Functional Design and Operational Requirements for a Storage Facility for High Level Waste Canisters, New York, USA – 10309

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ABSTRACT

Liquid High-Level Waste (HLW) vitrification was conducted at the West Valley Demonstration Project (WVDP, the Project) between 1996 and 2002, and resulted in 275 stainless steel canisters filled with solidified HLW waste see Figure 1). The HLW canisters were placed in a shielded cell within the former Main Plant Process Building (MPPB, Main Plant) that was decontaminated and retrofitted for temporary storage.

The West Valley Demonstration Project Act of 1980 requires the U.S. Department of Energy (DOE) to safely store the canisters and ship them off site for permanent disposal at a federal HLW repository when one becomes available. While storage of the canisters in the Main Plant was considered a viable short-term option, long-term storage inside the facility is undesirable due to the WVDP's plan to demolish the former nuclear fuel reprocessing facility and the negative impact storing the canisters in the Main Plant has on "hotel costs" associated with their continued storage in the aging facility. As a result, the WVDP has begun pursuing other options for onsite storage of the canisters until their disposal at a federal repository is possible.

Fig. 1. 275 HLW canisters are currently safely stored in the Main Plant Process Building.

INTRODUCTION

The WVDP began evaluating design options and siting locations for alternate onsite storage of the HLW canisters in 2009. Two expert teams were assembled to 1) review the functional requirements of an alternate onsite storage facility, and 2) to determine the best location for that facility on the 55-hectare (165-acre) Project premises. The design team reviewed existing storage systems for dry storage of spent nuclear fuel (SNF) and compared them to the WVDP's HLW canister storage needs. The siting team reviewed existing and future site uses and environmental investigation data to determine the recommended location for the storage area.

The team that conducted this work included representatives from DOE, the New York State Energy Research and Development Authority (NYSERDA), West Valley Environmental Services (WVES), and Washington Safety Management Solutions (WSMS). This paper will discuss the teams' efforts to design and locate (site) a functional facility for long-term (up to 50 years) storage of the West Valley HLW canisters.

FUNCTIONAL REQUIREMENTS

WVES initiated the HLW canister relocation project with an extensive review of historical documents and existing technologies. The historical review included documents containing alternative storage concepts satisfying different objectives and criteria. The content and depth of analysis and recommendations or conclusions were commensurate with the objective of the analysis. The review included documents written for the following objectives or audiences:

- Draft Environmental Impact Statement support cases
- Shipping and licensing potential
- Federal baseline
- Overall feasibility for technology
- Potential continued use of Main Plant
- Potential use of other WVDP structures

Rough-order-of-magnitude cost estimates were similar in data referenced from each report. The general consensus of these reports was that operational costs associated with the continued, long-term storage of the HLW canisters in the Main Plant would be prohibitive over the life cycle of interim storage (50 years).

CANISTER STORAGE OPTIONS

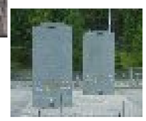
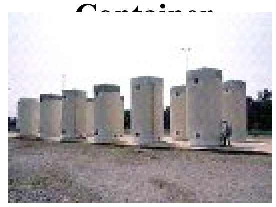
The evaluation was predicated upon and considered the following:

a) Ability of the system to safely contain and store the canisters for a minimum of 50 years,
b) Ability for the selected storage system to remain uncontaminated,
c) Minimization of future operational costs and
d) Removal and disposition of the uncontaminated storage system after canisters have been shipped off site.

Several HLW canister storage options were evaluated (Table 1), including below- and above-grade options. The former were not considered attractive because of the high water table and flat terrain at the WVDP.

Above-ground, shielded storage was the consistent storage recommendation.

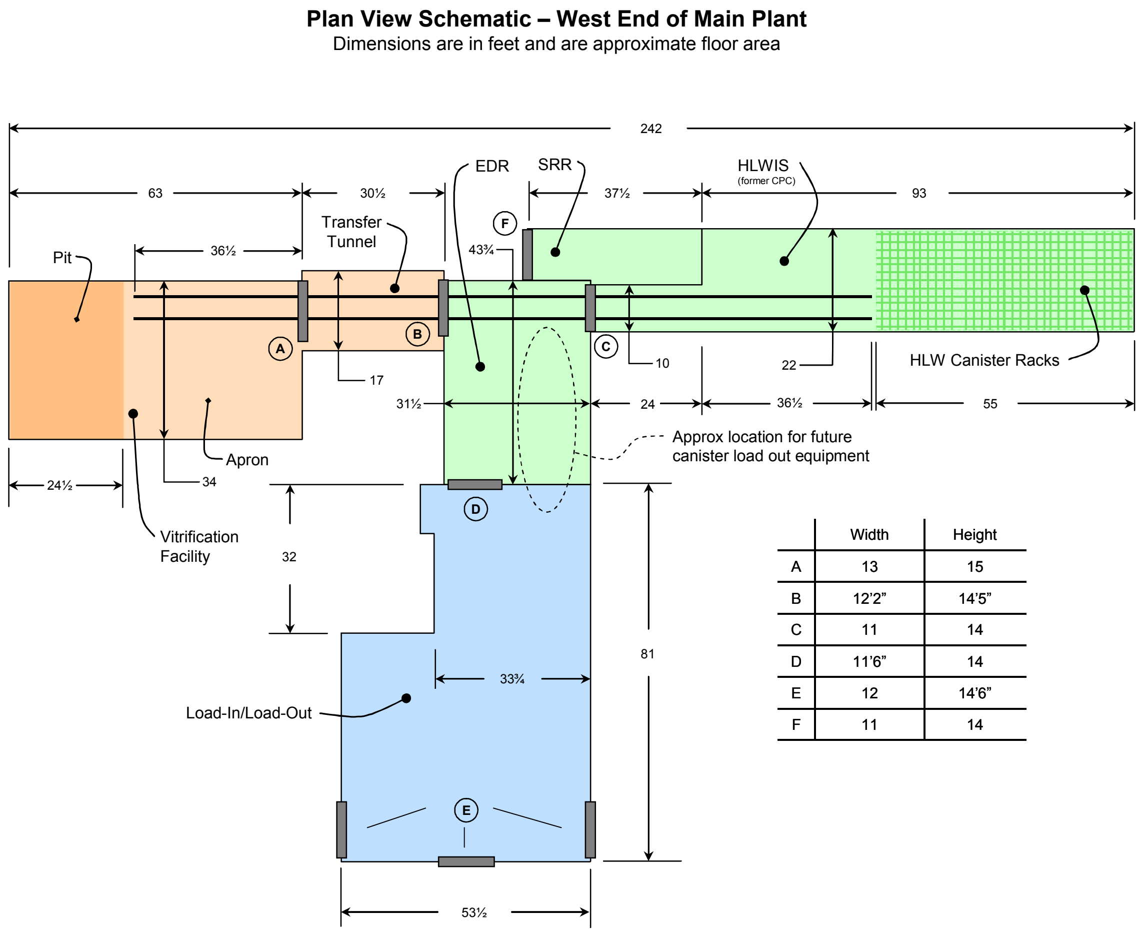
Table 1. HLW Canister Storage Options.

Options/Criteria	**SNF Dry Storage**  	**Single Canister Container** 	**Glass Waste Storage Building Section** 
Store the canisters for a minimum of 50 years	Designed for 50 years/ Licensed on a 20-year cycle	Design could accommodate	Design could accommodate
Ability for the selected storage system to remain uncontaminated	Requires clean overpack	Requires clean canister	Requires clean canister
Minimization of future operational costs	Surveillance and Maintenance (S&M) low Vendor service for rail shipping	S&M similar to SNF – Design would minimize maintenance Remote handling to be determined for shipping	Design would minimize maintenance Remote handling in facility for shipping
Removal and disposition of the uncontaminated storage system after canisters have been shipped off site	Modular unit disassembly and disposal of concrete and steel	Same as SNF but more units	Building demo requires all canisters be shipped prior to demolition

CANISTER MOVEMENT REQUIREMENTS

Upon creation, the HLW canisters were moved from the Vitrification Facility (VF) to the Chemical Processing Cell (CPC) in the Main Plant by a transfer cart and stored in racks with an existing 16-ton crane equipped with a canister grappler and load-lowering device. Presently, the transfer cart, load-lowering device, 16-ton crane, and canister grappler will require upgrades or return-to-service testing.

For any of the storage options, the HLW canisters need to be moved remotely within the facility with extreme care for loading in the Equipment Decontamination Room (EDR). The EDR crane has two 10-ton hoists. The EDR does not have enough headroom for vertically loading canisters into shields or overpacks. For vertical loading, the EDR "soaking pit" could be utilized but would have to be modified. Horizontal loading would require all new equipment in the EDR or in the Load-in Facility. In any case, HLW canister movement within the existing plant is a challenge. The next phase of the project is to conceptualize and economically solve these challenges. Figure 2 illustrates the proposed canister movement within the existing plant.



	Width	Height
A	13	15
B	12'2"	14'5"
C	11	14
D	11'6"	14
E	12	14'6"
F	11	14

Fig. 2. Proposed Canister movement within Main Plant

Onsite movement of HLW canisters will be based on storage technology and may require some facility and road upgrades.

STORAGE FACILITY SITING

The historical documents that were reviewed in the early stages of the project considered what the storage system might be, not where it would be located. Therefore the team carefully considered three major factors in establishing siting criteria for the alternate canister storage facility. Specifically, the area needed to:

- Be a valid location for all the canister storage systems under consideration
- Have minimal overall impact on current and future decontamination and decommissioning work
- Have minimal environmental impact

Both DOE and NRC siting guidelines were used in developing a scoring and evaluation system for areas considered for the new storage system. Several areas on site were evaluated, and then dropped from consideration because they did not meet the siting criteria. In the end, WVES recommended placing the facility on the southern plateau of the Project premises for several reasons. First, the northern plateau portion of the site where the Main Plant is located is more congested with existing buildings in various stages of decontamination and / or demolition than the south plateau, which would make for a better work environment in terms of industrial and environmental safety. And second, the proposed site is also adjacent to the rail line that runs onto the site, which is expected to facilitate the eventual offsite shipment of the canisters to a HLW repository.

TECHNOLOGY ALTERNATIVES AND SELECTION CRITERIA

SNF / HLW Canister Properties

HLW canisters such as those at West Valley and spent nuclear reactor fuel share certain common characteristics with respect to their storage. Both are:

- Heavy
  - Pressurized Water Reactor (PWR) fuel assemblies approximately 635 kg. (1400 lbs.)
  - HLW canister approximately 2268 kg. (5000 lbs.)
- Generally grappled from the top in a vertical orientation
- Highly radioactive with substantive penetrating radiation dose rates
- Thermally active generating heat as a result of radioactive decay

There are also important differences. HLW canisters at West Valley:

- Are not as tall, are larger in individual cross-section, and are cylindrical
- Have no residual radioactive gaseous inventory
- Have no criticality concerns
- Are in a configuration that has withstood a 7-meter (23-foot) drop onto an essentially unyielding surface without breaching
- Do not require draining and drying
- Generate a relatively small quantity of heat
- Do not require an inert atmosphere for storage
- Have a lower energy gamma radiation spectrum and no neutron dose contribution
- Present a fixed (limited) inventory

These differences conceptually simplify the dry storage of HLW canisters when compared to SNF assemblies. As a result, storage of HLW canisters primarily reduces to two major technical issues: handling and shielding.

Storage System Options

The general alternative characteristics and features associated with the dry storage of highly radioactive nuclear materials are:

- Vertical versus Horizontal. Vertical orientation is in line with gravity and typically matches the as-created and as-handled configuration of the highly radioactive SNF and HLW canisters; horizontal orientation generally maintains a lower storage profile in above-grade applications.

- Passive versus Active. Passivity relates primarily to cooling, long-term maintenance, and secondary waste generation aspects of storage with the former relying on natural heat dissipation processes (conduction, radiation, and convection) and the latter relying on physical barriers between the contamination and the accessible environment. Active heat-removal systems are usually demanded where needed to ensure minimum heat-removal rates or, as in the case of water-cooled systems, to also mitigate the release of particulate contamination to the accessible environment. As more active systems are designed into the system, the cost of long-term maintenance increases.

- Modular versus Non-Modular. Modularity enables implementation on a small-unit basis that a) allows implementation to occur on an as-needed basis, b) accommodates an increase or decrease in capacity in a straight-forward manner to mitigate uncertainties in future inventories, and c) allows for individual unit design updates to be easily accommodated. Non-modular or semi-modular systems are especially appropriate when the inventory is a fixed, known quantity or is known to continually increase at a reasonably uniform, predictable rate.

- Above-Ground versus Below-Ground. Above-ground systems are typically more visible, have a higher vulnerability issue, have easier exterior access and inspection, and have the inherent need to include appropriate materials and thicknesses for shielding as part of the storage system. Below-ground systems typically have a lower profile, have a lesser vulnerability issue, have more complicated access for inspection, and take advantage of natural in-situ materials for shielding and heat dissipation.

- Singular versus Multiple. In any case, operations begin with handling individual single units. Individual units are trades lighter to handle, but require more repetitions and more storage units or storage unit positions. Multi-unit overpacks are heavier to handle, but require fewer repetitions and fewer storage units or storage unit positions.

Dry storage system technologies generally consist of vertical casks, drywells, vaults, and horizontal casks. Table 2 describes each of these in more detail.

Table 2. HLW Canister Dry Storage Alternatives.

HLW Canister Dry Storage Alternatives				
Orientation	**Vertical**			**Horizontal**
Technology	**Cylindrical Shield**	**Drywell**	**Rack (Vault)**	**Rectangular Shield**
Description	Cylindrical metal shell inside a thick cylinder made primarily of concrete and/or metal	Cylindrical metal shell surrounded primarily by in situ soil or soil-like material	Structural open gridwork inside a concrete building	Structural tray inside a thick rectangular enclosure made primarily of concrete
Below Ground	Optional	Typical	Typical	N/A
Above Ground	Typical	N/A	Optional	Typical
General Characteristics				
Configuration	Modular	Modular/Semi-Modular (Berm)	Semi-Modular	Modular
Heat Dissipation	Passive	Passive	Active or Passive	Passive
Shielding	Concrete/metal	Soil	Concrete/Soil	Concrete
HLW Canisters per Module/Unit	1 to 7 (large diameter packages typical)	1 to 7	1 to 7 (individual packages typical)	1 to 7 (large diameter packages typical)
Experience				
Suppliers, Providers	NAC HOLTEC DOE Others	HOLTEC DOE	DOE GEC Alsthom Foster Wheeler	AREVA (NUHOMs®)
Existing Locations	LWRs (Humboldt Bay) INL	LWR	WVDP (AG) SRS (BG) FSV (AG) LaHague (AG)	LWRs INL
Industry Use	SNF	GTCC Hardware	SNF HLW	SNF SF Debris (TMI-2)

Light Water Reactor (LWR), Idaho National Lab (INL), Above Grade (AG), Below Grade (BG), Savannah River Site (SRS), Fort Saint Vrain (FSV), Three Mile Island Unit-2 (TMI-2), Greater than Class C (GTCC)

EVALUATION

There are multiple options available for dry, passive storage of West Valley's HLW canisters. The first part of the concept evaluation and selection process consists of screening. This screening applies upper-level considerations and site-specific issues and preferences that eliminate some alternatives from further evaluation. The second step is to consider the options based on a set of mutually-agreed upon functional requirements.

Functional requirements were developed and reviewed by the team and applied to various technologies. The discussion below summarizes the screening for the options initially considered.

1) Due to the extreme nature of local climatology, freeze-thaw cycles require extra measures to avoid seasonal-based concerns. Soil-based properties with respect to load-bearing capability, residual heat removal capability, and shielding vary between north and south plateaus and vary vertically in local strata due to the glacial formation associated with the site geology. Below-ground level concepts are particularly troublesome for the West Valley site both technically and from a public perception point-of-view. From the technical perspective, locating, qualifying, and preparing a suitable site for a below-ground installation within the 200-acre controlled area of the West Valley site is not practical. The water table is generally high, fluctuates, and the groundwater flow is substantive, requiring extra protection or upstream diversion or both. The freeze-thaw cycles require extra measures to avoid seasonal-based heaving. In addition to these issues, there is a known negative public perception associated with underground wastes currently in other locations at the West Valley site. Placing HLW canisters in below-ground storage is not likely to be viewed in an overall positive manner. The below-grade options could not meet the customer schedule objectives and would likely require additional evaluation under the National Environmental Policy Act (NEPA) and public participation beyond the current draft Environmental Impact Statement. Among other things, below-ground storage is likely to involve more complicated surveillance, monitoring, and detection capabilities.

   As a result, the drywell and below-ground air-cooled vault concepts are not likely to be considered further.

2) A non-modular configuration is inconsistent with West Valley's overall removal objectives for the HLW canisters from the MPPB because of the length of time it would take to implement. For application at West Valley, the air-cooled vault concept requires the design, construction and commissioning of the entire facility before the transfer and storage of the first unit. This incurs a prerequisite delay in the schedule before transfer and storage operations can begin and still requires the same amount of time for transfer as other concepts. Similarly, a berm-based drywell system requires full design, construction and commissioning of the entire berm prior to the start of transfer and storage operations. Individual drywell locations within the berm unit could be added incrementally but like the air-cooled vault concept discussed above, there would be an unrecoverable front-end delay. As a result, the berm-based drywell concepts have been removed from further consideration.

   Although the above-ground air-cooled vault wasn't a preferred option, it remains under consideration because of the precedence of existing HLW storage vaults at the Savannah River site as a demonstrated technology. A WVDP-specific above-ground vault concept was carried through for evaluation for comparative purposes.

3) The concept of storing HLW canisters in metal-based shipping casks that could also function as Type B licensed shipping casks is not preferred. There is no cask licensed for the shipment of HLW canisters. There are large SNF shipping casks that could possibly be adapted for such transportation but only after review and regulatory approval of the cask's design and certificate of compliance. As a result of more demanding requirements, shipping casks are inherently more costly than storage casks. In addition, the combination of long-lead time materials, construction, inspections, and regulatory approvals make such casks unattractive from a schedule point-of-view. Thus, it is not economically attractive or schedule competitive to consider using such shipping casks for storage of HLW canisters at West Valley. For the same reasons, storage casks whose shielding and containment material is solid metal are also considered to be unrealistic for cost-effective and timely implementation. As a result, metal-based shipping casks are not preferred for further consideration.

This screening process leaves three preferred alternatives for further consideration for dry storage for HLW canisters at West Valley:

- Single-Multiple Canister Storage System – Vertical orientation, above-grade, concrete-based shielding, single-multiple canister, passive storage units
- SNF Storage Technologies – Vertical/Horizontal orientation, above-grade, concrete-based shielding, passive storage units
- Above-Ground Vault – Vertical orientation, above-grade, concrete-based shielding, racked canisters, passive building

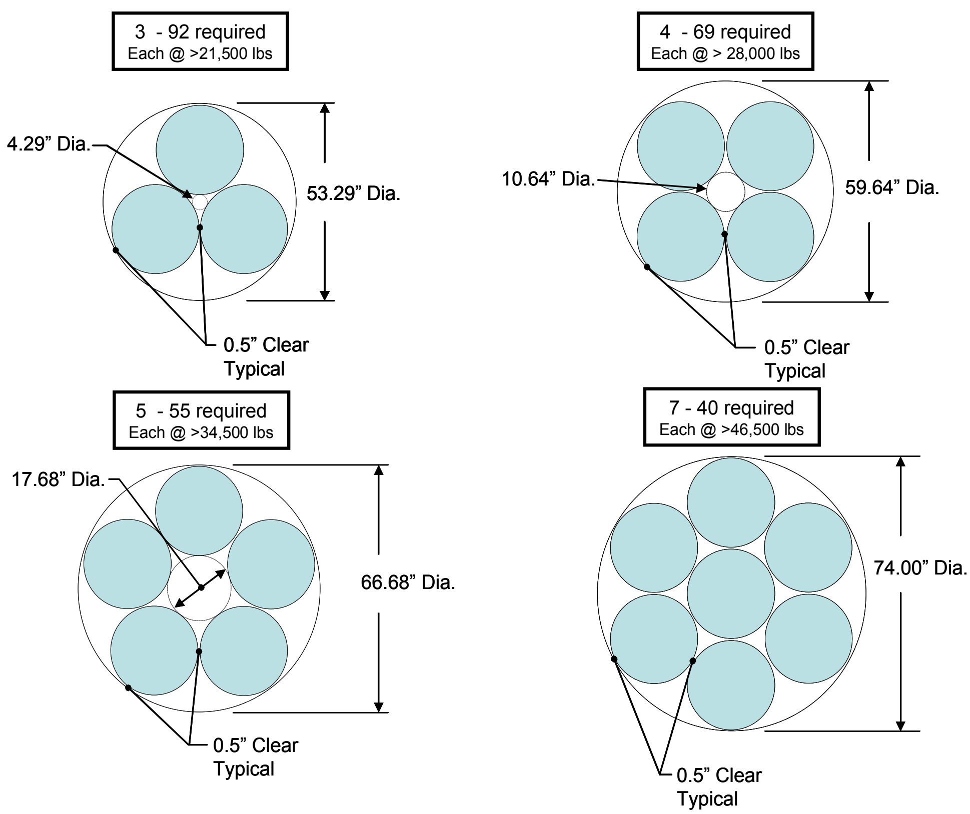


Fig. 5. Canister Overpack Schematics

SINGLE – MULTIPLE CANISTER STORAGE SYSTEM

Single – multiple canister storage systems can be reconfigured into overpacks containing multiple HLW canisters, as illustrated in Figure 5 above. As noted earlier, individual units (i.e., individual SNF assemblies or HLW canisters) are handled in any case. Multi-unit overpacks reduce the number of subsequent handlings and the number of modular storage units but increase both the size and weight of the handling equipment and the modular storage units.

Existing NRC-licensed Light Water Reactor SNF storage designs of vertical and horizontal storage systems deployed at nuclear power reactor sites across the U.S. are based on holding and storing multiple SNF assemblies in large diameter overpacks. This is done with the thought that once in this configuration, individual assemblies will not need to be handled again through the transportation and intended disposal of the overpack unit. This, of course, assumes that the overpack configuration meets all requirements existing at the future time of such transportation and disposal, thus eliminating a need for re-handling and repackaging. The existing air-cooled vault systems mentioned earlier typically based on storing individual single units can also be modified to store multi-unit overpacks.

Existing vendor overpack design sizes that hold multiple SNF assemblies appear able to accommodate from 4 – 7 HLW canisters. Such multi-unit overpacks would be shorter as a result of West Valley's HLW canisters being about 3.048 meters (10 feet) tall compared to SNF assemblies that are 4.267 to 5.182 meters (14 – 17 feet) tall. The use of 5 multi-unit overpacks for West Valley would reduce the number of storage units from 275 to 55. For reference, a single West Valley HLW canister is nominally .61 meters (24 inches) in diameter.

There is a revealing relationship between individual storage unit costs and total storage unit costs. As modular storage units get bigger, they are also inherently more costly. They use more material, need more fabrication time, include additional cost for multi-unit overpacks and related components, and have generally higher material delivery and shipping costs. WVES developed a conceptual single canister storage option based on SNF technology. However, the breakeven for purchase of initial units plus long term repetitive costs of 275 units versus 55 units did not clearly favor the single storage unit option. In addition, the logistics of developing a single canister storage system were not conducive based on technological or economical criteria, therefore, DOE has decided not to pursue this any further.

SNF STORAGE TECHNOLOGIES

Horizontal SNF Storage System

The horizontal SNF storage system provided by AREVA's Transnuclear Division consists of a welded sealed metal container used to house the canisters in concrete storage modules. The vendor system includes the onsite transfer cask and the metal container is part of the SNF shipping cask design currently licensed by the Nuclear Regulatory Commission (NRC). A typical Nuclear Horizontal Modular System (NUHOMS) metal container could contain 4 – 5 HLW canisters. AREVA provided a presentation to WVDP on the system and company capabilities. Team members were able to ask general system questions of the vendor to clarify system configurations.

WVDP representatives were able to schedule a visit to the Robert E. Ginna Nuclear Power Plant in Webster, New York to witness installation of the horizontal units. Discussions with the Project Manager and Operations/Training Manager were helpful in understanding the logistics relative to plant configuration and system startup. Figure 3 illustrates a typical horizontal storage system.

Fig. 3. Typical horizontal storage system

Vertical SNF Storage Systems

The vertical SNF storage systems typically consist of a welded metal container placed inside a concrete or concrete/metal overpack. Similar to horizontal units, vendor-designed transfer carts/cranes are provided and the inner metal container is used as part of the SNF shipping cask design. Current vertical systems are provided by Holtec International and NAC, International. WVDP representatives were able to visit the Palo Verde Plant in Arizona to tour the installation of NAC International units and the FitzPatrick Power Plant in New York to observe a typical Holtec installation. Both vendors also provided presentations to the team on technology solutions offered by their companies. Figure 4 illustrates a typical horizontal storage system.

Fig. 4. Typical vertical concrete / metal storage configuration

Advantages of SNF dry storage technologies:

- Proven NRC 10 CFR 72 licensed design
- Overpack part Licensed NRC 10 CFR 71 transport design
- Current designs accommodate up to five canisters
- Solid appearance and moderate profile
- Bounded by reference storage case in the WVDP Environmental Impact Statement
- Passive storage function
- Concrete modules can be pre-fabricated off site or poured on site
- Modules can be removed as they are emptied
- Contamination controlled inside sealed metal container

Disadvantages

- Loads exceed current facility and potentially haul-road capacities, requiring further upgrades
- Welded metal container decreases accessibility to single canisters
- Some conflicts with current expectations for future shipping configurations
- Requires potential Waste Qualification Report (WQR) modifications
- Vertical height challenges current EDR limits, requiring modifications
- Transfers of metal container to cask and then metal container to storage module

ABOVE-GROUND VAULT

A conceptual design for the above-ground vault was developed. The technology was similar to the present storage of HLW canisters, but the schedule constraints of this option were not favorable for the WVDP mission.

SUMMARY AND RECOMMENDATION

To accomplish storage of the HLW canisters to facilitate MPPB removal, a canister storage system is intended to be located on the southwest corner of the Project premises and to use modified SNF multi-canister storage designs. The use of current SNF multi-pack designs could also incorporate shipping cask analysis for potential NRC review. The path forward would ensure safe, interim HLW storage and potential offsite shipping alternatives while supporting the WVDP mission.