize duct length between the ventilated areas and filters.

Figure B.2 shows the plan configuration for this alternative.

B4.2.3 Alternative A3 – Open Rack Vault, Dual Vault Single Stack

In Alternative A3, canisters are single-stacked in two open vault areas, with each vault having a 6-ton overhead crane operating over the racks. An intermediate structural wall divides the two vault areas. The canisters are arrayed 10 wide by 100 long in each of the 2 vault areas at 36-inch centers, providing a rectangular storage configuration. A clear center corridor is provided down the center of each vault to enable greater flexibility for rack loading, as the crane lift height is minimized, to enable the canister to clear the rack structure, but not clear a stored canister.

There is a separate crane maintenance area at one end of each vault adjacent to the load-in/load-out cell, separated by one common shield door. The shield door is a single sliding door that provides shielding for one of the two crane maintenance areas at one time. The shield door incorporates a top rack and pinion drive and bottom air skates to eliminate the need for complicated lifting mechanisms on such a heavy door. The door is lifted approximately 1.25 feet off the floor by the skates and then driven sideways by the rack and pinion drive system. This type of shield door has been proven to be more cost effective than providing individual crane maintenance shield doors, where the vaults can be configured to allow adjacent crane maintenance areas.

The load-in/load-out functions, including staging racks, are located in a cell adjacent to the vault, with a bogie transfer between the load-in/load-out cell and each of the storage vaults. This bogie tunnel extends to the building perimeter and would be used for canister transfer to an adjacent storage expansion module. A separate crane is provided for the load-in/load-out cell.

An active ventilation system is assumed to be required for this concept and HEPA filters, fans, and a single stack will be located in rooms adjacent to the storage vault and load-in/load-out cell crane maintenance areas to minimize duct length between the ventilated areas and filters.

Figure B.3 shows the plan configuration for this alternative.

Figure B.2. Alternative A2 – Open Rack Vault, Single Vault Double Stack

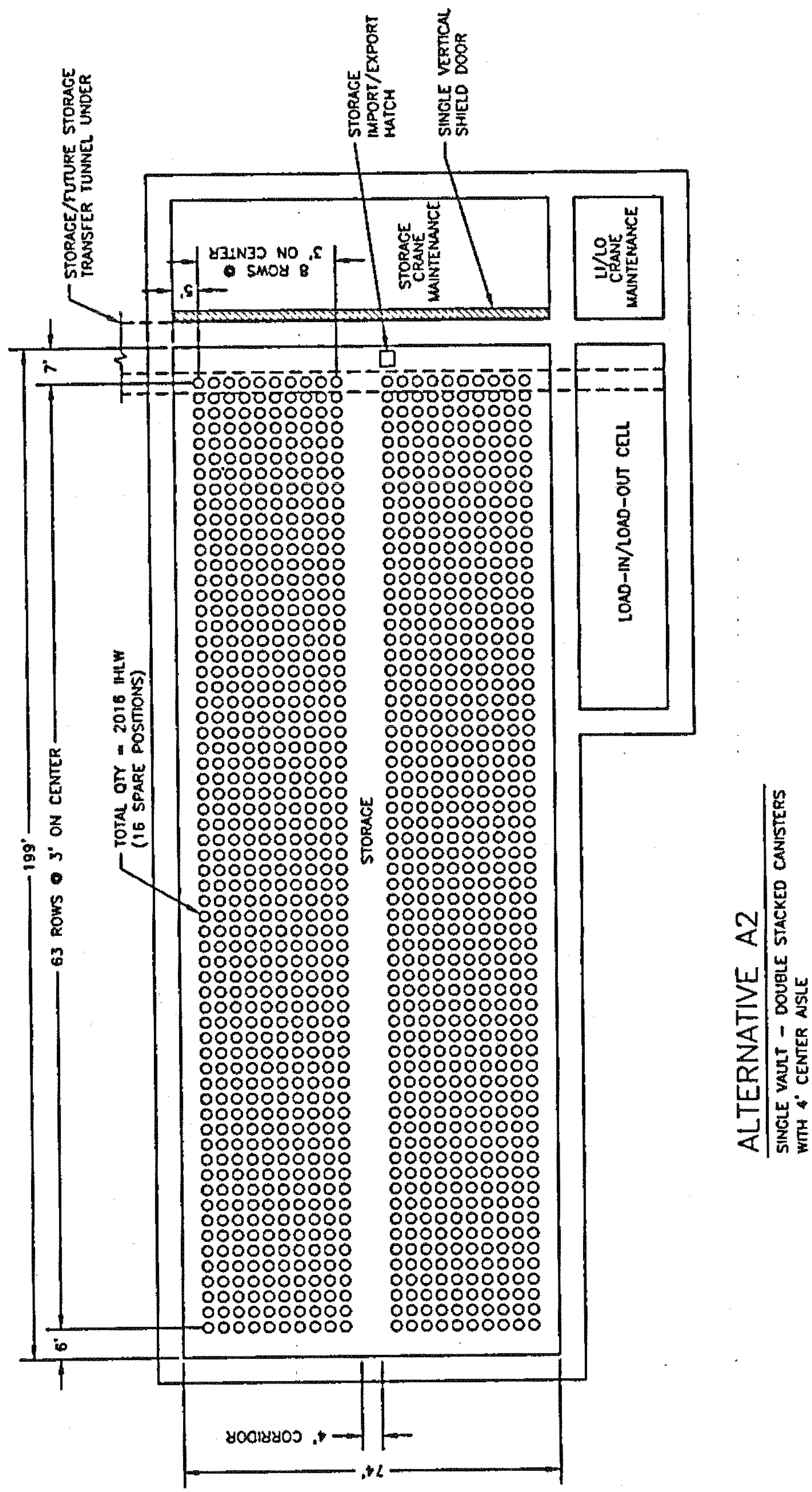
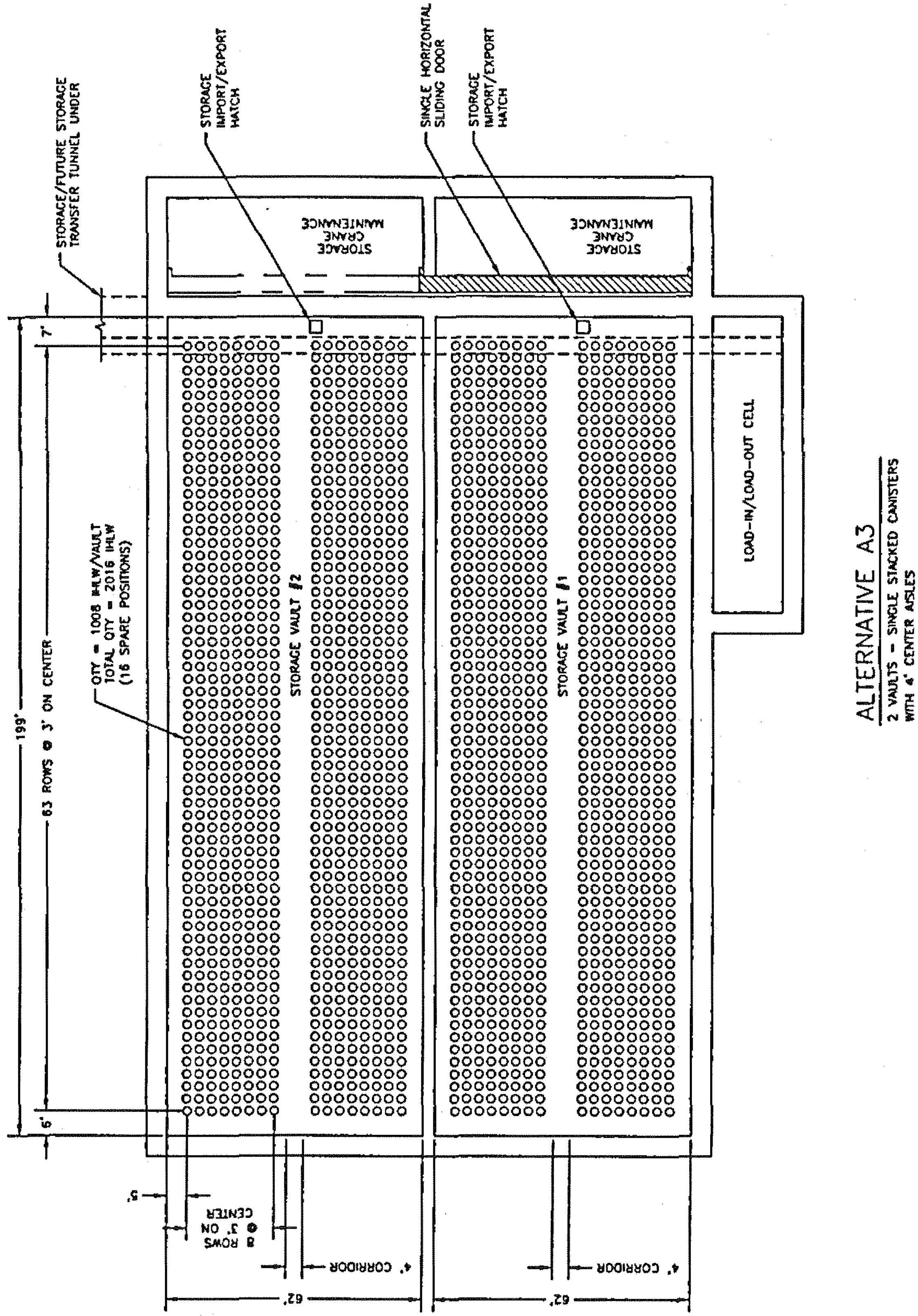


Figure B.3. Alternative A3 – Open Rack Vault, Dual Vault Single Stack



B4.2.4 Alternative A4 – Open Rack Vault, Dual Vault Double Stack

In Alternative A4, canisters are double-stacked in two open vault areas, with one vault having a 6-ton overhead crane operating over the racks and one vault having a 12-ton overhead crane operating over the racks. An intermediate structural wall divides the two vault areas. The two vault areas have different canister arrays, as the vault containing the 12-ton crane also has the load-in/load-out cell, including staging at one end, directly connected to the vault area. This gives an array of 16 wide by 36 long by 2 high in one vault and 16 wide by 28 long by 2 high in the other vault. The canisters are arrayed at 36-inch centers, providing a rectangular storage configuration. A clear center corridor is provided down the center of each vault to enable greater flexibility for rack loading, as the crane lift height is minimized, to enable the canister to clear the rack structure, but not clear a stored canister.

As the 6-ton vault crane cannot access canisters directly from the load-in/load-out cell, a bogie transfer is provided between the two vault areas, adjacent to the load-in/load-out cell. This bogie tunnel extends to the perimeter of the building to facilitate canister transfer to a future storage expansion module.

There is a separate crane maintenance area at one end of each vault adjacent to the load-in/load-out cell, separated by one common shield door. The shield door is a single sliding door that provides shielding for one of the two crane maintenance areas at one time, as described in Alternative A3.

An active ventilation system is assumed to be required for this concept and HEPA filters, fans, and a single stack will be located in rooms adjacent to the storage vault and load-in/load-out cell crane maintenance areas, to minimize duct length between the ventilated areas and filters.

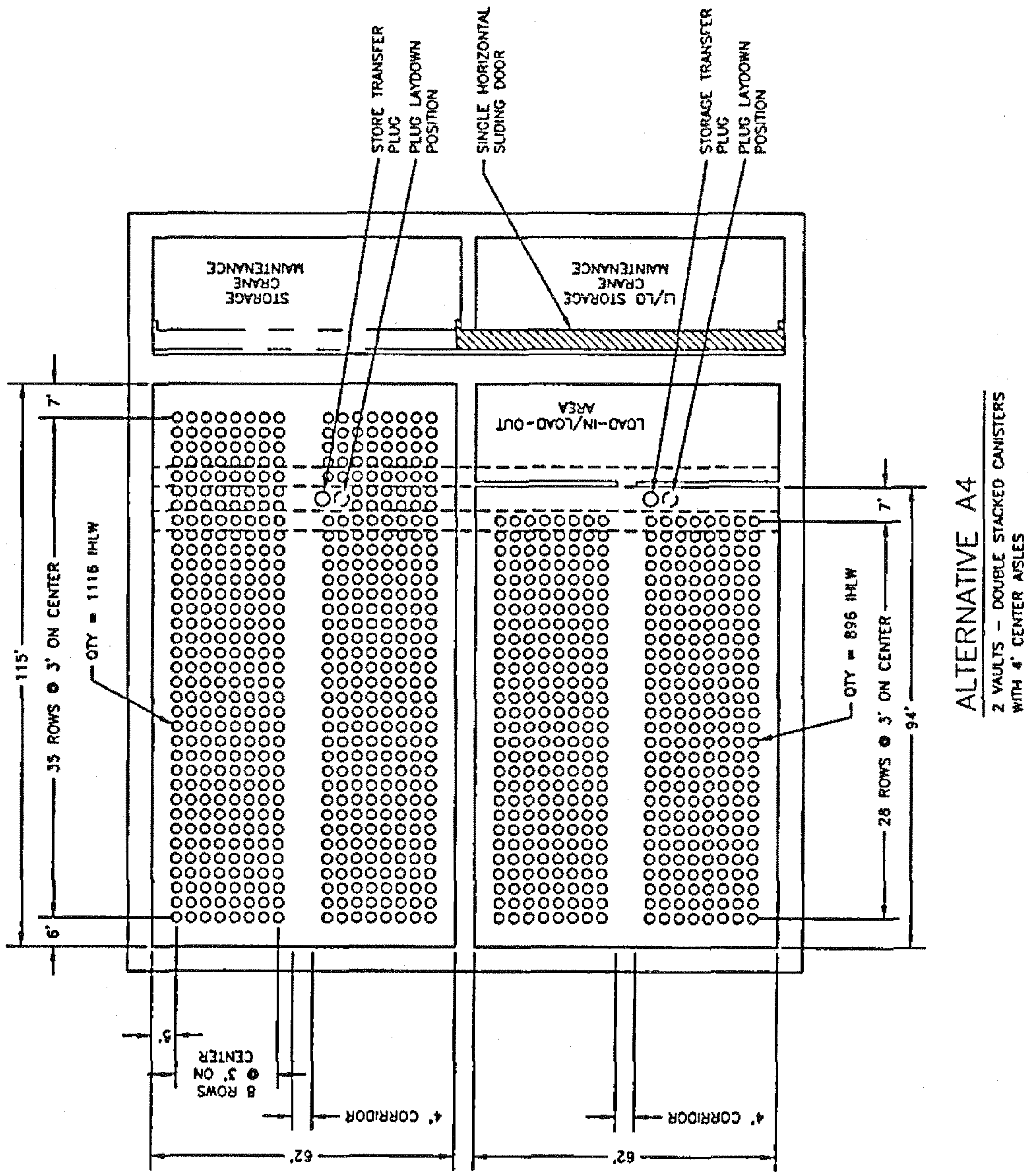
Figure B.4 shows the plan configuration for this alternative.

B4.3 VARIATIONS ON THE OPEN RACK VAULT ALTERNATIVES

B4.3.1 Rack/Canister Clearance Options

Variations for the open rack vault alternative include providing clearance over stored canisters to enable the crane to load a canister in any of the storage positions without sequencing. In base Alternatives A1 through A4, the lift height of the canister is limited to nominally 6 inches above the rack structure. A clear center corridor is provided to provide unobstructed access to each row of canisters, but within a specific row canister loading/unloading has to be sequenced, as a canister cannot pass over another canister. Removing the center corridor could further reduce the loading flexibility in the base option.

Figure B.4. Alternative A4 – Open Rack Vault, Dual Vault Double Stack



However, providing full canister clearance adds approximately 5 feet to the height of the vault. It was determined that providing full canister clearance was an unnecessary flexibility based on the following factors:

- Overall usage of the storage vault is very limited. If the whole inventory from WTP were to be cycled through the storage vault, then each rack position would be loaded and unloaded a maximum of five times during its operational life if all storage positions were used. In addition, it is not envisioned that shipments to the MGR will specify a wide range of canister mixes, and hence no need to pick canisters from a variety of locations in the storage vault, for any specific cask shipment.

- Providing full canister clearance increases the overall height of the vault, which increases cost. One major driver in nuclear facility design is to minimize the radioactive areas of the facility.

- The base option provides a degree of flexibility for loading, which is a compromise position. The clear center corridor also has other benefits such as providing potential location for heating, ventilation, and air conditioning (HVAC) ductwork, minimizing canister drop heights in the double stacking arrangement, and providing installation access.

B4.3.2 Location of the Load-In/Load-Out Cell

The location of the load-in/load-out cell is variable, dependent upon the specific alternatives evaluated. For the single-stack alternatives (Alternatives A1 and A3), the load-in/load-out cell cannot easily be located at one end of the storage vault because of head room restrictions. The load-in/load-out cell would be located directly below the crane maintenance area. As the floor of the crane maintenance area is lower than the roof of the storage vault, there is not enough head room below the crane maintenance floor for the operating equipment in the load-in/load-out cell. This assumes that the floor of the load-in/load-out cell is maintained at the same elevation as the loading bays to simplify the structural configuration and optimize the cask unloading/loading operations. It also assumes that the crane maintenance function is grouped with all the other facility functions (e.g., services) at one end of the canister storage area. Providing a crane maintenance area at the far end of the storage area, remote from all the other functions, would complicate personnel access and distribution of power.

In the double-stack alternatives (Alternatives A2 and A4) the storage vault is higher than in the single-stack arrangement so the crane maintenance area is also further elevated. This configuration provides head room below for the load-in/load-out cell equipment. This provides the flexibility to directly couple the load-in/load-out cell to the vault area and utilize the same crane for storage and load-in/load-out functions. This is further analyzed in Section B6.0.

B4.3.3 Other Storage Arrays for the Open Rack Vault Concept

Other storage arrays for the open rack concept were analyzed, but the width of each vault was constrained to a 20-canister array as a maximum because of the following:

- Spans for the high-integrity bridge crane should be maintained at less than 75 feet per crane manufacturers recommendations. This is due to a number of factors including minimizing loads on the cable reel during remote crane recovery and to simplify construction, shipment, and installation.

- It was thought that minimizing the vault array in width would lend itself to configure the HVAC to provide better air distribution and circulation over the racks than if a square configuration was used. This would need to be confirmed using computational fluid dynamic modeling of the HVAC system in the design phase.

Stacking more than two canisters in one storage position was also not analyzed for the following reasons:

- With a two-stack arrangement, the roof of the building in the crane maintenance area is approximately 90 feet, if the facility is built at grade. This was deemed a building height consistent with similar facilities. Existing crane designs were used as the basis for this study and designed to be seismically stable and the impact of seismic on cranes at higher elevations could affect and complicate the crane design. The height of the building needs to be minimized.

- It could not be determined whether the IHLW canister is designed to be stacked more than two high from a structural standpoint; therefore, stacking was limited to proven arrangements (e.g., storage at CSB).

- Ability to dissipate heat from canisters may be impacted as the density of canisters increases. Computational fluid dynamic modeling would be required to determine the severity of impact.

- Accuracy of grappling and guide features for the canister is affected as the overall stack height increases. The build up of tolerances on canisters will affect the positional repeatability of the canisters and therefore the crane positioning and grappling functions.

B4.4 CLOSED TUBE VAULT ALTERNATIVES

B4.4.1 Alternative B1 – Closed Tube Vault, Single Bank of Vaults Single Stacked

In Alternative B1, the canisters are placed in tubes beneath a reinforced-concrete 'charge floor.' Canisters are single-stacked, with the storage tubes spaced at 4-foot, 8-inch centers in one direction and 4 feet, 6 inches in the other direction ("'Drawing Index' for SNF-Canister Storage Building, Project W-379" [H-2-116004]). To optimize the storage arrangement, each row is offset by 2 feet, 4 inches; however, tube spacing is governed primarily by (1) size of the steel shield plug that seals the tube, and (2) the structural requirements for the charge floor, to achieve re-bar continuity and adequate spacing. This staggering of canisters provides a honeycomb effect. As dissipation of heat is important, it was determined that the basic configuration of the vault arrays should be maintained as that provided at CSB except the width of the vault was increased by 2 rows of 10 to make the capacity of each vault area 250. In this alternative, 8 vaults are required to achieve a 2,000 canister storage capacity. Each vault has its own passive vent system with an intake plenum and exhaust plenum coupled to a stack. Eight stacks are required. Each vault area is coupled to the next via an intermediate reinforced-concrete wall.

The charge machine/gantry crane operates over each vault area and covers each of the eight vault areas. It has a maintenance area at the load-in/load-out end of the vault array.

In this alternative the load-in/load-out cell is located at one end of the vault array and the canisters are transferred via a roof plug in the roof of the cell into the charge machine for subsequent transfer to the selected storage position. A separate crane is provided in the load-in/load-out cell to perform the cask load-in/load-out functions, staging, and other canister handling functions. This layout drives the floor of the load-in/load-out cell below grade, assuming that the storage vault floors (bottom of the vaults) are located at grade.

A bogie tunnel is provided adjacent to the load-in/load-out cell and provides a transfer route to an adjacent storage module. The bogie tunnel can be configured for the charge machine to load canisters into the bogie or the load-in/load-out cell crane can perform this function. If the load-in/load-out crane provides these functions the length of the load-in/load-out cell will increase.

Figure B.5 shows the overall Alternative B1 plan configuration.

B4.4.2 Alternative B2 – Closed Tube Vault, Single Bank of Vaults Double Stacked

In Alternative B2, the canisters are placed in tubes beneath a reinforced-concrete 'charge floor.' Canisters are double-stacked, with the storage tubes spaced as in Alternative B1. In this alternative, 4 vault areas, each with 500 canisters in a 25 wide by 10 long array, are required to achieve a 2,000-canister storage capacity. Each vault has its own passive vent system with an intake plenum and exhaust plenum coupled to a stack. Four stacks are required. Each vault area is coupled to the next via an intermediate reinforced-concrete wall.

The charge machine/gantry crane operates over each vault area and covers each of the four vault areas. It has a maintenance area at the load-in/load-out end of the vault array.

In this alternative the load-in/load-out cell is located at one end of the vault array and the canisters are transferred via a roof plug in the roof of the cell into the charge machine for subsequent transfer to the selected storage position. A separate crane is provided in the load-in/load-out cell to perform the cask load-in/load-out functions and staging. As the storage vault height increases with double-stacking, the floor of the load-in/load-out cell is at grade, assuming that the storage vault floor (bottom of the vaults) are located at grade.

A bogie tunnel is provided adjacent to the load-in/load-out cell and provides a transfer route to an adjacent storage module. The bogie tunnel can be configured for the charge machine to load canisters into the bogie or the load-in/load-out cell crane can perform this function. If the load-in/load-out crane provides these functions, the length of the load-in/load-out cell will increase.

Figure B.6 shows the overall Alternative B2 plan configuration.

Figure B.5. Alternative B1 – Closed Tube Vault, Single Vault Arrays Single Stack

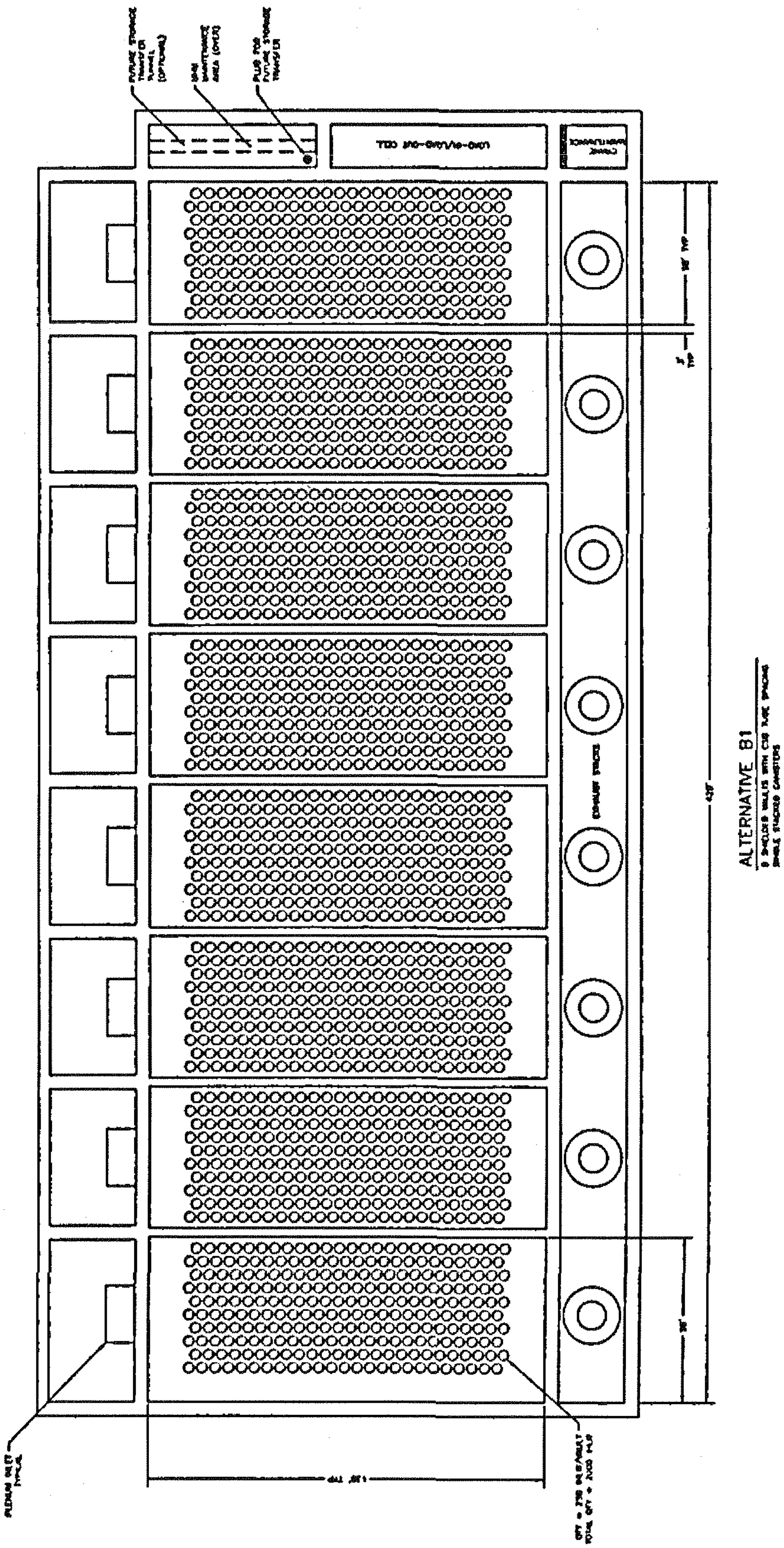
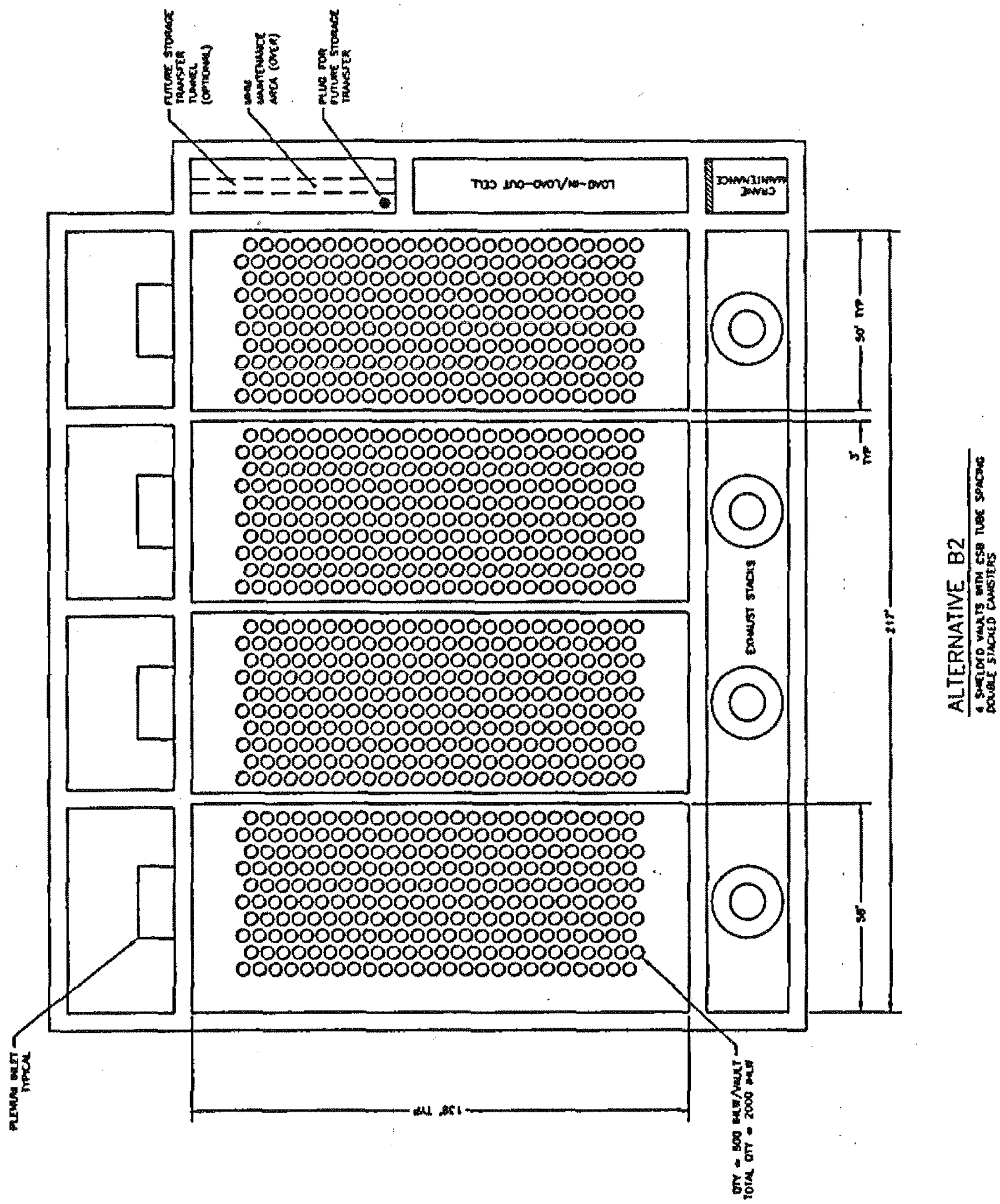


Figure B.6. Alternative B2 – Closed Tube Vault, Single Vault Arrays Double Stacked



B4.4.3 Alternative B3 – Closed Tube Vault, Dual Bank of Vaults Single Stacked

In Alternative B3, the canisters are placed in tubes beneath a reinforced-concrete 'charge floor.' Canisters are single stacked, with the storage tubes spaced as in Alternative B1. In this alternative, 8 vault areas, each with 250 canisters in a 25 wide by 10 long array, are required to achieve the 2,000-canister storage capacity. The vaults are arrayed in two banks of four, adjacent to each other. Each bank of four vaults has its own charge machine/gantry crane operating over the vault area. Each vault has its own passive vent system with an intake plenum and exhaust plenum coupled to a stack. Eight stacks are required. To minimize the overall footprint, the center portion of the vaults is dedicated to the intake plenums, with the exhaust plenums at the outside periphery of the overall vault structure. Each vault area is coupled to the next via an intermediate reinforced-concrete wall.

The charge machine/gantry crane operates over each vault area and covers each of the four vault areas. It has a maintenance area at the load-in/load-out end of the vault array.

In this alternative the load-in/load-out cell is located at one end of the vault array and the canisters are transferred via a roof plug in the roof of the cell into one of the charge machines for subsequent transfer to the selected storage position. As the two charge machine operating areas do not overlap, a bogie transfer tunnel is provided between the two vault operating areas from the load-in/load-out cell. Provision is made for an empty bogie tunnel to the periphery of the building for future storage expansion.

A separate crane is provided in the load-in/load-out cell to perform the cask load-in/load-out functions and staging. The crane maintenance area for the load-in/load-out cell is located between the two vault areas, adjacent to the intake plenum area to minimize impacts on height of the storage area and load-in/load-out cell interface. This layout drives the floor of the load-in/load-out cell below grade, assuming that the storage vault floors (bottom of the vaults) are located at grade.

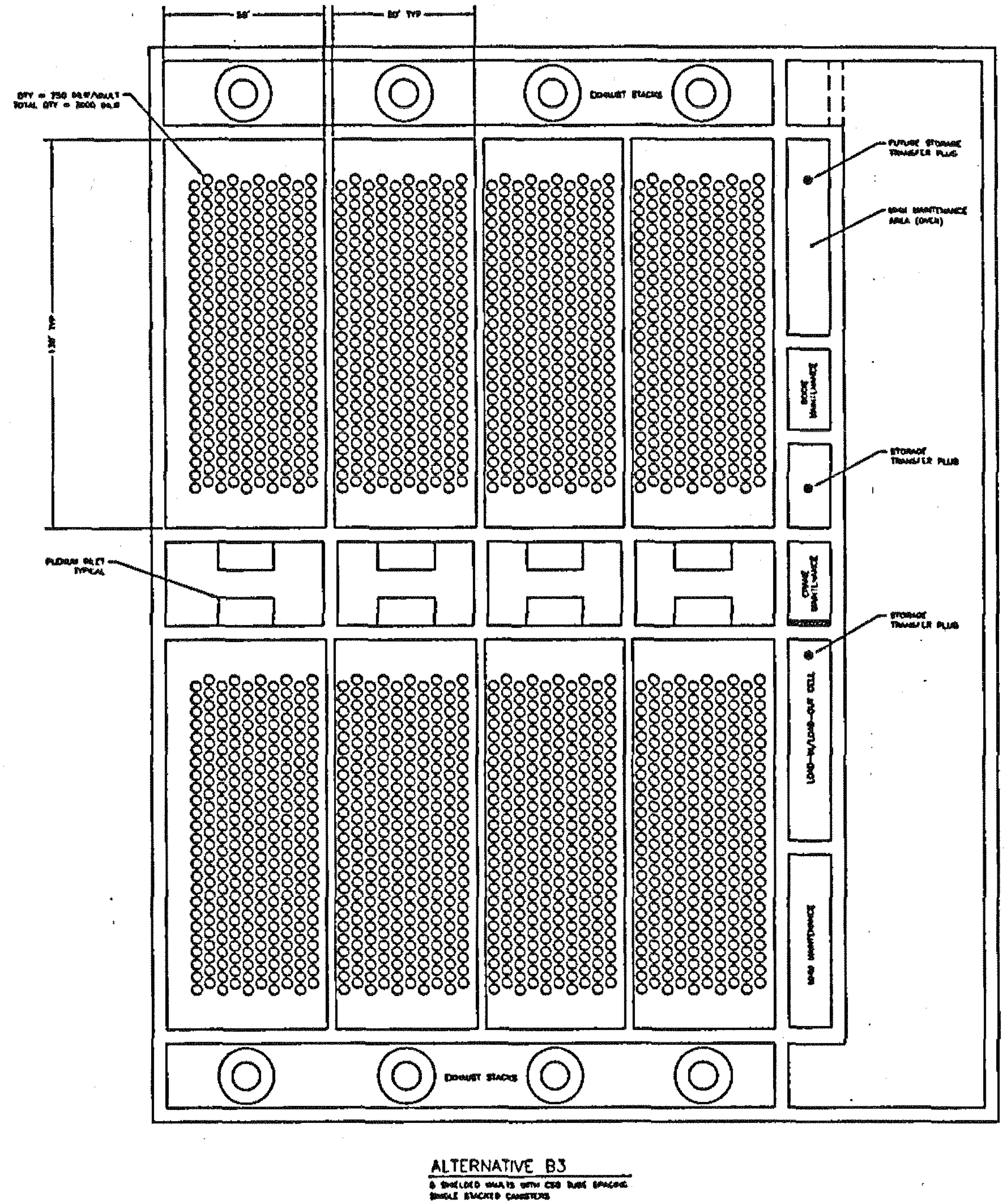
Figure B.7 shows the overall Alternative B3 plan configuration.

B4.4.4 Alternative B4 – Closed Tube Vault, Dual Bank of Vaults Double Stacked

In Alternative B4, the canisters are placed in tubes beneath a reinforced-concrete 'charge floor.' Canisters are double stacked, with the storage tubes pitched as in Alternative B1. In this alternative, 4 vault areas are required, with each having 500 canisters per vault in a 25 wide by 10 long array. The vaults are arrayed in two banks of two, adjacent to each other. Each bank of two vaults has its own charge machine/gantry crane operating over the vault area. Each vault has its own passive vent system with an intake plenum and exhaust plenum coupled to a stack. Four stacks are required. To minimize the overall footprint, the center portion of the vaults is dedicated to the intake plenums, with the exhaust plenums at the outside periphery of the overall vault structure. Each vault area is coupled to the next via an intermediate reinforced-concrete wall.

The charge machine/gantry crane operates over each vault area and covers each of the two vault areas. It has a maintenance area at the load-in/load-out end of the vault array.

Figure B.7. Alternative B3 – Closed Tube Vault, Dual Vault Arrays Single Stacked



In this alternative the load-in/load-out cell is located at one end of the vault array and the canisters are transferred via a roof plug in the roof of the cell into one of the charge machines, for subsequent transfer to the selected storage position. As the two charge machine operating areas do not overlap, a bogie transfer tunnel is provided between the two vault operating areas, from the load-in/load-out cell. Provision is made for an empty bogie tunnel to the periphery of the building for future storage expansion.

A separate crane is provided in the load-in/load-out cell to perform the cask load-in/load-out functions and staging. The crane maintenance area for the load-in/load-out cell is located between the two vault areas, adjacent to the intake plenum area to minimize impacts on height of the storage area and load-in/load-out cell interface.

As the storage vault height increases with double-stacking the floor of the load-in/load-out cell is at grade, assuming that the storage vault floors (bottom of the vaults) are located at grade.

Figure B.8 shows the overall Alternative B4 plan configuration.

B4.5 VARIATIONS ON CLOSED TUBE VAULT ALTERNATIVES

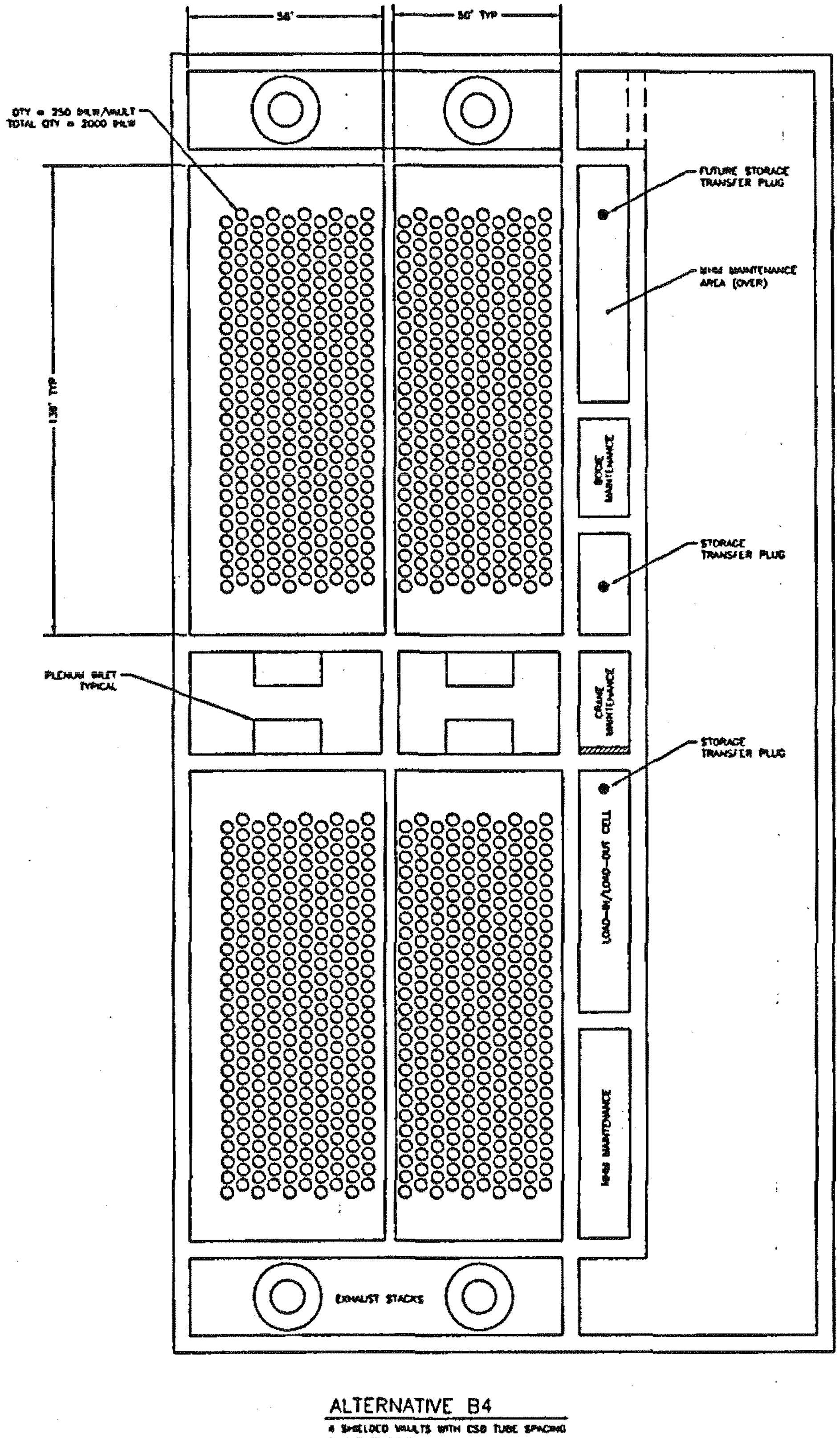
B4.5.1 Location of the Load In/Load Out Cell

The location of the load-in/load-out cell is variable, dependent upon the specific alternatives evaluated. In all closed tube concept alternatives (B1 through B4), the load-in/load-out cell is located at one end of the vault array. For the single stack alternatives (Alternatives B1 and B3) that use a locally shielded canister handling machine, the overall height of the load-in/load-out cell is greater than that of the storage vault because of the additional headroom required for placement and retrieval of canisters in the staging racks. Thus, the load-in/load-out cell floor must be below the floor of the storage vault. The load-in/load-out cell could be configured with the long axis parallel to the long axis of the vault arrays as in Alternatives A1 and A3 in the open rack vault concept. However, this is not ideal as the intake and exhaust plenums are located along the length of the vaults, meaning the load-in/load-out cell could not directly adjoin the vault structure. A bogie route would be required to transfer from the load-in/load-out cell.

In the double-stack alternatives (Alternatives B2 and B4), as the storage vault is taller than in the single stack arrangement, the load-in/load-out cell can be founded at the same elevation as the vault floor (bottom of vault).

Locating the vaults on each side of the load-in/load-out cell to reduce charge machine long-travel movements is also an option. This was analyzed and discounted because the loading bays for the canister casks and MGR casks must directly interface with the load-in/load-out cell. This means that the charge machine would have to operate over or through the loading bay spaces.
This could be achieved but would add to the overall footprint of the building and complicate equipment and operations. It was determined therefore that the best configuration was to locate the load-in/load-out cell at one end of the vault arrays.

Figure B.8. Alternative B4 – Closed Tube Vault, Dual Vault Arrays Double Stacked



B4.5.2 Combining the Storage and Load-In/Load-Out Equipment

An option exists for the charge machine that loads the storage vaults to be used to provide the load-in/load-out cell functions. In this configuration a series of floor plugs would be required (approximately 30) in the roof of the load-in/load-out cell through which the charge machine would provide the load-in/load-out cell functions. Canisters would be moved to different positions in the load-in/load-out cell by drawing the canister up into the cask through the roof penetration and transferring to another station, by moving the charge machine accordingly to adjacent positions.

There are serious drawbacks to this concept as follows:

- Charge machine casks are typically designed to handle one type of item, in this case a canister. The cask contains hoisting mechanisms and a bottom gamma gate, which interfaces with the floor penetration to provide requisite shielding and containment during transfer operations. For the load-in/load-out cell functions, at least three different canisters must be handled, each with different lifting attachments. Hoisting arrangements must therefore be flexible to account for different lift heights and different grappling features. This further complicates an already complex machine. A grapple change-out station would be required in the load-in/ load-out cell for the charge machine hoist to lower and enable remote grapple change out.

- Operations necessary to remove shield plugs and access the canisters are time consuming when compared to direct transfer using an in-cell crane.

- Indexing to different matrices of positions in the approximately 9-foot diameter for the loading the MGR cask is required. The charge machine has no ability to do this, as it is constrained by the single roof penetration. This means that the cask loading bogie would have to have an indexing mechanism incorporated into it to enable each loading position to be achieved. This complicates the bogie, which is not advisable, when carrying a 160-ton load.

- Based on the above, an in-cell crane to perform load-in/load-out functions is the best alternative for the closed tube vault alternatives (B1 through B4). The charge machine would have a single interface with the load-in/load-out cell to transfer IHLW canisters from the load-in/load-out cell to the storage vaults.

B4.6 SAVANNAH RIVER SITE VAULT CONCEPT

For the SRS vault concept only two alternatives were analyzed. This is primarily due to the fact that dual vault arrays, where dual equipment is provided for loading the racks, would not affect the vault configuration in this concept. In the other concepts where cranes and master slave manipulators are used they are constrained by rails. In the SRS concept, as a wheeled unit is used, there are no constraints on positioning; therefore, the quantity of loading equipment does not affect the vault configuration. It was determined that only single-vault arrays were worthy of analysis. Details of those analyses are provided in the following sections.

B4.6.1 Alternative C1 – Single Stacked

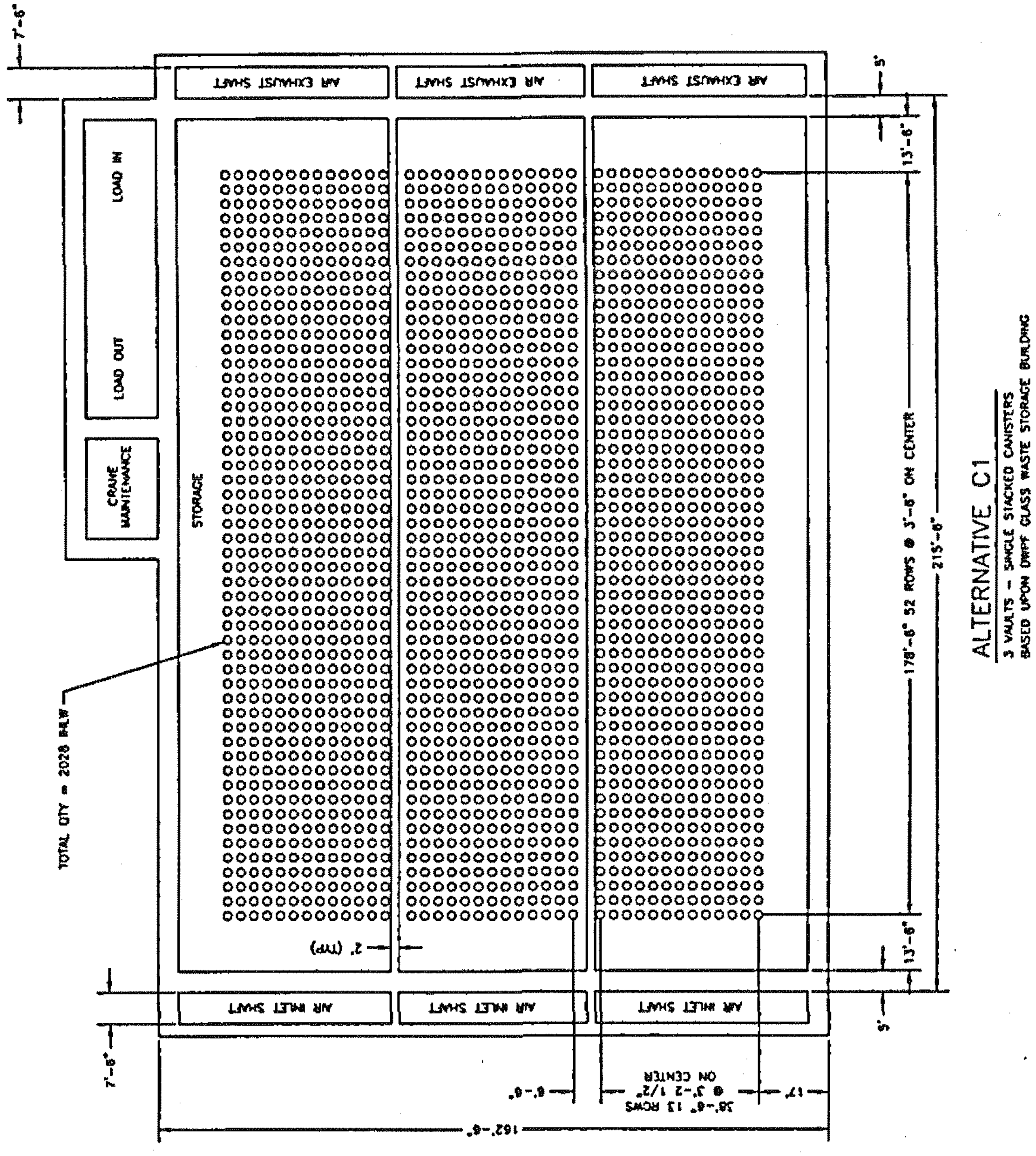
In Alternative C1, the canisters are placed in racks beneath a reinforced-concrete 'charge floor.' Canisters are single stacked, with the storage racks spaced at 3-foot, 2.5-inch centers in one direction and 3 feet, 6 inches in the other direction ("DWPF Glass Waste Storage Building #2 Drawing Legend" [A-A1-S-0004]). Tube spacing is governed primarily by the size of the concrete/steel shield plug in the charge floor above each rack position, and the structural requirements for the charge floor. The charge floor is comprised of pre-cast concrete panels, which span the width of each vault and have encast penetrations for each shield plug. It is assumed that each of these shield plugs will also require a seal to provide containment for the vault from the operating area above the charge floor. No seals are provided on the SRS vault plugs, as they have operating data that shows that sealing is not required, based on the fact that the canisters are checked in the Defense Waste Processing Facility and found to be free from contamination. At SRS a passive ventilation system is incorporated where, based on the configuration of the vaults and the plenum and exhaust duct, a stack effect is created to draw air in through the plenums, across a plenum baffle arrangement created by staggered plates incorporated into the rack design, and exhausting the air via exhaust ducts up an individual stack for each vault. Cooling air is in direct contact with the canisters, as in the open rack vault concept. For the HSF storage concept it is assumed that because the cooling air will contact the canister, environmental requirements will stipulate the need for an active nuclear ventilation system. Therefore, the plenum air would be provided from air handling units and the exhaust air would be routed to single-stage HEPA filters, fans, and then discharged to a single stack. As dissipation of heat is important, it was determined that the basic configuration of the vault arrays should be maintained as that provided at SRS, which has 585 canister positions per vault on a 13 wide by 45 long array with 4 vaults. The width of the vault was therefore maintained at 13 wide by 52 long to make the capacity of each vault area 676 canisters. In this alternative, 3 vault areas are therefore required to achieve the 2,000-canister storage capacity. Each vault area is divided from the next via an intermediate reinforced-concrete wall.

The canisters would be handled using a locally shielded charge machine. For the similar storage concept used at SRS, the charge machine is mounted to a wheeled tractor unit (i.e., SCT) that operates over each vault area and covers each of the three vault areas. Use of the wheeled tractor charge machine would necessitate that the storage vault be below grade with the charge floor at grade. Use of a crane mounted charge machine [redacted] would allow the storage vault to be constructed above grade.

In this alternative the load-in/load-out cell is adjoined to the long side of the vault array and the canisters are transferred via a roof plug in the roof of the cell into the charge machine, for subsequent transfer to the selected storage position. A separate crane is provided in the load-in/load-out cell to perform the cask load in/out functions and staging. This layout drives the floor of the load-in/load-out cell below the floor of the storage vault,. Expansion for this alternative is assumed by adding further vaults adjacent to the existing ones, and making provision for the SCT to travel over the new vault area.

Figure B.9 shows the overall Alternative C1 plan configuration.

Figure B.9. Alternative C1 – Single Vault Arrays, Single Stacked



B4.6.2 Alternative C2 – Double Stacked

Alternative C2 is a variation on Alternative C1, using the SRS concept but making provision in the storage rack configuration for double stacking the canisters. In Alternative C2, only 2 vaults are required, each with a 13 wide by 39 long array of rack positions, providing storage of 1,014 canisters in each vault. The internal height of each vault increases from 20 feet in Alternative C1 to 38 feet in Alternative C2 to allow for double-stacking the canisters. Ventilation provisions are similar to those provided for Alternative C1, with plenum and exhaust chambers into each vault and active ventilation provisions for the vault area and the operating area above the vault.

In this alternative the load-in/load-out cell is adjoined to the long side of the vault array and the canisters are transferred via a roof plug in the roof of the cell into the charge machine, for subsequent transfer to the selected storage position.

A separate crane is provided in the load-in/load-out cell to perform the load-in/load-out functions and staging. As the vault height is increased in this alternative, the floor of the load-in/load-out cell will be at grade, as will the floors of the storage vaults. Expansion for this alternative is assumed by adding further vaults adjacent to the existing ones and making provision for the SCT to travel over the new vault area.

Figure B.10 shows the overall Alternative C2 plan configuration.

B4.7 ALTERNATE D1 – DRY CASK STORAGE – SINGLE CANISTER OVERPACKS, HORIZONTALLY LOADED/STORED

In Alternative D1, IHLW canisters are stored external to the HSF on a large concrete storage pad in concrete overpacks designed to accept a single canister. The canisters are loaded horizontally into the overpack at the HSF load-in/load-out cell using a ram, after being turned to the horizontal in the load-in/load-out cell. The overpack uses a docking collar at the interface with the load-in/load-out cell and an engineered air gap around a docking door to maintain containment during docking operations. This concept is based on systems used for loading overpacks with SNF at nuclear utilities and could be performed in an annex to the high-level waste vitrification building.

The overpacks have a shield plug lid, which is removed remotely before loading.

The overpack is received on a low loader into a dedicated receipt bay for transfer to a bogie that will be used to transfer the overpack to the load-in/load-out cell interface. After loading, the overpack lid is remotely replaced and the overpack is moved out to the concrete storage pad on a low loader for single placement, horizontally on the storage pad. Placement is by mobile crane.

Single canister overpacks can be constructed offsite and shipped to the HSF as required.
Two thousand overpacks will be required, needing approximately 2 million cubic feet total of concrete to construct and weighing 147,000 pounds each.

The storage area required for storage of the single canister overpacks would be approximately 650 feet by 250 feet for overpacks single stacked.

Figure B.10. Alternative C2 – Single Vault Arrays, Double Stacked

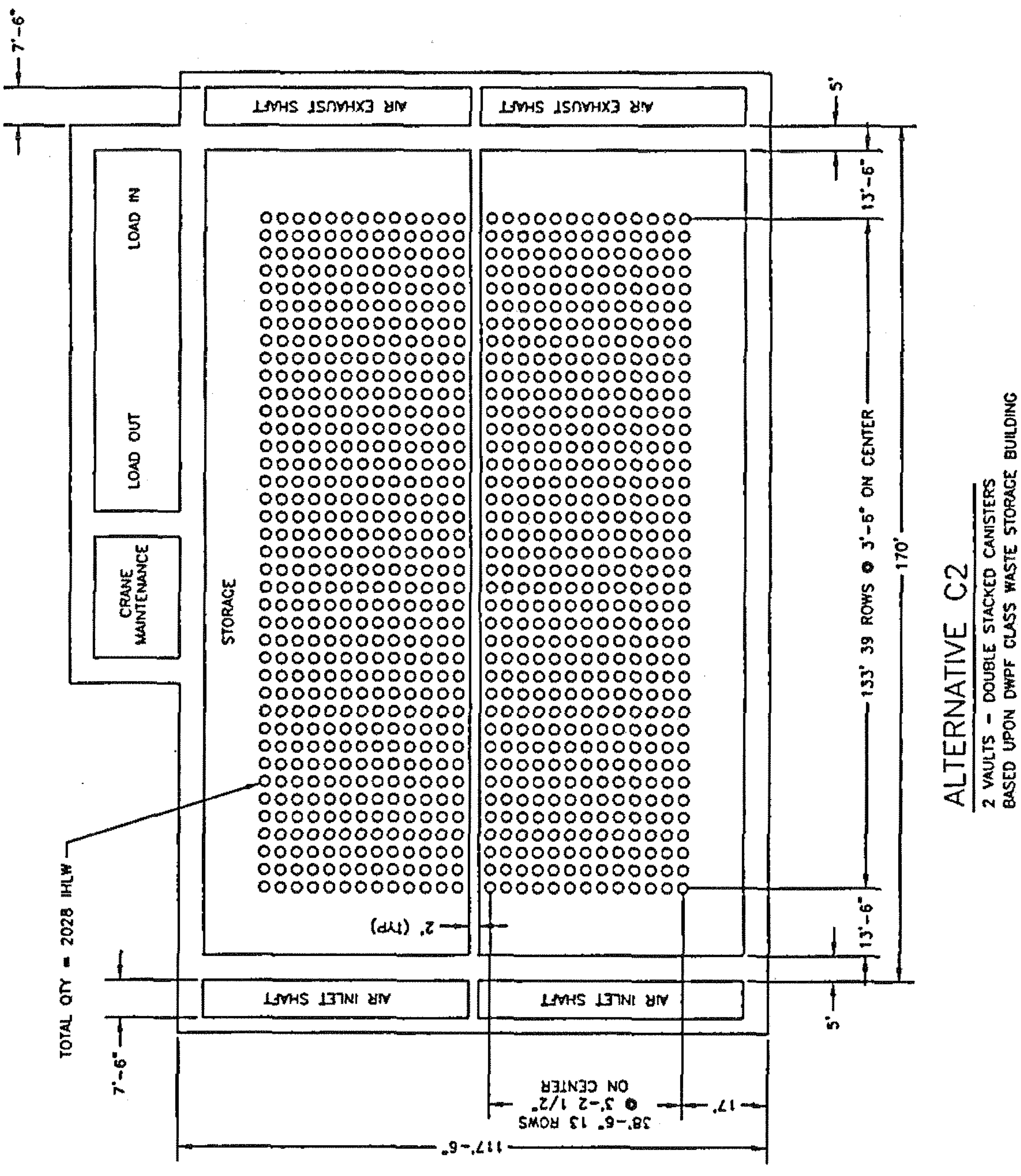


Figure B.11 shows the conceptual configuration of the single canister overpack.

B4.8 ALTERNATIVE D2 – DRY CASK STORAGE FIVE-CANISTER OVERPACKS – VERTICALLY LOADED/STORED

In this alternative IHLW canisters are stored external to the HSF on a large concrete storage pad in concrete overpacks designed, to accept five canisters (the same configuration as the MGR cask). The canisters are loaded vertically into the overpack at the HSF load-in/load-out cell using the in-cell crane. The overpack is transferred from a trailer via loading bay crane into a bogie for transfer to the load-in/load-out cell.

The overpacks have a shield plug lid, which is removed remotely before loading. After loading, the overpack lid is remotely replaced and the overpack is moved out to the concrete storage pad on a vertical transporter for placement, vertically on the storage pad. Placement is by mobile crane.

The overpacks should ideally be constructed onsite and transported to the HSF as required. Four hundred will be required, needing approximately 735,000 ft^3 total of concrete to construct and weighing approximately 296,000 pounds each.

Figure B.12 shows the conceptual configuration of the five-canister overpack. Figure B.13 shows the typical overpack transporter that is used. Figures B.14 and B.15 show the configuration and overall plan of the storage area required for Alternative D2.

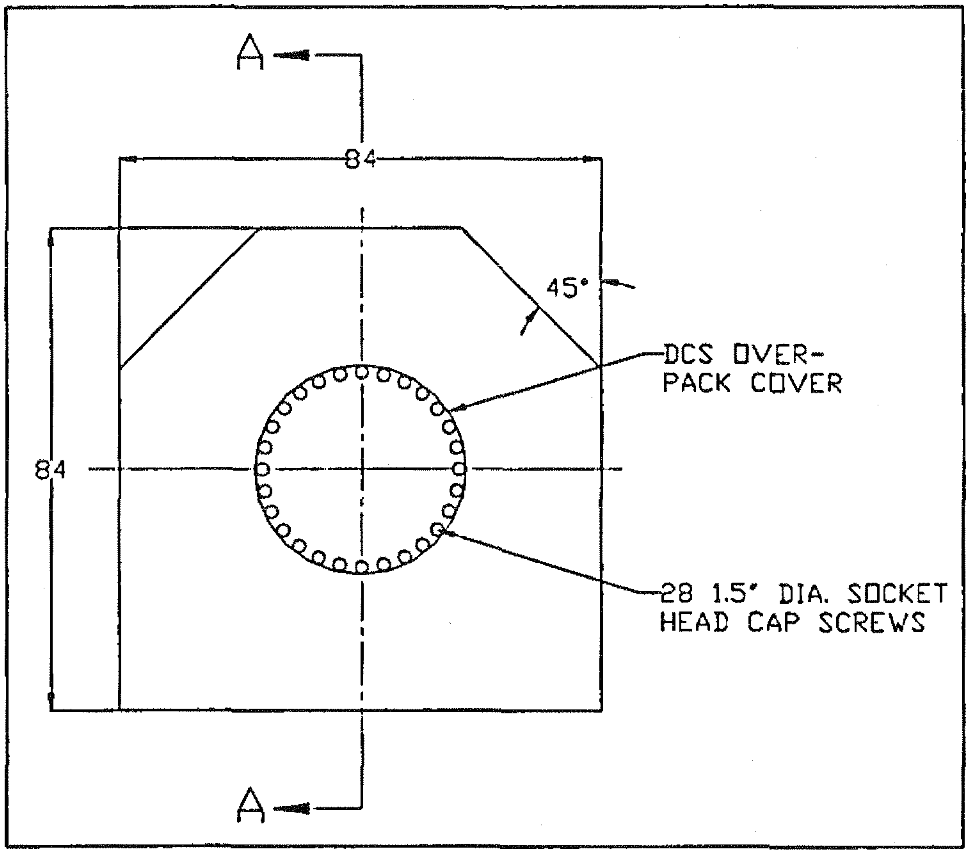
B4.9 STAGING ALTERNATIVES

The staging function is provided to account for time variations in receiving and shipping canisters. As the staging function is directly related to these load-in/load-out functions it makes sense for the staging area to be located in close proximity to load-in/load-out areas. Before loading, the canisters must be visually inspected. It is assumed that this visual inspection must be of the whole canister.

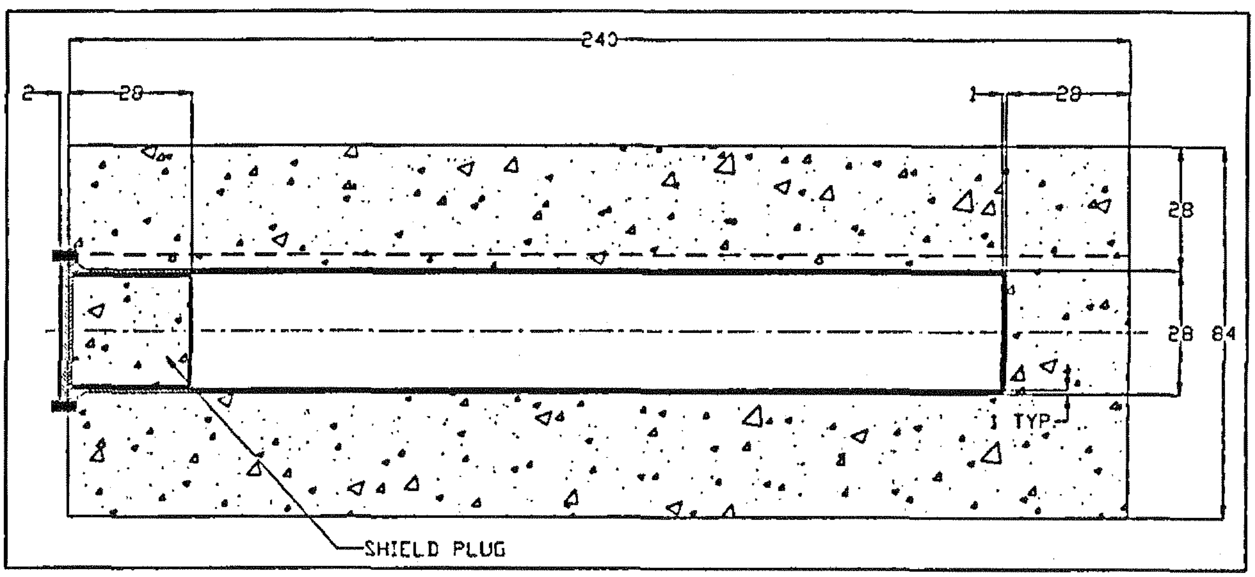
Space is provided within the load-in/load-out cell for installation of equipment to check canisters for contamination, if operationally this is found to be a requirement. This contamination check would include locations on the canister where contamination is more likely to be present. This must therefore include the lid and the base of the canister at a minimum. It is anticipated that this equipment would include swabs deployed by master slave manipulators and transferred, via direct transfer port, to an out-cell glovebox for manual survey with handheld instruments.

Performance of the above functions on the canister requires the canister to be located in an area that provides radiation shielding and containment to maintain radiation doses to the operators as low as reasonably achievable (ALARA). This means that these functions shall be performed in a shielded cell. The amount of staging positions is dependent upon the anticipated variations between receiving and shipping, with the goal to minimize this area.

Figure B.11. Single Canister Horizontal Overpack (all linear dimensions are in inches)

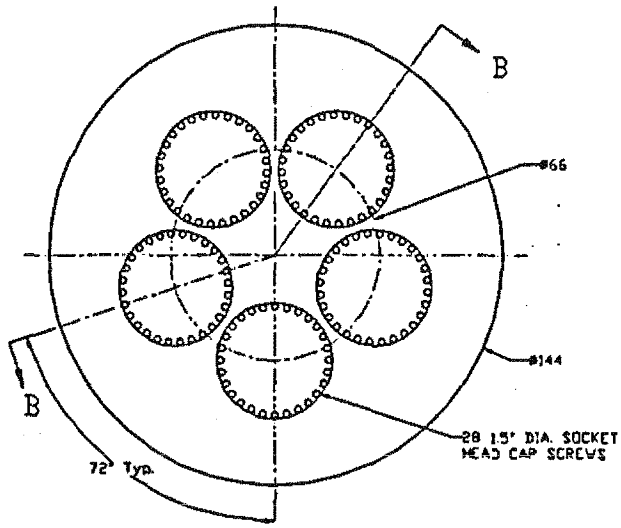


End View

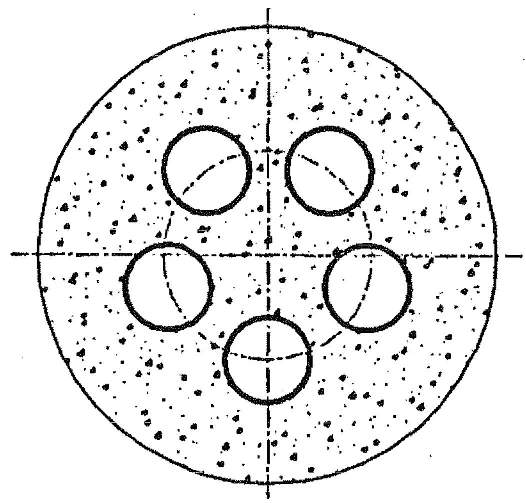


Section A-A

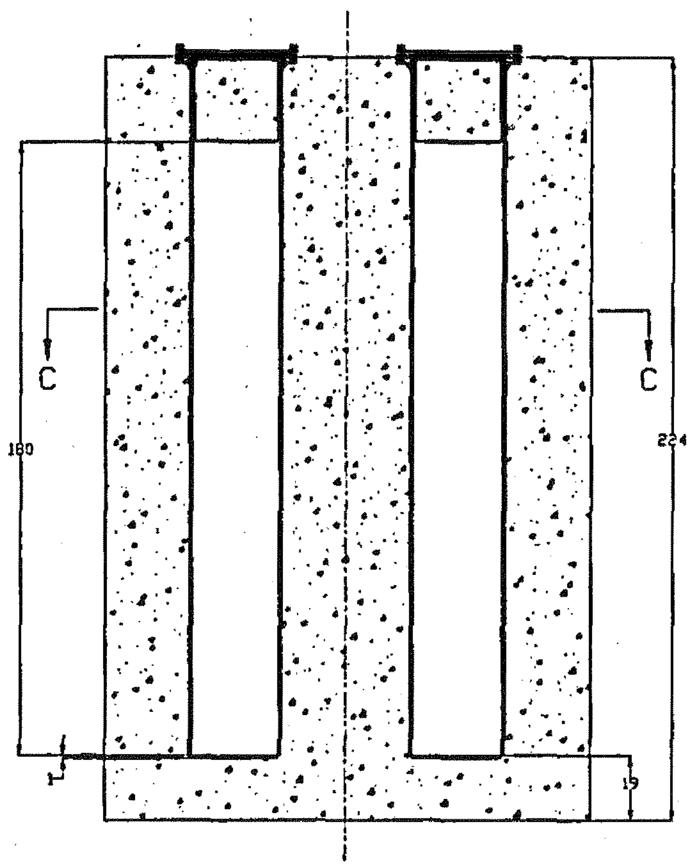
Figure B.12. Vertical Five-Canister Overpack
(all linear dimensions are in inches)



Top View



Section C-C



Section B-B

Figure B.13. Typical Vertical Storage Cask Transporter

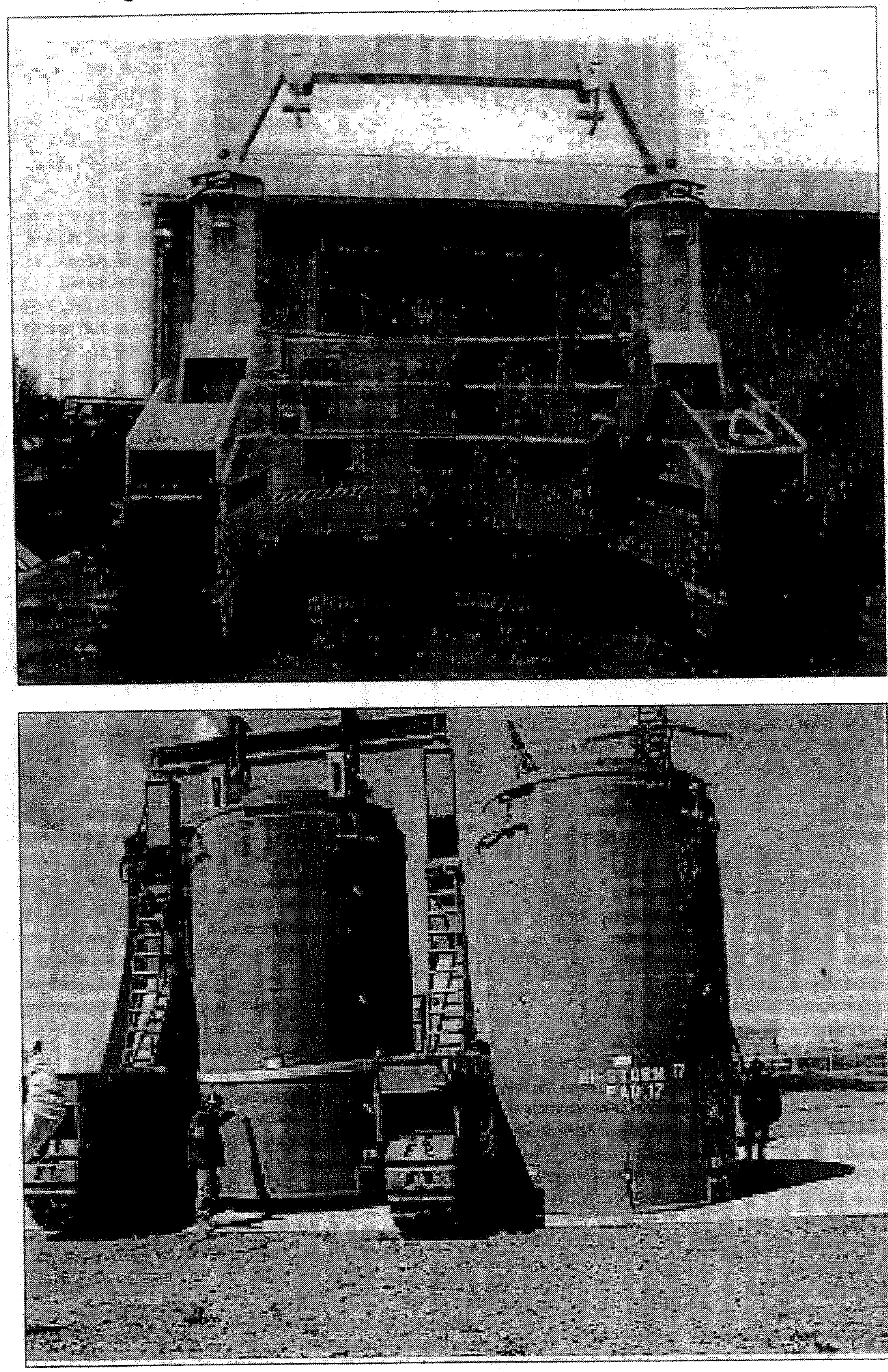
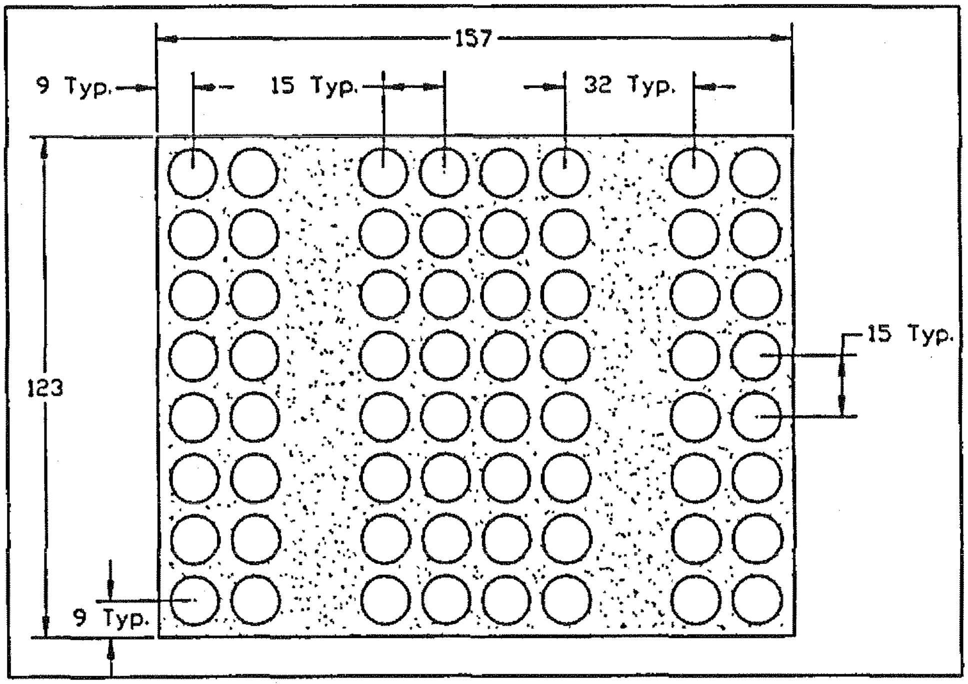
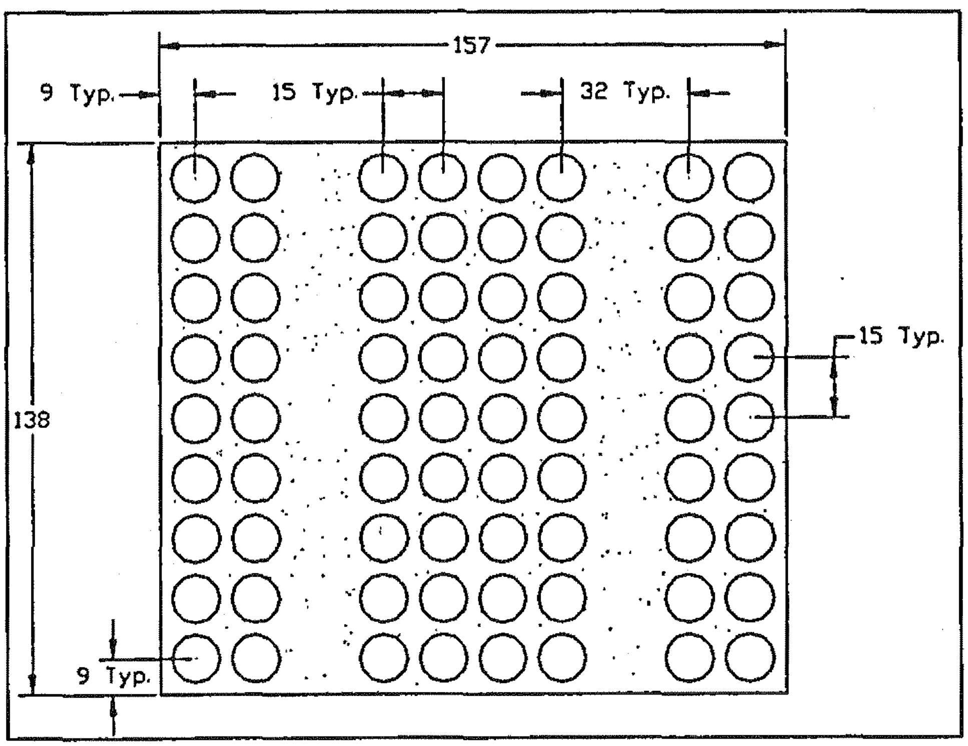


Figure B.14. Storage Area Configuration

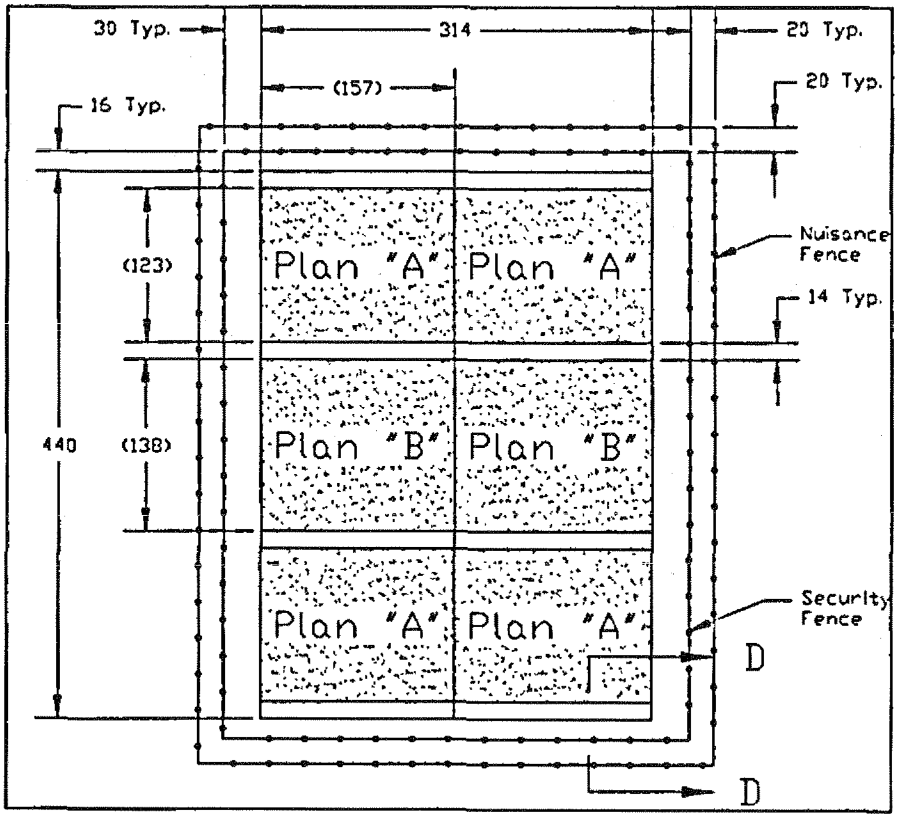


Lag Storage Area Layout - Plan "A" Details
(all dimensions are in feet)

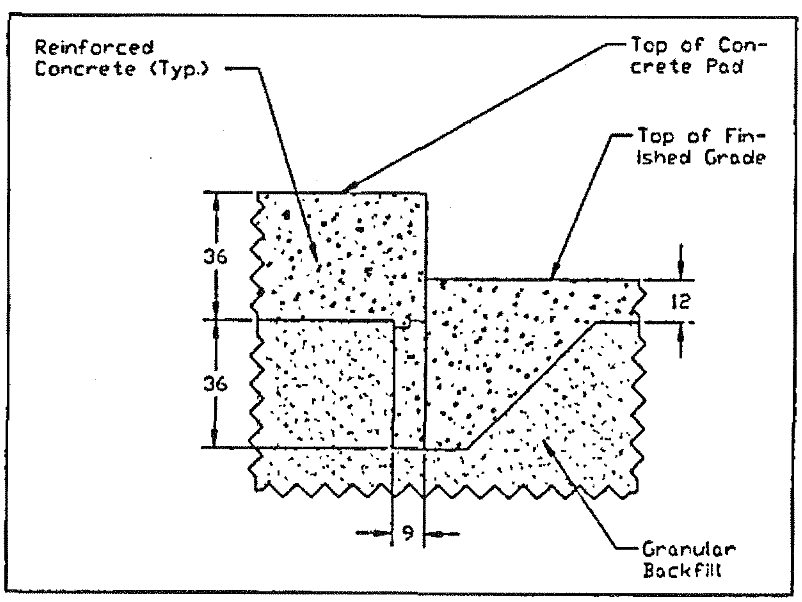


Lag Storage Area Layout - Plan "B" Details
(all dimensions are in feet)

Figure B.15. Storage Area Layout



Plan View
(all dimensions are in feet)



Section D-D
(all dimensions are in inches)

Lag Storage Area Layout

For initial layout purposes a conservative approach to the staging area was defined as providing positions for each canister type to load a total of three MGR shipping casks. Therefore, five positions are provided for IHLW, four for MCOs, and seven for DOE standard canisters. The staging area would be a simple rack module, similar to that provided in the storage vault, based on single stacking. Each rack position would be designed to handle all three canister types making this a total 16-position rack.

The size of the staging area has a moderate impact on the overall load-in/load-out cell size. The baseline concept for the load-in/load-out cell, including the staging area is shown in Figure B.16. Canisters are loaded into the staging racks if they cannot be directly taken from the inspection station to the load-out port and into the MGR shipping cask.

Operational modeling was performed on the HSF to determine availability, equipment usage and define system bottlenecks, including use of the staging and storage areas. A summary of the results is provided in Appendix C, Attachment C1. The results provide valuable input to the overall facility layout.

The initial results show that with a single-shift system (i.e., one 8-hour shift, 5-days-per-week, 240 days-per-year), a maximum throughput of 1.1 canisters per day is achievable. In this system 100 canisters maximum (with a mean of 50) would need to be staged. By modifying the shift system to 2 shifts, throughput increases to 1.9 canisters per day with a maximum buffer capacity of 25 canisters needed. One bottleneck, driving staging requirements, is the MGR cask preparation times. If provisions were made to be preparing one cask for loading while another cask was in place being loaded then staging capacity is reduced to 14 canisters maximum with a mean of 1 and throughput is increased to the required 2 canisters per day.

This data is used in the development of layout alternatives, provided in Appendix E. Because the staging area is an integral part of the load-in/load-out cell, options for layout revolve around combining or not combining the load-in/load-out cell with the storage vault areas.

The operational modeling performed during this study shows that under normal operating conditions, with no constraints on shipments to the Yucca Mountain MGR, the vault area is not normally used, and only limited staging positions are used in the load-in/load-out area. This would, therefore, lend itself to combining the two functions. However, divorcing the load-in/load-out cell function from the storage function has some clear benefits:

- Cross-contamination between the load-in/load-out area and the storage area is significantly reduced because they are physically separated. A major goal of the storage concept should be to maintain the vault area in a clean uncontaminated condition, and especially in the open rack concept this is important. Activities in the load-in/load-out area may involve swabbing, minor decontamination (using the moistened wipe method), and temporary storage of damaged/out-of-specification canisters, thus this area has a greater potential for becoming contaminated.

- Physical separation of the vault area reduces the extent of integration between the two functions and therefore lends itself better to delete the storage function or modify storage quantity during design development if requirements change.

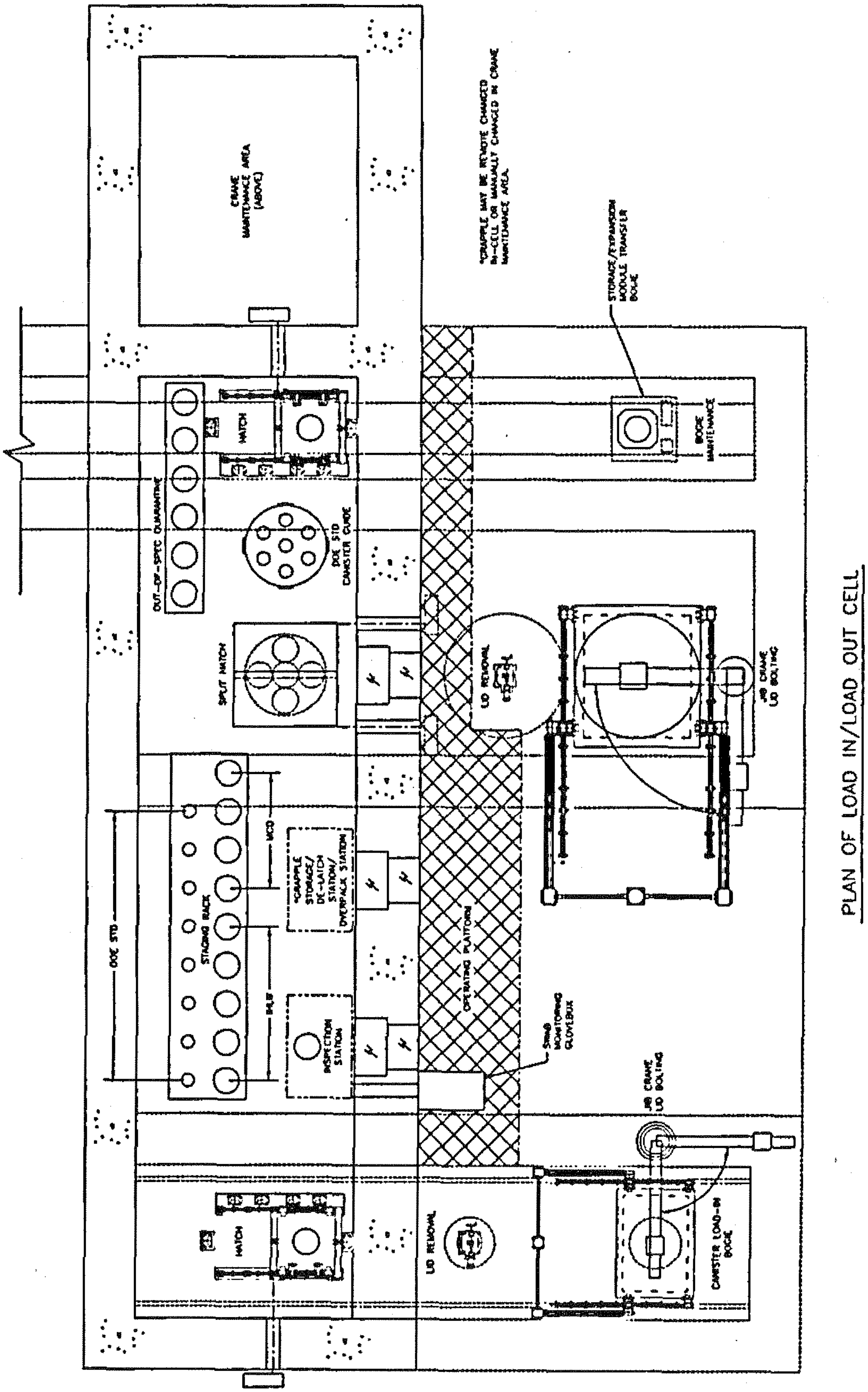


Figure B.16. Baseline Concept for the Load In/Out Cell, Including the Staging Area

- Separating the load-in/load-out area from the storage area gives more flexibility to site the load-in/load-out area to best integrate with the loading bays and the services annex. The location can be at the end of the vault or along one side of the vault.

By divorcing the two functions discriminating equipment costs will increase to account for the additional crane, crane maintenance area, and storage transfer bogie. The impact of this is evaluated in the discriminating cost development for the options.

In closed tube vault alternatives (B1 through B4), unless the staging area is a series of closed tubes, then the load-in/load-out cell must include a physical separation between the load-in/load-out cell and vault areas. The vault area HVAC is passive and the load-in/load-out cell HVAC requires an active ventilation system. As stated in Section B4.5.2, the use of the charge machine to perform load-in/load-out functions is not preferred. It is therefore preferred that staging is simplified, with placement into the staging rack using the load-in/load-out crane.

B5.0 EVALUATION CRITERIA

To select the preferred concept and alternative for the storage and staging concepts, a set of evaluation criteria was developed and provides the mechanism for selecting a preferred alternative. The evaluation criteria selected for the storage and staging options are listed with a basic description in Table B.2 together with criteria weighting. The weighting is applied according to the relative degree of importance of each evaluation criterion. An assigned numerical value quantifies each evaluation criteria. The performance of each alternative is estimated with respect to the defined evaluation criteria. The performance level is judged as poor to good, with a corresponding score of 1 through 4, respectively, when compared to each other. Amongst the alternatives at least one must receive a score of 1 and another a score of 4 for a specific evaluation criterion. The remaining alternatives receive a score based on comparison with the best (4) and worst (1) score for that evaluation criterion. No two alternatives shall receive the same score unless they are identical in the manner in which they meet the evaluation criterion. For the SRS vault concepts and the dry cask overpack storage concepts, there are only two concepts; therefore, scoring will be either 1 or 2.

The weighted score is the product of each weighted criterion and the performance level score. The total score for an alternative is the sum of the weighted scores.

Similarly, selection of the overall preferred alternative is done by comparatively scoring the best alternative from each storage concept. Scoring will be based on comparison between the four alternatives, with scores ranging from 1 to 4.

Table B.2. Storage and Staging Evaluation Criteria

Evaluation Criteria	Description	Criteria Weight
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	10
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	10
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	5
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	5
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	10
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	15
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning. Cell areas should have space optimized and minimized.	5
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	5
Capital cost	Comparison of the capital cost of the vault portion of the HSF for each option; capital cost is a relative cost factor only, *based on cost elements that are major* discriminators only. Space utilization has a significant impact on cost; cell areas shall be optimized and minimized.	20
Operating cost	Comparison of the O&M costs for each option; costs will be a relative cost factor only.	15

ALARA = as low as reasonably achievable.
HSF = Hanford Shipping Facility.
O&M = Operations and Maintenance.

B6.0 ANALYSIS OF ALTERNATIVES

This section provides the approach to analysis of the alternatives and the results of the analysis, including the rationale for scoring of the alternative against each of the evaluation criteria.

B6.1 ANALYSIS APPROACH

The approach taken to analyze the storage and staging alternatives is as follows:

1. Develop each alternative to a sufficient level to enable fair evaluation (i.e., description, layouts, major equipment definition)
2. Develop evaluation criteria and criteria weighting, as defined in Section B5.0
3. Evaluate each of the alternatives for each storage concept
4. Select the preferred alternative for the open rack vault concept
5. Select the preferred alternative for the closed tube vault concept
6. Select the preferred alternative for the SRS vault concept
7. Select the preferred alternative for the dry cask storage overpack concept
8. Evaluate and select the preferred overall alternative from the preferred alternative from each storage concept.

Once the preferred storage and staging alternative is determined, develop facility layout options based on the preferred alternative (refer to Appendix D).

B6.2 EVALUATION OF STORAGE CONCEPT ALTERNATIVES

Based on the description of the alternates and layouts developed in Section B4.0, the alternatives for each concept were evaluated using the set of criteria and scoring system defined in Section B5.0. Attachment B1 provides the detailed evaluation criteria matrices, which are summarized in the following sections.

B6.2.1 Evaluation of the Open Rack Vault Alternatives

Table B.3 provides tabulated results of evaluation for the open rack vault concepts (Alternatives A1 through A4). The table shows that Alternative A2 has clear advantages over the other three alternatives, as evaluated in the following sections against the evaluation criteria.

Table B.3. Evaluation Criteria Matrix for Open Rack Vault Alternatives

Evaluation Criteria	Criteria Weight	A1 – Single Vault Single Stack		A2 – Single Vault Double Stack		A3 – Dual Vault Single Stack		A4 – Dual Vault Double Stack	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Operability	10	1	10	4	40	3	30	3	30
Availability	10	1	10	2	20	4	40	3	30
Technology maturity	5	1	5	4	20	4	20	4	20
Expandability	5	2	10	4	20	1	5	3	15
Environmental	10	3	30	4	40	1	10	3	30
Safety	15	3	45	4	60	3	45	1	15
Decontamination and decommissioning	5	3	15	4	20	1	5	3	15
Constructability	5	3	15	4	20	1	5	3	15
Capital cost	20	3	60	4	80	1	20	3	60
Operating cost	15	3	45	4	60	1	15	3	45
Total score	100		245		380		195		275

B6.2.1.1 Operability

Alternative A1 is ranked worst, due to the perceived additional complexity involved in providing an in-cell crane with travel length of 340 feet. As part of this study, technical data and budget estimates were obtained for all the major facility cranes. The crane manufacturer's recommendations are that travel length be limited to less than 250 feet for a crane that is powered, controlled, and remotely recovered using a cable reel system. Alternative 2 scores the best, as crane span and length are reduced to within crane manufacturer's recommendations.

Alternatives A3 and A4 have two cranes; therefore, although availability is greater, physical complexity and operator interfaces are increased and therefore operability is scored lower than Alternative A2.

B6.2.1.2 Availability

Alternative A1 is ranked worst, due to the additional complexity in the canister storage crane design, to develop an in-cell crane that will operate over the 340-foot length of the storage area. Alternative A3 has two cranes for the storage function and one crane for the load-in/load-out function and therefore will have the best overall availability. Crane travel is within proven limits. Alternatives A2 and A4 are ranked in between Alternatives A1 and A3.

B6.2.1.3 Technological Maturity

Alternative A1 is ranked worst, due to the unproven crane design to accommodate the travel length required. All the other alternatives are scored the best, because there are no differences in technology.

B6.2.1.4 Expandability

All alternatives are similar in that a bogie tunnel (or tunnels) will be provided to the periphery of the vault, such that it can be extended to future adjacent storage modules.

Alternative A3 uses the bogie tunnel to feed each of the two vaults and, in addition, would feed the future storage module. This arrangement is slightly more complex than other options so receives the lowest score. In addition, this option has the largest overall footprint (25,472 ft^2) and therefore would have the greatest constraint on facility siting.

Alternative A2 extends the storage transfer tunnel to the periphery of the building. Because the vault has the smallest footprint (12,338 ft^2), this provides the most compact arrangement overall and is the least constrained for siting additional storage modules. This alternative ranks best. The other alternatives rank between Alternatives A2 and A3 because of slightly different arrangements, complexities, and footprints.

B6.2.1.5 Environmental

Alternative A2 is ranked best as it has the lowest vault volume and therefore ventilation system and airborne effluents is the lowest of all alternatives. In addition, because lowest quantity of mechanical handling equipment amount of solid waste from maintenance should be lower than the other options.

Alternative A3 is ranked worst, because it has the largest volume to ventilate and has a larger quantity of mechanical handling equipment and, therefore, potential to have more secondary solid waste from maintenance. Other alternatives are scored between because of differences in vault volumes.

B6.2.1.6 Safety

Alternative A2 is ranked best because of separate load-in/load-out cell, which reduces potential for contamination of the storage area, and therefore places the least challenge on ALARA goals for operations and maintenance dose uptake. This alternative has a low quantity of mechanical handling equipment. Overall this alternative has the best chance of minimizing dose uptake to operators. This alternative also has half the number of canister storage positions as Alternatives A1 and A3 and, therefore, a lower potential for indexing and grappling problems.

Alternative A4 is ranked worst because of combined load-in/load-out cell, and increased quantity of mechanical handling equipment. All these elements have the potential to increase dose uptake and present more of a challenge from an industrial safety standpoint. The other alternatives are ranked between Alternatives A2 and A4.

B6.2.1.7 Decontamination and Decommissioning

In all of the alternatives, provisions will be made in the vault area to aid decontamination for decommissioning. Canister racks will be modular for installation and strip out, and decontaminable surfaces will be provided on equipment and the vault internal concrete structure.

Alternative A2 is ranked overall best because it has the smallest vault volume that will require decontamination and decommissioning (D&D) and limited amount of in-cell equipment.

Alternative A3 is ranked worst because it has the largest volume and most equipment to decontaminate, with Alternative A4 ranked lower than Alternative A1, due to increased quantity of vault equipment to D&D.

B6.2.1.8 Constructability

Single vault alternatives (A1 and A2) score better than the dual-vault alternatives because the overall construction is simpler. Alternative A2 is ranked best because it has 25% less bulk concrete (12,245 yd^3) than Alternative A1 (16,684 yd^3). The dual vault alternatives are scored lower, with Alternative A3 ranked worst because of its dual vault and largest required volume of concrete (191,889 yd^3).

B6.2.1.9 Capital Cost

Size and space utilization has an impact on capital cost. Alternative A3 is ranked worst, because of the use of two vault cranes and single stacking the canisters. The internal volume of the vault is 987,040 ft^3. This alternative is worse than Alternative A1 because of the additional dead volumes in the side and end approaches of the additional crane. Alternative A2 is ranked best, with an internal volume of 684,759 ft^3 cubic feet, which represents a 30% reduction in volume. This option makes best use of the crane operating area, by double-stacking the canisters and reduces the volume requiring ventilation. The other alternatives rank between Alternatives A3 and A2.

The approach to developing capital cost for the vault area was to focus only on discriminating cost and quantity elements for each of the alternates, and not to develop complete capital cost estimates. Therefore, capital costs and quantity estimates, excluding design and installation cost, were developed in two major areas:

- Major mechanical handling equipment, including storage rack quantity and cost
- Quantity of bulk concrete required.

Equipment costs were obtained from a combination of vendor quotes and using data from current applicable projects (e.g., WTP). Mechanical handling costs included vault equipment and discriminating costs for the load-in/load-out area only (e.g., where separate crane and bogie are required for storage transfer). Other costs for load-in/load-out cell equipment (e.g., inspection stations, staging areas) are not discriminators and are therefore excluded from the cost comparison.

Quantity of bulk concrete was developed by take-offs from the preliminary layouts developed for each alternative.

All other major capital costs elements (e.g., HVAC, design and engineering, control engineering and instrumentation) were assumed to be proportionate to the vault size and amount and complexity of major equipment. Table B.4 shows the summary costs and quantities respectively for each of the two discriminating areas. Table B.4 shows that the double stacking alternatives score best in terms of cost of mechanical handling equipment and overall quantity of concrete required, with Alternative A2 ranked best and Alternative A3 ranked worst. The double stacking alternatives make the best use of the mechanical handling equipment and minimize the overall vault volume.

Table B.4. Discriminating Capital Cost Elements for Open Rack Vault Alternatives

Alternative Identifier	Alternative Description	Discriminating Mechanical Handling Cost ($M)	Bulk Concrete Quantities (yd^3)
A1	Single vault – single stack	14	16,684
A2	Single vault – double stack	10.1	12,245
A3	Dual vault – single stack	18.3	19,189
A4	Dual vault – double stack	13.9	14,034

B6.2.1.10 Operating Costs

Operating costs were not estimated but merely assigned a cost factor, based on qualitative judgment and based on the volume of the vault, which affects HVAC and quantity of major equipment. Alternative A2 is ranked best in terms of providing the lowest running cost option. This is primarily due to minimizing the vault volume and therefore HVAC requirements and minimizing power usage for mechanical handling equipment. Alternative A3 was ranked worst and the other alternatives ranked in between.

B6.2.1.11 Summary of Results

The evaluation shows that Alternative A2 has significant advantages in most evaluation criteria, and is therefore the preferred alternative for the open rack vault concept. This is then evaluated against the best of the other storage concepts, evaluated in the following sections.

B6.2.2 Evaluation of the Closed Tube Vault Alternatives

Table B.5 provides tabulated results of evaluation for the closed tube vault concepts. The table shows that Alternative B2 has clear advantages over the other three alternatives as evaluated in the following sections against the evaluation criteria.

B6.2.2.1 Operability

Alternative B1 is ranked worst, due to additional complexity involved in having eight vaults and individual canister tubes. Each vault has its own plenum and exhaust stacks and associated stack monitoring, which adds to operations complexity. Loading canisters into storage is complicated because 2,000 individual storage tubes are used; therefore, twice the number of unique (loading point) operator interfaces than in the stacked configurations. Alternatives B3 and B4 have two gantry crane/charge machines; therefore, although availability is greater the physical complexity and operator interfaces are increased making operability score lower than Alternative B2.

B6.2.2.2 Availability

The dual vault alternatives have a greater availability than the single vault alternatives because two gantry crane/charge machines are provided. All alternatives have separate overhead cranes for the load-in/load-out functions. Alternative B1 is ranked worst because it has the greatest use of the single gantry crane/charge machine and the longest travel distances.

Alternative B4 has two gantry cranes/charge machines and has smallest travel distance and therefore is ranked best. Alternative B2 has greater availability than Alternative B1 because of reduced travel distances and reduced storage tube interfaces.

B6.2.2.3 Technological Maturity

No significant difference in technological maturity was determined among the alternatives. The equipment concept is mature and proven. All would use the same equipment with only span, travel distance, and loading capability being the difference. All were given maximum score.

B6.2.2.4 Expandability

There are two main alternatives with the closed tube vault concept for expansion. One option is to construct additional vaults at the end of the vault array so that the existing gantry crane/charge machine can be potentially extended over the new vault area, or a bogie tunnel could be provided to a storage module adjacent to the existing vault array. Both options have advantages and disadvantages in terms of siting, equipment availability, etc. Both expansion options can be used on any of the alternatives analyzed, and performance against the ability to expand using either option was evaluated.

Table B.5. Evaluation Criteria Matrix for Closed Tube Vault Alternatives

Evaluation Criteria	Criteria Weight	B1 – Single Vault Arrays, Single Stack		B2 – Single Vault Arrays, Double Stack		B3 – Dual Vault Arrays, Single Stack		B4 – Dual Vault Arrays, Double Stack	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Operability	10	1	10	4	40	2	20	3	30
Availability	10	1	10	2	20	3	30	4	40
Technology maturity	5	4	20	4	20	4	20	4	20
Expandability	5	2	10	4	20	1	5	3	15
Environmental	10	2	20	4	40	1	10	3	30
Safety	15	2	30	4	60	1	15	2	30
Decontamination and decommissioning	5	2	10	4	20	1	5	3	15
Constructability	5	3	15	4	20	1	5	2	10
Capital cost	20	2	40	4	80	1	20	3	60
Operating cost	15	2	30	4	60	1	15	3	45
Total score	100		195		380		145		295

Alternative B3 has the option to use a dedicated tunnel that would only require the bogie system to be installed when the adjacent storage module is built. However, because that alternative has the largest overall footprint, it was ranked lowest. Alternative B2 was ranked best, because it has the smallest footprint and therefore represents having the least constraints from a siting and expandability perspective.

The other alternatives rank between Alternatives B2 and B3 because of slightly different arrangements, complexities, and footprints.

B6.2.2.5 Environmental

Alternative B2 is ranked best because it has the lowest vault volume and gantry crane/charge machine operating area volume; therefore, ventilation and airborne effluents is the lowest of all alternatives. In addition, because of lowest quantity of mechanical handling equipment, amount of solid waste from maintenance should be lower than the other options.

Alternative B3 is ranked worst, because it has the largest volumes to ventilate and larger quantity of mechanical handling equipment, and therefore potential to have more secondary solid waste from maintenance. Other alternatives are scored in between due to differences in vault volumes.

B6.2.2.6 Safety

Alternative B2 is ranked best because of minimization of mechanical handling equipment and quantity of storage positions (and therefore half the quantity of confinement seals than the single stacked alternates); therefore, reducing potential for radiological and industrial safety incidents. Overall this alternative has the best chance of minimizing dose uptake to operators.

Alternative B3 is ranked worst because of increased quantity of mechanical handling equipment, and double the amount of storage positions; therefore, greater potential for safety incidents. Other alternatives are ranked between Alternatives B2 and B3.

B6.2.2.7 Decontamination and Decommissioning

In all alternatives provisions will be made in the vault areas to aid decontamination for decommissioning. Canister tubes are modular for installation and strip out and decontaminable surfaces will be provided on equipment and the concrete surface potentially exposed to contamination.

Alternative B2 is ranked overall best, due to having the smallest vault volume that will require D&D and limited amount of in-cell equipment. Alternative B3 is ranked worst due to the having the largest volume to decontaminate. Other alternatives are ranked in between B2 and B3.

B6.2.2.8 Constructability

Single vault alternatives (B1 and B2) score better than the dual vault alternatives due to the overall construction being simpler. Alternative B2 is ranked best as it has less bulk concrete (25,247 yd^3) than Alternative B1 (41,761 yd^3). The dual-vault alternatives are scored lower, with Alternative B3 ranked worst due to dual vault and largest volume of concrete required (43,199 yd^3).

B6.2.2.9 Capital Cost

Size and space utilization has an impact on capital cost. Alternative B3 is ranked worst, due to the use of dual vault arrays and individual gantry crane/charge machines and single stacking the canisters. Each gantry crane/charge machine requires significant side and end approaches and this adds 'dead volume' in the storage vault area. The internal volume of the vault is 1,272,128 ft^3. This alternative is worse than Alternative B1 due to the additional dead volumes in the side and end approaches of the additional gantry crane/charge machine. Alternative B2 is ranked best, *with an internal volume of 1,069,744 feet, which represents a 16% reduction in* volume. This alternative makes best use of the crane operating area, by double-stacking the canisters and reduces the volume requiring ventilation. The other alternatives rank in between Alternatives B3 and B2.

The approach to developing capital cost for the vault area was to focus only on discriminating cost and quantity elements for each of the alternatives, and not to develop complete capital cost estimates. Therefore, capital costs and quantity estimates, excluding design and installation cost were developed in two major areas as follows:

- Major mechanical handling equipment, including storage tube quantity and cost
- Quantity of bulk concrete required for vault areas and tons of primary steel required for the operating area above the vault.

Equipment costs were obtained from a combination of vendor quotes and using data from current applicable projects (e.g., CSB). Mechanical handling costs included vault equipment and vault transfer equipment only. Load-in/load-out equipment is similar across all alternatives and is therefore not a discriminator.

Quantity of bulk concrete was developed by take-offs from the preliminary layouts developed for each alternatives and quantities prorated from CSB quantities, based on volume comparison.

All other major capital costs elements (e.g., HVAC, design and engineering, control engineering and instrumentation) were assumed to be proportionate to the vault size and amount and complexity of major equipment. Table B.6 shows the summary costs and quantities, respectively, for each of the two discriminating areas. Table B.6 shows clearly that the double stack alternatives score best in terms of cost of mechanical handling equipment, with Alternative B2 ranked best and Alternative B3 ranked worst.

Table B.6. Discriminating Capital Cost Elements for Closed Tube Vault Alternatives

Alternative Identifier	Alternative Description	Discriminating Mechanical Handling Cost ($M)	Bulk Concrete Quantities (yd^3)/Steel (T)
B1	Single vault arrays – single stack	76	41,761/945
B2	Single vault arrays – double stack	49	25,247/496
B3	Dual vault arrays– single stack	92	43,199/1,984
B4	Dual vault arrays– double stack	63	27,607/1,076

B6.2.2.10 Operating Costs

Operating costs were not estimated but merely assigned a cost factor, based on qualitative judgment, on the volume of the vault, which affects HVAC and quantity of major equipment. Alternative B2 is ranked best in terms of providing the lowest running cost option. This is primarily due to minimizing the vault volume and therefore HVAC requirements and minimizing power usage for mechanical handling equipment. This alternative should also have the lowest maintenance costs because it has the least overall equipment. Alternative B3 was ranked worst and the other alternatives ranked in between.

B6.2.2.11 Summary of Results

The evaluation shows that Alternative B2 has significant advantages in most evaluation criteria, and is therefore the preferred alternative for the closed tube vault concept. The only criterion where this alternative did not score highest was availability because only one gantry crane/charge machine is provided.

The operational modeling performed during this study shows that under normal operating conditions with no constraints on shipments to Yucca Mountain the vault area is not used and only limited staging positions are used in the load-in/load-out area. Therefore, there are no real drivers to provide more than one gantry crane/charge machine in the vault area.

Section B4.5.2 describes the drawbacks of combining the load-in/load-out function with the storage function for the closed tube concept, with the gantry crane/charge machine not suitable to provide this variety of functions. Alternative B2 is therefore evaluated against best alternative from each of the other storage concepts to determine the overall preferred storage alternative.

B6.2.3 Evaluation of the Savannah River Site Vault Alternatives

Table B.7 provides tabulated results of evaluation for the SRS vault concepts. Table B.7 shows that Alternative C2 has clear advantages over the other alternative, as summarized in the following sections against the evaluation criteria.

Table B.7. Evaluation Criteria Matrix for Savannah River Site Vault Alternatives

Evaluation Criteria	Criteria Weight	C1 – Single Vault Arrays, Single Stack		C2 – Single Vault Arrays, Double Stack	
		Score	Weighted Score	Score	Weighted Score
Operability	10	1	10	2	20
Availability	10	1	10	2	20
Technology maturity	5	2	10	2	10
Expandability	5	1	5	2	10
Environmental	10	1	10	2	20
Safety	15	1	15	2	30
Decontamination and decommissioning	5	1	5	2	10
Constructability	5	1	5	2	10
Capital cost	20	1	20	2	40
Operating cost	15	1	15	2	30
Total score	100		105		200

B6.2.3.1 Operability

Alternative C1 is ranked worst, due to additional complexity involved in having three vaults and individual canister rack position. Loading canisters into storage is complicated because 2,000 individual storage positions are used; therefore, there are twice the number of unique (loading point) operator interfaces than in the stacked configuration.

B6.2.3.2 Availability

Both alternatives have separate overhead cranes for the load-in/load-out functions. Alternative C1 is ranked worst due to having the greatest use of the SCT, the longest travel distances, and twice the quantity of unique loading point interfaces, which will challenge availability.

B6.2.3.3 Technological Maturity

In this category no significant difference was determined between both alternatives. The equipment concept is mature and proven. All would use the same equipment. Both were given maximum score.

B6.2.3.4 Expandability

Extending the vaults to enable the existing SCT to be extended over them is the preferred concept for both alternatives. Due to overall larger footprint of Alternative C1, this alternative represents the least favorable from a siting and expandability perspective and is scored accordingly.

B6.2.3.5 Environmental

The active volume of the vault in Alternative C2 is 630,480 ft^3, which is slightly more (1.2%) than Alternative C1 at 622,665 ft^3, which means that active effluent volumes will be similar for both alternatives. However, the operating area for the SCT has the smallest volume (681,600 ft^3), which also requires active ventilation. This volume is 55% less than Alternative C1. Secondary solid and liquid waste generation will be similar across both alternatives. Alternative C2 receives the best score.

B6.2.3.6 Safety

Alternative C2 is ranked best due to minimization of mechanical handling equipment and quantity of storage positions (and therefore half the quantity of confinement seals than the single stacked alternative), therefore reducing potential for radiological and industrial safety incidents. Overall, Alternative C2 has the best chance of minimizing dose uptake to operators.

B6.2.3.7 Decontamination and Decommissioning

In both alternatives, provisions will be made in the vault areas to aid decontamination for decommissioning. Canister racks are modular for installation and strip out and decontaminable surfaces will be provided on equipment and the vault internal concrete structure.

The vault has slightly more active volume than Alternative C1; however, quantity of steel for racks will be smaller than in Alternative C1, and therefore more equipment to decontaminate. Alternative C2 is ranked overall best.

B6.2.3.8 Constructability

Constructability is similar in both options – Alternative C2 has smallest footprint and quantity of vaults and the load-in/load-out cell interface is least complicated as it will be above grade. Overall, Alternative C2 is marginally less complex than Alternative C1. Alternative C2 has 45% less bulk concrete (173 yd^3) than Alternative C1 (315 yd^3).

B6.2.3.9 Capital Cost

Size and space utilization has an impact on capital cost. Footprint of vault in Alternative C2 is 17,040 ft^2 and volume of vault is 630,480 ft^3. This is best of both alternatives, when the operating area volume is factored in. Alternative C2 will incur less capital costs to ventilate than the single stacking option, having overall 55% less volume to ventilate than Alternative C1.

The approach to developing capital cost for the vault area was to focus only on discriminating cost and quantity elements for each of the alternatives, and not to develop complete capital cost estimates. Therefore, capital costs and quantity estimates, excluding design and installation cost, were developed in two major areas as follows:

- Major mechanical handling equipment, including storage rack quantity and cost
- Quantity of bulk concrete required for vault areas and tons of primary steel required for the operating area above the vault.

Equipment costs were obtained from the current estimate for the Glass Waste Storage Building #2 at the SRS Defense Waste Processing Facility. Load-in/load-out equipment is similar across all alternatives and is therefore not a discriminator.

Quantity of bulk concrete was developed by take-offs from the preliminary layouts developed for each alternative and quantities prorated from CSB Hanford quantities, based on volume comparison.

All other major capital cost elements (e.g., HVAC, design and engineering, control engineering and instrumentation) were assumed to be proportionate to the vault size and amount and complexity of major equipment. Table B.8 shows the summary costs and quantities respectively for each of the two discriminating areas. Table B.8 shows that Alternative C2 scores best in terms of cost of vault equipment and bulk construction quantities.

Table B.8. Discriminating Capital Cost Elements for Savannah River Site Vault Alternatives

Alternative Identifier	Alternative Description	Discriminating Vault Equipment Costs ($M)	Bulk Concrete Quantities (yd^3)/ Steel (T)
C1	Single vault arrays – single stack	31	690/315
C2	Single vault arrays – double stack	22	482/173

B6.2.3.10 Operating Costs

Operating costs were not estimated but merely assigned a cost factor, based on qualitative judgment, on the volume of the vault and operating area, which affects HVAC and quantity of major equipment. Alternative C2 is ranked best in terms of providing the lowest running cost option. This is primarily due to minimizing the operating area above the vault and therefore HVAC requirements. This alternative should also have the lowest maintenance costs because it has the least overall equipment.

B6.2.3.11 Summary of Results

The evaluation shows that Alternative C2 has significant advantages in most evaluation criteria, and is therefore the preferred alternative for the SRS vault concept. Alternative C2 is therefore evaluated against the other preferred storage concept alternatives in Section B6.6 to determine the overall preferred storage alternative.

B6.2.4 Evaluation of the Dry Cask Alternatives

Table B.9 provides tabulated results of evaluation for the dry cask storage concepts. Table B.9 shows that Alternative D2 has clear advantages over the other alternative as evaluated in the following sections against the evaluation criteria.

Table B.9. Evaluation Criteria Matrix for Dry Cask Storage Alternatives

Evaluation Criteria	Criteria Weight	D1 – Single Canister Overpacks – Horizontally Loaded and Stored		D2 – 5-Canister Overpacks – Vertically Loaded and Stored	
		Score	Weighted Score	Score	Weighted Score
Operability	10	1	10	2	20
Availability	10	1	10	2	20
Technology maturity	5	1	5	2	10
Expandability	5	1	5	2	10
Environmental	10	1	10	2	20
Safety	15	1	15	2	30
Decontamination and decommissioning	5	1	5	2	10
Constructability	5	2	10	1	5
Capital cost	20	1	20	2	40
Operating cost	15	1	15	2	30
Total score	**100**		**105**		**195**

B6.2.4.1 Operability

Physical complexity of loading single canisters horizontally in Alternative D1 in the load-in/load-out cell is increased over vertical loading, as the canisters are designed for vertical handling and additional equipment would be required in the load-in/load-out cell to turn the canisters to the horizontal and push them into the overpack. In addition, due to size of storage pad required handling times will be more in Alternative D1 than handling the five canister storage cask, as five overpacks need to be retrieved to fill one MGR cask. Alternative D2 receives best score.

B6.2.4.2 Availability

There are more unit operations involved in handling the canister horizontally and vertically in Alternative D1, as opposed to just vertically in Alternative D2. This necessitates additional handling equipment and therefore probability of failure increases. Alternative D1 receives worst score.

B6.2.4.3 Technological Maturity

Alternative D1 involves both horizontal and vertical handling of the canisters. Horizontal handling of SNF into dry casks is a proven concept. However, the IHLW canister is thin-walled and not designed to be handled or stored horizontally and the existing design would have to be analyzed accordingly. Therefore for this particular application the technology is not proven and Alternative D1 receives the worst score.

B6.2.4.4 Expandability

Expandability is a simple matter of expanding the storage pad size to accommodate additional overpacks. The overall footprint required for the storage pad in Alternative D2 is 440 feet by 314 feet and is the least constrained of the two alternatives, and significantly smaller than Alternative D1. Alternative D2 scores best of both alternatives.

B6.2.4.5 Environmental

From a permitting standpoint there is little difference between the alternatives. Both overpack types would go through the same permitting process. There is significantly more handling equipment required in Alternative D1 than in Alternative D2 and, therefore, solid waste from maintenance activities would be the largest of both alternatives. Alternative D2 scores best of both alternatives.

B6.2.4.6 Safety

Both overpack types and storage configurations will be designed to be critically safe. There are five times as many overpacks in Alternative D2, as well as discrete handling operations, and therefore more challenge on operational safety. Alternative D1 scores worst of both alternatives.

B6.2.4.7 Decontamination and Decommissioning

The quantity of handling equipment in the load-in/load-out cell for Alternative D2 is less than in Alternative D1 and therefore less to D&D. Significantly less concrete is required to construct the 400 five-canister overpacks and therefore less concrete to dispose of than in the single canister overpack configuration. Alternative D2 scores best of both alternatives.

B6.2.4.8 Constructability

The single canister overpacks can be constructed offsite for shipment to the HSF. The Alternative D2 storage casks should be constructed onsite. The storage pad for Alternative D1 is significantly larger than in Alternative D2 (factor of 2.6) but has the same constructability issues as Alternative D2. Alternative D1 is marginally better than Alternative D2 and receives best score.

B6.2.4.9 Capital Cost

From an equipment standpoint Alternative D2 is the least expensive. The approach to developing capital cost for the dry cask alternative was to focus only on discriminating cost and quantity elements for each of the alternates, and not to develop complete capital cost estimates. Therefore capital costs and quantity estimates, excluding design and installation cost, were developed in two major areas as follows:

- Major mechanical handling equipment discriminators in the load-in/load-out cell and handling equipment to the storage pad
- Cost of overpacks and construction costs of the storage pad.

Equipment costs were obtained from BNFL Fuel Solutions, which specializes in the design, permitting, and construction of nuclear transportation and storage casks. Cask rough-order-of-magnitude estimates are based on price for VSC-24 storage casks at Arkansas Nuclear One. Table B.10 shows the summary costs and quantities respectively for each of the two discriminating areas. Table B.10 shows that Alternative D2 scores best in overpack costs, discriminating mechanical handling costs, and construction costs of the storage pad.

Table B.10. Discriminating Capital Cost Elements for Dry Cask Storage Alternatives

Alternative Identifier	Alternative Description	Overpack Construction Costs ($M)	Additional Handling Equipment and Storage Pad Construction Costs ($M)
D1	Single canister overpack	130	21
D2	Five canister overpack	110	12

B6.2.4.10 Operating Costs

Operating costs were not estimated but merely assigned a cost factor. Based on qualitative judgment, Alternative D2 is ranked best in terms of providing the lowest running cost. This alternative should also have the lowest maintenance costs because it has the least overall equipment. In Alternative D2, canisters are handled in fives and there are less operations required for transfer to and from the storage pad than single canister handling in Alternative D1. Operational time and cost is significantly smaller. Alternative D2 scores best of both alternatives.

B6.2.4.11 Summary of Results

The evaluation shows that Alternative D2 has significant advantages in most evaluation criteria, in terms of capital and operational costs, and from an operability and maintainability perspective, and is therefore the preferred alternative for the dry cask storage concept. Alternative D2 is therefore evaluated against the other preferred storage concept alternatives in Section B6.6 to determine the overall preferred storage alternative.

B6.3 EVALUATION OF PREFERRED STORAGE ALTERNATIVE

This section provides the results of the evaluation of the overall preferred storage alternative for the HSF. The evaluation was based on comparison of the following alternatives, selected from each of the four basic storage concepts:

- Alternative A2 – Open Rack Vault Concept – Single Vault, Double Stack
- Alternative B2 – Closed Tube Vault Concept – Single Vault Arrays, Double Stack
- Alternative C2 – SRS Vault Concept – Single Vault Arrays, Double Stack
- Alternative D2 – Dry Cask Storage Concept – 5-Canister Overpack.

Evaluation of the alternatives was performed using the evaluation criteria and criteria weight developed in Section B5.0. The performance level is judged as poor to good, with a corresponding score of 1 through 4, respectively, when compared to each other. Amongst the alternatives at least one must receive a score of 1 and another a score of 4 for a specific evaluation criterion. The remaining alternatives receive a score based on comparison with the best (4) and worst (1) score for that evaluation criterion. No two alternatives shall receive the same score unless they are identical in the manner in which they meet the evaluation criterion. Attachment B2 provides the detailed evaluation matrix for alternative evaluation.

Table B.11 tabulates the results of the alternative analysis. Table B.11 shows that open rack vault concept Alternative A2 has clear advantages over the other concepts. This is summarized in the following sections.

B6.3.1 Operability

The use of a remote-operated, overhead crane for placing canisters into an open rack module (Alternative A2) is an overall simpler concept than using a charge machine (Alternatives B2 and C2), which requires multiple operations to load the canister into the tube/rack. The crane is a less complex machine than the gantry crane/charge machine/SCT, as evidenced by the difference in capital cost. System responsiveness is better with an in-cell crane, speed is greater and overall operational time is less than the gantry crane/charge machine/SCT alternative. Dry cask storage is worst of all options due to multiple tasks required to transfer to and from storage pad. Alternative A2 receives best score, with Alternative D2 receiving worst and the other two alternatives receiving average scores.

B6.3.2 Availability

The in-cell overhead crane concept used in Alternative A2 is well proven and has been developed to be modular in design for maintenance. However, the crane is operating in a high-radiation environment and is therefore more susceptible to failure than if used in a non-radioactive area. Overall the crane is a simpler device than the gantry crane/charge machine used in Alternative B2 and the SCT in Alternative C2, and, although the gantry crane and SCT are readily accessible for maintenance in separate maintenance zone in the operating area, maintenance of the charge machine will require local tenting operations and potentially larger downtimes. Alternative A2 is ranked the best alternative against this evaluation criterion. In Alternative D2 more handling equipment is required than in all the other alternatives and therefore availability will be impacted. Alternative A2 receives the best score with Alternative B2 second, Alternative C2 third, and Alternative D2 ranked worst.

B6.3.3 Technology Maturity

The in-cell crane in Alternative A2 and the gantry crane/charge machine in Alternative B2 are proven both in the U.S. and U.K. Similarly, the rack storage and tube storage concepts are also both well proven. The SCT is proven at SRS and the use of dry cask for storage is proven in the U.S. There are no major differences between concepts and therefore all receive best score for this evaluation criterion.

Table B.11. Evaluation Criteria Matrix for Preferred Vault Options

Evaluation Criteria	Criteria Weight	A2 – Open Rack Single Vault Double Stack		B2 Closed Tube - Single Vault Arrays, Double Stack		C2 – Savannah River Concept – Single Vault Arrays – Double Stack		D2 – Dry Cask Storage – 5-Canister Overpack	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Operability	10	4	40	3	30	2	20	1	10
Availability	10	4	40	3	30	2	20	1	10
Technology maturity	5	4	20	4	20	4	20	4	20
Expandability	5	4	20	2	10	3	15	1	5
Environmental	10	2	20	3	30	1	10	4	40
Safety	15	4	60	3	45	2	30	1	15
Decontamination and decommissioning	5	2	10	4	20	3	15	1	5
Constructability	5	3	15	1	5	2	10	4	20
Capital cost	20	4	80	2	40	3	60	1	20
Operating cost	15	4	60	2	30	3	45	1	15
Total score	100		365		260		245		160

B6.3.4 Expandability

Closed tube vault concept Alternative B2 has the option to expand the vaults at the end of the existing array, and extend the gantry crane/charge machine travel to cover the new vaults, or incorporate a bogie tunnel transfer, as in the open rack vault alternative. In open rack Alternative A2, expansion must incorporate a new crane in the canister storage area, as the original vault area cannot easily be expanded, due to travel constraints on the in-cell crane, and the fact that the vault will be an active area. However, expansion is relatively easy, using a bogie transfer tunnel to transfer between adjacent vault modules. The dry cask storage pad can easily be expanded to add more overpacks. Facility footprint is an important aspect in expandability, as it affects siting. Alternative A2 has the smallest footprint (12,338 ft^2), with Alternative B2 (30,163 ft^2), Alternative C2 (17,040 ft^2) and Alternative D2 (138,000 ft^2). In Alternatives B2 and C2, the same loading equipment may be used. Alternative A2, although requiring an additional in-cell crane in the expansion module, has the smallest footprint of all options and is therefore the least constrained from a siting perspective. Alternative A2 receives the best score, with Alternative C2 second, Alternative B2 third, and Alternative D2 ranked worst.

B6.3.5 Environmental

Alternatives A2 and C2 require an active ventilation system to cool the vault. The closed tube vault alternative (B2) uses a passive system for vault cooling; however, an active ventilation system is needed in the large operating area above the vaults, as is also required in Alternative C2. The vault volume is minimized in the open rack alternative (A2) (684758 ft^3), which is 64% of that in the closed tube alternative (B2). Overall airborne emissions in Alternatives A2 and C2 have a potential to be greater than in the closed tube alternative (B2), due to the need to filter the exhaust air, although exhaust volumes will be greater in the closed tube alternative (B2). Alternative D2 receives the best score as the canisters are sealed in the overpacks and do not need a ventilation system. Alternative B2 is ranked second with Alternative A2 third and Alternative C2 ranked worst, primarily due to having active vault ventilation and a large operating area to ventilate.

B6.3.6 Safety

In the open rack alternative (A2) operations for loading canisters into the storage area are totally remote, therefore minimizing dose to operators. Maintenance of handling equipment is in a dedicated area with requisite shielding, whereas the charge machine in Alternatives B2 and C2 require temporary tenting/HVAC provisions for maintenance. In Alternatives B2 and C2, maintenance of the vault confinement relies on mechanical seals in each of the storage tube/rack plugs, whereas in the open rack concept the vault is sealed by a limited number of seals at the shield doors and transfer hatch. There is therefore a greater overall potential for containment to be challenged and safety incidents in Alternatives B2 and C2 than the open rack alternative. In Alternative D2 the canisters are constantly being transferred into and out of cell for the external storage and therefore more chance for a safety incident.

The IHLW canisters are designed to maintain containment in the event of a drop from a height of 22.9 feet. In the open rack concept of Alternative A2, the storage rack supports the top canister at approximately mid-length, allowing the canister lift height to be approximately equal to the canister's design drop height. For Alternatives B2 and C2, the lift height over an empty storage position will be greater than two canister lengths, and thus increases the potential of breaching the canister's containment in the event of a drop. In Alternative B2, a breach in the canister's containment would be confined to the individual storage tube with emissions mitigated by the charge machine and the storage tube plug seal; whereas in Alternatives A2 and C2, a canister breach could result in contamination of the storage vault and the other stored canisters and emissions would be mitigated by the ventilation system. In Alternative B2, the dropped canister could damage the integrity of the storage tube, resulting in a potential contamination of the ventilation system with unmitigated emissions to the atmosphere. In Alternatives A2 and C2, the dropped canister may locally damage the storage racks or ventilation air distribution system, resulting in structurally unsound storage racks or insufficient cooling of the stored canisters. For Alternative D2, dropped canister events would result in minimal impacts because of the low lift height requirements for loading the storage cask and because all canister handling operations are performed within the load-in/load-out cell. However, there are many more canister handling operations associated with Alternative D2 and additional handling and transportation operations of the storage cask outside of the HSF.

Considering the normal and off-normal safety aspects, Alternative A2 receives best score, with Alternative B2 second, Alternative C2 third, and Alternative D2 ranked worst.

B6.3.7 Decontamination and Decommissioning

All concepts will incorporate design features to aid D&D, including providing access points into the vault areas, selection of decontaminable materials and coatings for the vault structure. In open rack Alternatives A2 and C2, there is a slightly greater potential for contamination build up in the vault area over time that will require decontamination during decommissioning via cross-contamination of canisters, as they are not segregated in separate tubes, as in the closed tube alternative (B2). However the intention is that canisters will be checked for contamination before receipt, to maintain the cleanliness of the storage area. Decontaminable surfaces will be provided and the overall volume for decontamination is 56% of Alternative B2. Overall the closed tube alternative (B2) scores better than the open rack alternative (A2). Alternative A2 is slightly worse than Alternatives B2 and C2 with Alternative D2 being the worst, and the alternatives are scored accordingly.

B6.3.8 Constructability

In open rack Alternative A2, construction is a simple, regular box shape with the roof acting as a diaphragm. There are no complicated penetrations and 12,245 yd^3 of bulk concrete are required. This is 48% of that required in closed tube Alternative B2. In Alternative B2, construction of the basic vault uses regular box shapes; however, the charge floor is very complicated, because of the penetrations for the storage tubes. A much larger volume of bulk concrete is required in this option (B2) and in addition there is 496 tons of primary steel required for the operating area structure above the vaults. Alternative C2 requires 13,002 yd^3 of bulk concrete for the vault area, which is slightly more than that required for Alternative A2, but in addition requires 173 tons of primary steelwork for the large operating area above the vaults. Alternative D2 requires 42,500 yd^3 of bulk concrete to construct the storage pad and storage casks and is the simplest construction of all the alternatives. Alternative D2 receives best score, with Alternative A2 second, Alternative C2 third, and Alternative B2 ranked worst.

B6.3.9 Capital Cost

Space utilization has an impact on capital cost. The active volume of the open rack vault is 684,759 ft^3, which is 64% of closed tube vault. This is due to canister spacing, which is significantly less than in the closed tube concept (36 inches as opposed to 56 inches). Alternative A2 makes better use of the vault space and does not require a large operating area above the vault. Alternative C2 has a smaller vault volume than Alternative A2 (630,480 ft^3), but also has a large operating area (681,000 ft^3) above the vault that Alternative A2 does not have. Canister spacing is larger than in Alternative A2, but vault space is optimized above the racks. Alternative D2 requires a larger load-in/load-out area and an extra loading bay required for import and export of overpacks from the storage pad. The storage pad footprint is 138,000 ft^2, which is the largest of all the alternatives.

The approach to developing capital cost for the vault area was to focus only on discriminating cost and quantity elements for both alternatives, and not to develop complete capital cost estimates. Therefore, capital costs and quantity estimates, excluding design and installation costs, were developed in two major areas as follows:

- Major mechanical handling/equipment in the vault area and any additional equipment in the load-in/load-out area, including storage tube/rack quantity and cost
- Quantity of bulk concrete required for vault and storage areas and, for Alternatives B2 and C2, tons of primary steel required for the operating area above the vault.

Quantity of bulk concrete was developed by take-offs from the preliminary layouts developed for each alternative.

Table B.12 shows that Alternative A2 has significant capital cost advantages over the other options. The capital cost of the vault area open rack Alternative A2 is significantly less than the closed tube Alternative B2. The discriminating cost elements of $10.1 million for mechanical handling equipment (19% of Alternative B2) and quantity for bulk concrete construction in Alternative A2 is significantly smaller than the closed tube alternative (B2). The capital cost of the SRS vault concept (C2) will be less than the closed tube alternative (B2), as the racks are less expensive than the tubes provided in Alternative B2, and the SCT associated with Alternative C2 is a fraction of the cost of the gantry mounted charge machine in Alternative B2. The overall volume of Alternatives A2 and C2 is more compact than Alternative B2 with a smaller footprint and operating area. The overall construction cost for Alternative C2 will be significantly larger than Alternative A2 due to the cost of the vault equipment being more than double that of Alternative A2 and the increased cost for the large operating area above the vaults. Alternative D2 is ranked worst due to the cost of the 400 storage casks required at $275,000 each ($110 million total) and $8 million for the large concrete storage pad, and additional costs of the overpack loading bay and additional overpack handling equipment.

Table B.12. Discriminating Capital Cost Elements for the Preferred Vault Alternatives

Alternative Identifier	Alternative Description	Discriminating Mechanical Handling/Equipment Cost ($M)	Bulk Concrete Quantities (yd^3)/Steel (T)
A2	Open rack vault concept - single vault – double stack	10.1	12,245/0
B2	Closed tube vault concept - single vault arrays – double stack	49	25,247/496
C2	Savannah River vault concept - single vault arrays – double stack	22	13,004/173
D2	Dray cask storage concept – 5-canister overpack	122	42,500/0

B6.3.10 Operating Cost

The major discriminating area in terms of running costs for the alternatives (with the exception of Alternative D2) is associated with running costs for the ventilation system. In terms of power loads for mechanical handling, they will be similar across all alternatives. In the open rack alternative the vault requires active ventilation for the 684,759-ft^3 vault area. Ventilation will be via single-stage HEPA filtration and fan system to a single stack. This same arrangement will be required in Alternative C2. In the closed tube alternative (B2) the vaults are passively ventilated, therefore running costs are limited to additional monitoring requirements for each individual vault. However, in the closed tube alternative there is a large (1.95 million ft^3) operating area above the vaults that requires active ventilation. This area should normally be free from contamination, and therefore a re-circulating system is provided with a bleed off through HEPA filters to a local stack. The volume requiring active ventilation in the open rack alternative is 1/3 of the operating area volume requiring ventilation in the closed tube alternative (B2) and although no detailed estimates have been prepared within the timeframe of this study, overall running costs for the open-rack HVAC system are expected to be lower than in the closed tube alternative (B2). Alternative C2 also has a large operating area above the vaults that will require active ventilation, thus increasing running costs.

The main disadvantage in Alternative D2 is the operational costs associated with overpack loading and unloading which is not required in other alternatives. Overall, Alternative A2 scores best, with Alternative C2 second, Alternative B2 third, and Alternative D2 ranked worst.

B6.3.11 Summary

The analysis shows that there are clear advantages in utilizing an open rack vault concept over the other alternatives. Alternative A2 is therefore the preferred concept to be utilized in the overall facility layout provided in Appendix E of this report.

B6.4 FINDINGS AND RECOMMENDATIONS

B6.4.1 Findings

The analysis of alternatives for the storage and staging options, documented in Section B6.0 produced the following findings:

Staging

- Staging is closely linked to the load-in/load-out functions and from a layout perspective it is better if the staging function is separated from the storage function. This staging function is provided in a small cell, close to load-in/load-out ports. Staging positions were initially estimated at a total of 16 positions (enough to fill one cask for each canister type [i.e., three casks]). Initial operational modeling shows that, assuming no down stream delays, a maximum of 14 staging positions are needed during normal operations, to account for fluctuations in individual task times and equipment downtime.
- There are clear benefits in segregating the load-in/load-out cell (which includes the staging function) from the storage area (e.g., segregation to reduce cross-contamination, increase of availability, relative ease of expansion for increased canister storage capacity).
- The best handling method for operations in the staging area is to use an in-cell overhead crane. This method provides the flexibility and accuracy to enable the various functions to be performed that include inspection, staging, spot decontamination, handling all three canister types, and most importantly loading into the MGR cask in the various configurations required for each canister type.

Storage

- The overall preferred storage concept is the open rack vault Alternative A2. This concept has significant benefits over all the other three concepts from a capital cost, operations, and maintenance perspective. It provides the lowest capital cost storage alternative, and is based on proven use both in the U.K., and on a smaller scale in the U.S.

B6.4.2 Recommendations

It is clear that the solution for bulk canister storage must be a cost-effective method, meeting all safety requirements and providing a robust system from an operations and maintenance perspective. The closed tube storage concept, the SRS vault concept, and dry cask storage systems are all proven, both in the U.S. and U.K. as a safe, long-term storage concept, but they do not provide the simplest and most cost-effective solution, especially based on the low throughput requirements.

The operational modeling shows that a canister throughput of two per day can be achieved, if a two-shift system is adopted and an additional staging/preparation area is provided for the MGR cask. With these modifications there is only a limited requirement for staging required (14 positions maximum).

The recommendation from this appendix is to pursue an open rack vault concept, based on using a single vault and double stacking the canisters, with a separate load-in/load-out cell containing a small staging area. This concept is incorporated into the facility layout options developed in Appendix E.

B7.0 REFERENCES

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ATTACHMENT B1
EVALUATION CRITERIA MATRICES FOR STORAGE VAULT ALTERNATIVES

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Alternative A1 – Open Rack Vault – Single Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased in this option due to separate load-in/load-out cell and associated equipment and there are more operator interfaces with this option. System responsiveness increases with separate equipment. Overall operability is complicated by providing additional features necessary for the 340 foot travel length. Overall worst of all options.	10	1	10
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	As the canister storage crane is dedicated to storage functions, the *availability is greater than options* where these are combined. However utilization of crane is very low. Crane manufacturers recommendations are to keep travel lengths to <250 feet for a remote operated crane using a cable reel system for power, control and retrieval. Travel length of this crane is 340 feet and therefore reliability is in question. *Inspectability is the same in* all options.	10	1	10
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature however, because the crane span is at maximum recommended by crane manufacturer, travel length increases, and is greater than proven on any remote crane with cable reel system. Therefore, overall maturity is the least of all options.	5	1	5

Alternative A1 – Open Rack Vault – Single Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Expandability	Qualitative measure of the ease with which each concept can be expanded to add an additional storage module.	The storage transfer bogie tunnel is extended to periphery of the facility and is easily extendable to an adjacent facility. However, this concept has the second largest footprint of all the concept that may limit expandability, dependent upon chosen site and therefore receives an average score.	5	2	10
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the second largest active volume and therefore will incur more capital and running costs to ventilate the vault than the double stacking options – having 34% more active volume than Alternative A2. There will be more solid waste generated with this option than A2 but not as much as A3 and A4.	10	3	30
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all options as same rack spacing is utilized for all alternatives. Potential *dose uptake is reduced in this option* due to separate load-in/load-out equipment (storage equipment should be less contaminated). Receives second best score due to separate load-in/load-out equipment and reduced overall quantity of equipment.	15	3	45

Alternative A1 – Open Rack Vault – Single Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	The storage vault has second largest active volume and therefore volume to decontaminate. This is partially offset due to segregated load-in/load-out cell. All options will be designed for vault access to facilitate rack strip out and decontaminable surfaces and equipment materials will be provided.	5	3	15
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The single vault alternatives are simpler in construction than the dual vault alternatives and therefore this option scores well.	5	3	15
Capital Cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements that are major discriminators only.	From an equipment standpoint this option is the second most expensive – with approximately $14M vault MH equipment costs and second most bulk concrete required. HVAC will also be proportionate due to second most active volume. From space utilization standpoint footprint of vault is 22,940 ft^2 and volume of vault is 917,600 ft^3. This is second worst of all the options and represents an additional 34% volume over the double stacking options.	20	3	60
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be second greatest.	15	3	45
Total score					245

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative A2 – Open Rack Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased this option due to separate load-in/load-out cell and associated equipment but there are less operator interfaces with this option. Crane travel length and span are reduced increasing confidence in crane system. Overall best option.	10	4	40
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	Dual vault alternatives have greater availability, due to more equipment for discrete functions. Inspectability is the same in all options. Scores second lowest of all alternatives, having better availability due to smaller travel distance of storage crane.	10	2	20
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is same as A3 and A4.	5	4	20
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	A future storage transfer bogie tunnel is included that extends to periphery of the facility and is easily extendable to an adjacent facility. Due to the vault having the smallest footprint (12,338 ft^2), this provides the most compact arrangement overall and is the least constrained for siting additional storage modules. Gets best overall rating.	5	4	20

Alternative A2 – Open Rack Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the smallest active volume and therefore will incur least capital and running costs to ventilate the vault than the single stacking options and dual vaults. There will be less solid waste generated with this option than all the other options. *Gets best score.*	10	4	40
Safety	Assessment of the following factors: • Radiological protection and criticality safety • *Industrial safety* • ALARA.	Criticality safety is similar across all options as same rack spacing is utilized for all alternatives. Overall this option has the best chance of minimizing dose uptake to operators. This option also has half the number of canister storage positions than A1 and A3, and therefore a lower potential for indexing and grappling problems.	15	4	60
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to *facilitate future decontamination* for decommissioning.	Canister storage area has smallest active volume and therefore volume to *decontaminate. All options will be designed* for vault access to facilitate rack strip out and decontaminable surfaces and equipment materials will be provided. Receives best overall score.	5	4	20
Constructability	*Qualitative measure of ease of* construction assessing complexity, ability to use standard construction methods and materials.	The single vault alternatives are simpler in construction than the dual vault alternatives, has 25% less bulk concrete than A1 and *therefore this best option.*	5	4	20

Alternative A2 – Open Rack Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements which are major discriminators only.	Internal footprint of vault is 12,338 ft^2 and volume of vault is 684,759 ft^3. This is best space utilization of all options and makes best use of the in-cell crane. From an equipment standpoint this option is the least expensive – with a $9.2M vault MH equipment costs and least bulk concrete required. HVAC will also be less expensive than other options.	20	4	80
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be smallest of all options.	15	4	60
Total score					380

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative A3 – Open Rack Vault – Dual Vault Single Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased in this option due to dual vaults and separate load-in/load-out cell and associated equipment and there are more operator interfaces with this option. Storage loading is more complicated than A1 and A2 due to dual vaults with this option. System responsiveness increases with separate equipment. Crane travel length and span are reduced increasing confidence in crane system. Overall better than A1.	10	3	30
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	As the storage crane is not combined with the load-in/load-out crane, this system will have best availability. However, utilization of crane is very low. As normal operations will not use crane for storage function, then availability is not normally impacted. Inspectability is the same in *all* options. Scores highest of all alternatives	10	4	40
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is same as A2 and A4.	5	4	20
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	A storage transfer bogie tunnel is extended to the periphery of the facility and is extendable to an adjacent *facility. As this is not a dedicated* tunnel then bogie provisions increase capital cost. Most complex, has the largest footprint of all the options and therefore receives lowest score.	5	1	5

Alternative A3 – Open Rack Vault – Dual Vault Single Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the largest active volume and therefore will incur most capital and running costs to ventilate the vault. There will be more solid waste generated with this option than all the other options. Gets worst score.	10	1	10
Safety	Assessment of the following factors: • Radiological protection and criticality safety • *Industrial safety* • ALARA.	Criticality safety is similar across all options as same rack spacing is utilized for all alternatives. Potential dose uptake may be lower than A1 in this option due to separate load-in/load-out equipment. Average score.	15	3	45
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	Canister storage has largest active volume and therefore volume to decontaminate. However the vault and storage/load-in/load-out are separated and therefore less chance for long-term contamination build up in the vault. All options will be designed for vault access to facilitate rack strip out and decontaminable surfaces and equipment materials will be provided. *Overall given worst score.*	5	1	5
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The dual vault alternatives are more complex to build and this option has the most bulk concrete – receives lowest score.	5	1	5

Alternative A3 – Open Rack Vault – Dual Vault Single Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements which are major discriminators only.	Internal footprint of vault is 25,472 ft^2 and volume of vault is 987,040 ft^3. This is worst space utilization of all options and makes least use of the in-cell cranes. From an equipment standpoint, this option is the most expensive – with $18.3M vault MH equipment costs and most bulk concrete required. HVAC will also be more expensive than other options.	20	1	20
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be largest of all options.	15	1	15
Total score					195

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative A4 – Open Rack Vault – Dual Vault Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased in this option due to dual vaults, however partially offset due to combining the load-in/load-out cell and associated *equipment. Canister storage loading* is more complicated than A2 due to dual vaults with this option. Overall second best option.	10	3	30
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	As the storage crane is combined with the load-in/load-out crane, system availability is reduced from A3. However, utilization of crane is very low. As normal operations will not use crane for storage function then availability is not normally impacted. Inspectability is the same in all options. Scores second highest of all alternatives.	10	3	30
Technology Maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is same as A3 and A4.	5	4	20
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	A canister storage transfer bogie tunnel is extended to the periphery of the facility and is easily extendable to an adjacent facility. As this is not a dedicated tunnel, then bogie provisions increase capital cost. Gets average overall rating.	5	3	15

Alternative A4 – Open Rack Vault – Dual Vault Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the second least active volume and therefore will incur less capital and running costs to ventilate the vaults. There will be more solid waste generated with this option than single vault options but better than A3. Gets second best score.	10	3	30
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all options as same rack spacing is utilized for all alternatives. Potential dose uptake may be greater than other options due to potential contamination spread from combined load-in/load-out equipment. Lowest score.	15	1	15
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	The storage vault has second least active volume and therefore volume to decontaminate. However, the vault and storage/load-in/load-out are combined and therefore more chance for long-term contamination build up in one of the vaults. All options will be designed for vault access to facilitate rack strip out and decontaminable surfaces and equipment materials will be provided. Average rating.	5	3	15
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The dual vault alternatives are more complex to build – receives average score.	5	3	15

Alternative A4 – Open Rack Vault – Dual Vault Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements, which are major discriminators only.	Internal footprint of vault is 14,605 ft^2 and volume of vault is 782,068 ft^3. *This is the second best space* utilization of all options and makes more use of the in-cell cranes. *From an equipment standpoint this* option ranks second least expensive – with $13.9M vault MH equipment costs. HVAC will also be more expensive than other options.	20	3	60
Operating cost	Comparison of the O&M costs for each option. *Costs will be a* relative cost factor only.	Operating costs will be similar scoring *to capital costs – HVAC running costs* will be second largest of all options.	15	3	45
Total score					**275**

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative B1 – Closed Tube Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased due to quantity of vault and individual canister tubes, which provides double the quantity of unique operator interface points than the double stacked alternatives. Eight exhaust stacks and associated monitoring increases operation monitoring. Having separate tubes for each canister doubles the unique loading points and therefore has greater potential for complications during storage loading and travel length of gantry is longest of all options. Overall worst of all options.	10	1	10
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	Gantry crane usage is greatest of all options, therefore availability will be impacted. Inspectability is the same in all options. Maintainability is similar in all options.	10	1	10
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is similar for all options. All receive same score.	5	4	20

Alternative B1 – Closed Tube Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Expandability	Qualitative measure of the ease with which each concept can be expanded to add an additional storage module.	There are two main options for expandability with the closed tube options – extending the vaults to enable the existing gantry crane to be extended over them or providing a bogie tunnel link between the storage *module and an adjacent module. In* this option a bogie tunnel is shown with transfer into the tunnel using the gantry crane. Bogie equipment would not be required on initial construction, as this bogie does not perform other functions. Due to overall footprint of this option it represents the second least favorable from a siting and expandability perspective and is scored accordingly.	5	2	10
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	The operating area for the gantry crane has the second most volume, which also needs ventilation. There will be more solid waste *generated with this option than* B2 but not as much as B3 and B4.	10	2	20

Alternative B1 – Closed Tube Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all options as same tube spacing is utilized for all alternatives. Receives second worst score due to overall quantity of equipment and storage positions, which increase potential for safety incident/contamination, by having 2,000 unique operator interfaces with individual elastomeric seals providing containment.	15	2	30
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	Vault has second largest active volume and therefore volume and storage tubes to decontaminate. All options will be designed for vault access to facilitate tube strip out and decontaminable surfaces and equipment materials will be provided.	5	2	10
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The single vault alternatives are simpler in construction than the dual vault alternatives (which have complex internal structures for the individual HVAC plenums), and therefore this option scores average.	5	3	15

Alternative B1 – Closed Tube Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements that are major discriminators only.	Footprint of vault is 59,631 ft^2 and volume of vault is 1,247,664 ft^3. This is second worst of all the options and represents an additional 17% volume over the double stacking options. This option will incur more capital costs to ventilate the vault than the double stacking options – having 17% more active volume than Alternative B2. From an equipment standpoint this option is the second most expensive – with a $76M vault MH equipment costs and second most bulk concrete required. HVAC will also be proportionate due to second most active volume.	20	2	40
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be second greatest.	15	2	30
Total score					**195**

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative B2 – Closed Tube Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Storage loading slightly more complicated with this option; however, as canisters are stacked operator interfaces are reduced due half the quantity of storage tubes. Has shorter travel distances than the A1 option. Overall best option.	10	4	40
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	A single gantry/charge machine is provided, and therefore will have lower availability than B3 and B4. However, utilization of storage gantry crane is very low. Inspectability is the same in all options. Better availability because less usage than in B1 but not as good as B3 an B4.	10	2	20
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is similar for all options. All receive same score.	5	4	20

Alternative B2 – Closed Tube Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	There are two main options for expandability with the closed tube options – extending the vaults to enable the existing gantry crane to be extended over them or providing a bogie tunnel link between the storage module and an adjacent module. In this option a bogie tunnel is shown with transfer into the tunnel using the gantry crane. Bogie equipment would not be required on initial construction, as this bogie does not perform other functions. Due to overall footprint of this option it represents the most favorable from a siting and expandability perspective and is scored accordingly.	5	4	20
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the lowest active volume and therefore will incur least capital costs to ventilate the vault. In addition, the operating area for the gantry crane has the smallest volume, which also needs ventilation. There will be less solid waste generated with this option than the other. Receives best score.	10	4	40
Safety	Assessment of the following factors: • Radiological protection and criticality safety • *Industrial safety* • ALARA.	Criticality safety is similar across all options as same tube spacing is utilized for all alternatives. *Receives* best score due to overall quantity of MH equipment and storage positions, which decreases potential for safety incident/contamination, etc.	15	4	60

Alternative B2 – Closed Tube Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	Vault has smallest active volume and therefore volume and storage tubes to decontaminate. All options will be designed for vault access to facilitate tube strip out and decontaminable surfaces and equipment materials will be provided.	5	4	20
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The single vault alternatives are simpler in construction than the dual vault alternatives, has 40% less bulk concrete than B1 and therefore this best option.	5	4	20
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements which are major discriminators only.	Internal footprint of vaults is 30,163 ft^2 and volume of vaults is 1,069,744 ft^3. This is best space utilization of all options and makes best use of the storage tubes and operating area. From an equipment standpoint this option is the least expensive – with a $49M vault MH equipment costs and least bulk concrete required. HVAC will also be less expensive than other options.	20	4	80
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be smallest of all options.	15	4	60
Total score					380

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative B3 – Closed Tube Vault – Dual Vault Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased in this option due to dual vaults and the need for a bogie transfer between the vault areas and there are more operator interfaces with this option. Storage loading is more complicated than B2 due to dual vaults with this option. System responsiveness increases with separate equipment. Gantry crane/charge machine has smaller travel distance than B1 and therefore receives second lowest score.	10	2	20
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	Two gantry/charge machines are provided, and therefore will have greater availability than B1 and B2. However utilization of storage gantry crane is very low. Inspectability is the same in all options. Overall second best availability.	10	3	30
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is similar for all options. All receive same score.	5	4	20

Alternative B3 – Closed Tube Vault – Dual Vault Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	There are two main options for expandability with the closed tube options – extending the vaults to enable the existing gantry crane to be extended over them or providing a bogie tunnel link between the storage module and an adjacent module. In this option a bogie tunnel is shown with transfer into the tunnel using the gantry crane. Bogie equipment would not be required on initial construction, as this bogie does not perform other functions. Due to overall footprint of this option it represents the least favorable from a siting and expandability perspective and is scored accordingly.	5	1	5
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the largest active volume and therefore will incur most capital and running costs to ventilate the vault/operating area. There will be more solid waste generated with this option than all the other options. Gets worst score.	10	1	10

Alternative B3 – Closed Tube Vault – Dual Vault Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all options as same tube spacing is utilized for all alternatives. Receives worst score due to overall quantity of MH equipment and number of unique storage positions, which increases potential for safety incident/contamination, etc.	15	1	15
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning	Vault has largest active volume to decontaminate. All options will be designed for vault access to facilitate tube strip out and decontaminable surfaces and equipment materials will be provided. Receives worst score	5	1	5
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The dual vault alternatives are more complex to build and this option has the most bulk concrete – receives lowest score.	5	1	5
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements which are major discriminators only.	Internal footprint of vault is 60,326 ft^2 and volume of vault is 1,272,128 ft^3. This is worst space utilization of all options and makes least use of the in-cell cranes. From an equipment standpoint this option is the most expensive -- with a $92M vault MH equipment costs and most bulk concrete required. HVAC will also be more expensive than other options.	20	1	20

Alternative B3 – Closed Tube Vault – Dual Vault Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be largest of all options.	15	1	15
Total score					**145**

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative B4 – Open Rack Vault – Dual Vault Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased in this option due to dual vaults. Canister storage loading is more complicated than B2 due to dual vaults with this option. System responsiveness increases with separate equipment. Overall second best option.	10	3	30
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	Two gantry/charge machines are provided, and therefore will have greater availability than B1 and B2. However, utilization of storage gantry crane is very low. Inspectability is the same in all options. Overall best availability.	10	4	40
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is similar for all options. All receive same score.	5	4	20

Alternative B4 – Open Rack Vault – Dual Vault Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	There are two main options for expandability with the closed tube options – extending the vaults to enable the existing gantry crane to be extended over them (preferred in this option due to vault configuration) or providing a bogie tunnel link between the storage module and an adjacent module. In this option a bogie tunnel is shown with transfer into the tunnel using the gantry crane. Bogie equipment would not be required on initial construction, as this bogie does not perform other functions. Due to overall footprint of this option it represents the second most favorable from a siting and expandability perspective and is scored accordingly.	5	3	15
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	This option has the second least active volume and therefore will incur less capital and running costs to ventilate the vaults/operating area. There will be more solid waste generated with this option than single vault options but better than B3. Gets second best score.	10	3	30

Alternative B4 – Open Rack Vault – Dual Vault Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all options as same tube spacing is utilized for all alternatives. Receives second worst score due to overall quantity of MH equipment and storage positions, which increases potential for safety incident/contamination etc.	15	2	30
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	Vault has second smallest active volume. All options will be designed for vault access to facilitate tube strip out and decontaminable surfaces and equipment materials will be provided. Receives second best score.	5	3	15
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	The dual vault alternatives are more complex to build and this option has the most bulk concrete – receives second lowest score.	5	2	10
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements which are major discriminators only.	Internal footprint of vaults is 30,858 ft^2 and volume of vault is 1,110,888ft^3. This is the second best space utilization of all options. From an equipment standpoint this option is ranked second least expensive – with $63M vault MH equipment costs.	20	3	60
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be second largest of all options.	15	3	45
Total score					295

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.

Alternative C1 – Savannah River Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Physical complexity is increased due to quantity of vault and individual canister rack positions, which provides double the quantity of unique operator interface points than the double-stacked alternative. Having separate tubes for each canister doubles the unique loading points and therefore has greater potential for complications during storage loading and travel distance is longest of both options, decreasing storage loading/unloading responsiveness. Overall worst of both options.	10	1	10
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	SCT usage is greatest of both options; therefore, availability will be impacted. Inspectability is the same in both options. Maintainability is similar in both options.	10	1	10
Technology maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is similar for all options. Both receive same score.	5	2	10

Alternative C1 – Savannah River Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Expandability	Qualitative measure of the ease with which each concept can be expanded to add an additional storage module.	Extending the vaults to enable the existing SCT to be extended over them is the preferred concept for this alternative. Due to overall footprint of this option, it represents the least favorable from a siting and expandability perspective and is scored accordingly.	5	1	5
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	The active volume of the vault is 622,665 ft^3, which is slightly less than C2 at 630,480 ft^3, which means that effluent volumes will be similar for both options. However, the operating area for the SCT has the largest volume 1,241,220 ft^3, which also require active ventilation. This area is 82% more than C2. Secondary solid and liquid waste generation will be similar across both options. Overall receives worst score.	10	1	10
Safety	Assessment of the following *factors:* • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all *options as same canister spacing is* utilized for all alternatives. Receives worst score due to overall quantity of equipment and storage positions, which increase potential for safety incident/contamination, by having 2,000 unique operator interfaces with individual elastomeric seals providing containment.	15	1	15

Alternative C1 – Savannah River Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	Vault has slightly less active volume than C2; however, quantity of steel for racks will be larger than in C2 and therefore volume to decontaminate. Both options will be designed for vault access to facilitate rack strip out and decontaminable surfaces and equipment materials will be provided.	5	1	5
Constructability	Qualitative measure of ease of construction assessing complexity, ability to use standard construction methods and materials.	Constructability is similar in both options – C1 has largest footprint and quantity of vaults and the load-in/ load-out cell interface is complicated as it will be below grade. Overall C1 is marginally more complex than C2.	5	1	5
Capital cost	Comparison of the capital cost for each option. Capital cost is a relative cost factor only, based on cost elements which are major discriminators only.	Footprint of vault is 31,133 ft^2 and volume of vault is 622,655ft^3. This is worst of both options, when the operating area volume is factored in. This option will incur more capital costs to ventilate than the double-stacking option – having overall 80% more volume to ventilate than Alternative C2. From an equipment standpoint this option is the most expensive – with a $31M vault equipment costs and most bulk concrete required. HVAC will also be proportionate due to most overall volume.	20	1	20

Alternative C1 – Savannah River Vault – Single Stack (4 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operating cost	Comparison of the O&M costs for each option. Costs will be a relative cost factor only.	Operating costs will be similar scoring to capital costs – HVAC running costs will be second greatest.	15	1	15
Total score					105

ALARA = as low as reasonably achievable.
HVAC = heating, ventilation, and air conditioning.
MH = mechanical handling.
O&M = Operations and Maintenance.
SCT = shielded canister transporter.

Alternative C2 – Savannah River Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Operability	Qualitative measure of inherent complexity determined by the following factors: • Physical complexity • Operator interfaces • System responsiveness.	Canister storage loading slightly more complicated with this option; however, as canisters are stacked unique operator interfaces are reduced due half the quantity of storage tubes. Has shorter travel distance for the SCT than the C1 option. Overall best option.	10	2	20
Availability	Qualitative measure of the following: • Maintainability • Reliability • Inspectability.	SCT usage is smallest of both options; therefore, availability should be better than C1. Inspectability is the same in both options. Maintainability is similar in both options.	10	2	20
Technology Maturity	Measure of the relative maturity of the concept applied on a production scale in the nuclear industry.	The overall concept is mature and is similar for all options. Both receive same score.	5	2	10
Expandability	Qualitative measure of the ease with which each concept can be expanded to add additional storage modules.	Extending the vaults to enable the existing SCT to be extended over them is the preferred concept for this alternative. Due to the smallest overall footprint (55% of C1), this option represents the most favorable from a siting and expandability perspective and is scored accordingly.	5	2	10

Alternative C2 – Savannah River Vault – Double Stack (3 Sheets)

Evaluation Criteria Category	Evaluation Criteria Description	Performance of Alternative	Weight	Score	Subtotal
Environmental	Measurement of the following factors: • Airborne effluent generation and associated cleanup equipment • Secondary solid and liquid waste generation and disposal • Permitting requirements.	The active volume of the vault is 630,480 ft^3, which is slightly more (1.2%) than C1 at 622,665 ft^3, which means that active effluent volumes will be similar for both options. However, the operating area for the SCT has the smallest volume 681,600 ft^3, which also require active ventilation. This area is 55% less than C1. Secondary solid and liquid waste generation will be similar across both options. Overall receives best score.	10	2	20
Safety	Assessment of the following factors: • Radiological protection and criticality safety • Industrial safety • ALARA.	Criticality safety is similar across all options as same canister spacing is utilized for all alternatives. Receives best score half the overall quantity of storage positions, and therefore half the quantity of elastomeric seals providing containment, therefore being less of a challenge which increases potential for safety incidents/contamination.	15	2	30
Decontamination/ decommissioning	Qualitative measure of features incorporated into design to facilitate future decontamination for decommissioning.	Vault has slightly more active volume than C1; however, quantity of steel for racks will be smaller than in C1 and therefore volume to decontaminate. Both options will be designed for vault access to facilitate rack strip out and decontaminable surfaces and equipment materials will be provided.	5	2	10