# RETRIEVING AND DISPOSING OF HANFORD'S HIGH-LEVEL WASTE

E. J. Cruz, P. E. LaMont, W. J. Taylor
Office of River Protection, U.S. Department of Energy
Richland, Washington

## ABSTRACT

The U.S. Department of Energy (DOE) plans to retrieve, treat, immobilize, and dispose of 200,000 $m^3$ (53 million gal) of high-level waste (HLW) that has accumulated in large underground tanks at the Hanford site since 1944. Treatment and immobilization will be performed by a privatized contractor in privately owned facilities to be constructed at Hanford, while waste retrieval and immobilized product storage and disposal will be performed in government-owned facilities. Current plans are for processing approximately 10% of the waste in an initial "demonstration" phase (Phase I) from about 2007 to 2018. The remaining waste will be processed in Phase II. The DOE Office of River Protection (ORP) at Hanford was created to implement tank cleanup and is moving forward with this project. Two major activities are (a) waste retrieval and final clean out of the Hanford tanks and (b) storage and disposal of immobilized high-level waste (IHLW) and immobilized low-activity waste (ILAW).

## INTRODUCTION

The U.S. Department of Energy (DOE) plans to retrieve, treat, immobilize, and dispose of the 200,000 $m^3$ (53 million gal) of high-level waste (HLW) that has accumulated in large underground tanks at the Hanford Site since 1944. The Hanford Federal Facility Agreement and Consent Order, commonly known as the Tri-Party Agreement (TPA), primarily governs the Hanford Site's waste storage, treatment, and disposal activities. The TPA is an agreement between the Washington State Department of Ecology, the United States Environmental Protection Agency, and the DOE. Cleanup roles, responsibilities, requirements, and schedules are all part of the TPA (1).

The responsibility for defining and implementing these plans falls under the recently formed DOE Office of River Protection (ORP). The Office of River Protection plans to retrieve, treat, immobilize, and dispose of the waste in two phases. Phase I will process approximately 10% of the current waste inventory. A private contractor will perform treatment and immobilization in privately owned and operated facilities. Tank waste characterization, retrieval, and storage as well as immobilized product storage and disposal will be done by a management and operations contractor in government-owned facilities. Phase II builds from the Phase I experience as the "production" phase and will treat the balance of the tank waste inventory.

The current baseline schedule for Phase I calls for treatment and immobilization processing from 2007 through 2018. The Phase I contract includes a minimum order quantity of 600 canisters of HLW glass and approximately 6000 containers of low-activity waste glass. If the privatization contractor can complete the minimum order quantity before 2018, ORP will continue delivering feed. Tank waste retrieval and immobilized waste storage and disposal activities have been planned to support treatment and immobilization.

## WASTE RETRIEVAL

Retrieving the waste is a major challenge. The technologies for retrieval must have the capability to mobilize and transfer a wide range of waste forms in a variety of tank configurations and eventually meet tank closure goals. Waste will be delivered to the privatization contractor from the double-shell tank (DST) system. Single-shell tank (SST) wastes will be retrieved and staged in the DST system. Double-shell tank space is limited; therefore, waste must be processed to increase space in the DST system to enable SST retrieval.

During Phase I, DST wastes will be mobilized, sampled, qualified, and then transferred to the privatization contractor. The ultimate purpose of tank retrieval operations is cleanup. This requires that tank retrieval technologies remove the maximum amount of waste practicable to avoid multiple retrieval operations in a selected tank. During Phase I, DST retrieval technologies will be focused on the mobilization and transfer of waste through the DSTs. Single-shell tank retrieval technology development will continue through Phase I. As DST space becomes available, ORP will pursue opportunities to demonstrate SST retrieval technologies. Tank waste and tank configurations vary widely, and ORP is developing a retrieval technology "toolbox." A given tool or set of tools will be used to address the retrieval challenge of each SST or DST on a customized basis.

Historically, Hanford used hydraulic sluicing to mobilize wastes for pumping. This technique uses a recirculated high-velocity stream of diluted liquid waste to mechanically dislodge and dissolve or suspend the waste. The stream is delivered using a nozzle, roughly similar to a fire nozzle, mounted on the end of an articulated arm that can be aimed at locations around the tank. The mobilized waste was then transferred to another tank. The nozzle may not be equally effective on all tank surfaces, leading to some areas being "cleaner" than others. Sluicing operations usually result in several thousand gallons of liquid in the tank. This translates to approximately 3.7 m (12 ft) of hydrostatic head.

Recently, the Waste Retrieval Sluicing System (WRSS) operations in SST 241-C-106 removed more waste than expected. Current estimates from 241-C-106 include a residual liquid inventory of approximately 189 $m^3$ (50,000 gal) and a sludge heel of approximately 19-30 $m^3$ (5000-8000 gal).

However, sluicing is unlikely to clean most tanks to the extent required for closure and is unlikely suitable for use in tanks that are known or assumed to have leaked due to the limited cleaning ability and concerns regarding additional leaks. Sluicing also requires the addition of liquid to the system. Using this technique, the liquid addition required for SST retrieval is estimated to be a three-to-one dilution (2). If ORP retrieves the 128,000 $m^3$ (34 million gal) of waste in the SST farms using this method, approximately 378,000 $m^3$ (100 million gal) of DST space will be required over time. Unfortunately, building new DSTs to meet SST retrieval needs is an expensive operation simply because of the number of tanks required (approximately 80, depending on the size) and because these tanks would eventually require cleanup and closure similar to the existing tanks. Lower dilution retrieval methods are necessary to support the timely and cost-effective retrieval of the SST wastes within the existing DST operating space.

## Tank Waste Description

Hanford's tank waste inventory includes the following (see Fig. 1):

- Saltcake is a crust of salt material that typically resides on the uppermost layer of the tank. Saltcake is formed when tank waste that has been concentrated by evaporation is returned to a tank and cools. As the temperature of the concentrated solution decreases, the crystallized salts form. Saltcakes vary in consistency from wet sand to concrete.
- Supernatant liquids reside either above or within saltcakes (if they are present) and typically contain nitrates, phosphates, and other chemicals with a relatively small amount of suspended solids.
- Slurries are a mixture of solid particles suspended in liquid.
- Sludges are thick and dense combinations of liquids and solids. The liquid fraction of sludge is called "interstitial liquid" and is usually similar to the supernatant liquid. The solid fraction is mostly insoluble metal hydroxides and oxides precipitated from neutralized waste.
- Some miscellaneous items have been abandoned in tanks. These items range from small hand tools to pump assemblies.

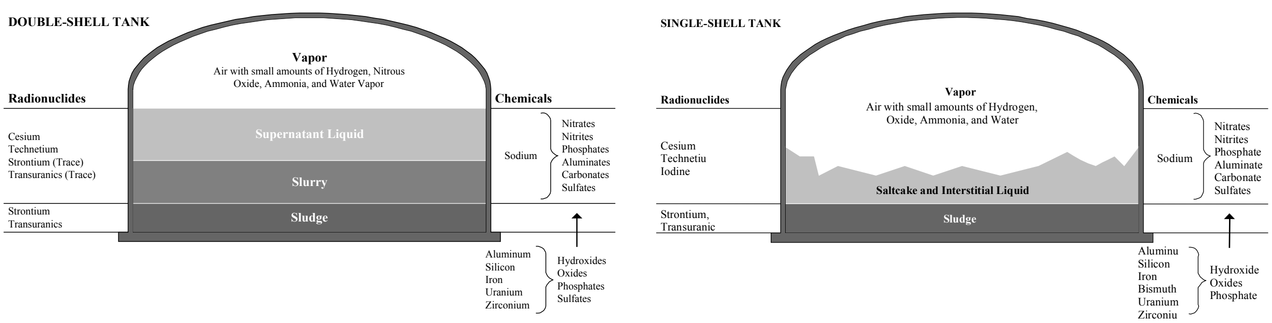


Fig. 1. Double-Shell and Single-Shell Tank Inventory Cutaway.

Approximately 35% of the waste resides in the DSTs and 65% resides in the SSTs. Table I is a summary of the tank waste inventory. Wastes vary significantly and the limited set of historical information does not meet current data needs. Hanford has an extensive characterization and data reconstruction program to supply this vital information.

Table I. Summary of Tank Waste.

| Inventory | Double-Shell Tanks | Single-Shell Tanks |
|---|---|---|
| Total, $m^3$ (gal) | 72,000 (19,000,000) | 128,000 (34,000,000) |
| Average density, $kg/m^3$ ($lb/in.^3$) | 1500 (0.0542) | 1600 (0.0578) |
| Chemicals, kg (tons) | 50,000 (55,000) | 173,000 (190,000) |
| Water, $m^3$ (gal) (drainable/nondrainable) | 59,000 (15,600,000) | 36,000 (9,400,000) |
| Radioactivity, TBq (Ci) | 3 (80,000,000) | 4 (110,000,000) |

NOTES:
1. Data are rounded numbers and estimates provided for informational purposes only (3).
2. More detailed and current data are available on the Tank Waste Information Network System (TWINS). TWINS can be accessed via the internet at: http://twins.pnl.gov/twins.htm.

## Hanford Tanks

These tanks are constructed of reinforced concrete with either one or two carbon steel liners. Most tanks are 23 m (75 ft) in diameter with a capacity of 1893 $m^3$ (500,000 gal) to 3785 $m^3$ (1 million gal) (4). Approximately 3785 $m^3$ (1 million gal) of waste have leaked from 67 of the 149 older SSTs. No waste has leaked from the 28 newer DSTs. These tanks have a wide variety of access ports or "risers," internal obstacles, and installed equipment. The structural integrity of the tanks varies as well. All of these variables must be adequately addressed to enable successful retrieval.

The in-tank environment includes thermal, chemical, and radiation hazards. In-tank equipment must be designed to survive this challenging environment with minimal maintenance. If the equipment were removed for maintenance or repair, there would be substantial dose to workers and increased costs.

## Double-Shell Tank Waste Retrieval

The current baseline for DST sludge mobilization and retrieval is long-shaft mixer pumps combined with deep-well turbine transfer pumps. In situations requiring subsequent dilution, dissolution, and decanting steps without the requirement for substantial mobilization, deep-well turbine transfer pumps will be equipped with a flexible floating suction intake to transfer the waste. The DST retrieval and transfer systems associated with Phase I processing are currently in the design phase.

The long-shaft, centrifugal mixer pumps will be used in 600-horsepower combinations of either two 300-horsepower or four 150-horsepower centrifugal pumps, depending on the size and number of risers available (4). Each pump has two outlet nozzles mounted on opposite sides of the housing and a central intake (see Fig. 2). The pumps can be rotated 180 degrees in either direction during operation to enhance mixing action. The electric motor is mounted on top of the pump and is easily accessible from the tank farm surface. This allows replacement and maintenance of the motor and rotation system without removing the remainder of the pump. The mixer pumps use variable speed drives so the mixing action can be adjusted and to provide additional monitoring capability. The 300-horsepower pumps are approximately 15.2 m (50 ft) long and designed for use in a 1.07-m (42-in.) diameter riser. These pumps have two 0.15 m - (6-in.) diameter opposed outlet nozzles, and can pump at a rate of 38 $m^3$ (10,000 gal) per minute (4). Mixer pumps of similar designs have been used at both the Savannah River Site and Hanford (most recently in tank 241-SY-101). During FY 2000, two mixer pumps will be demonstrated in Hanford's tank 241-AZ-101. This data will be used to evaluate mixer pump performance and provide design input into the next generation of mixer pumps.

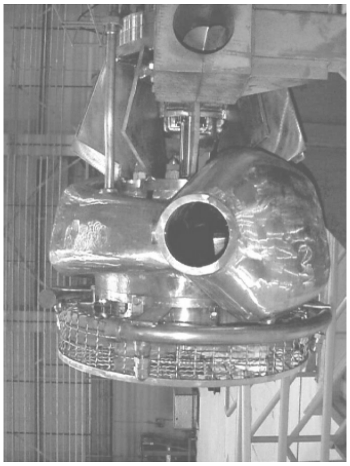

Fig. 2. Long-Shaft, Centrifugal Mixer Pump Housing.

The transfer pumps are deep-well turbine pumps that can be equipped with a flexible, floating suction intake. These pumps will be stiffened to withstand forces resulting from the mixer pumps but are not designed for operation at the same time as the mixer pumps (4). These pumps have 60-horsepower motors connected to a variable speed drive system. Variable speed drives are used to vary the flow rate and provide additional pump monitoring capability. The flexible intake versions use a 0.076-m (3-in.), corrugated, flexible, stainless-steel hose with a cylinder-shaped intake screen at the end of the hose. A winch located at the pump baseplate is used to position the flexible intake through a range of 0.61 m (2 ft) below to 6.1 m (20 ft) above the pump. The transfer pumps incorporate in-line dilution capabilities to ensure the waste being transferred is dilute enough to flow through the transfer piping system without plugging (4).

## Single-Shell Tank Waste Retrieval

Single-shell tank retrieval is a more complex problem. The possibility of tank leaks requires new retrieval methods and significant leak detection, mitigation, and monitoring (LDMM) capabilities. In many cases, the tank infrastructure (transfer piping, ventilation, etc.) has been abandoned and must be replaced for retrieval. These factors result in significant costs to retrieve SST waste.

The retrieval cleanup requirement, often referred to as the "How clean is clean?" question, is based on regulatory clean closure requirements. There are other regulatory options, such as landfill closure, that are based on "practicable" standards (i.e., cost, performance, and risk of retrieval comparisons). The Tri-Party Agreement requirement is "retrieval of as much waste as technically possible, with tank waste residues not to exceed 360 cubic feet . . ., or to the limit of waste retrieval technology capability, whichever is less."

Using results from the vadose zone characterization, cumulative site assessment programs, and the SST program, ORP is pursuing a technically defensible, integrated Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), risk-based cleanup standard for the tanks. The development of a retrieval specification is closely linked to the end state and land use designation of the surrounding area, the location and type of contamination currently in the vadose zone, potential additional leaks during retrieval, and the composition and amount of residual waste left in the tank. Depending on how each of the parameters described above are defined and using the somewhat limited set of available data, studies have shown that ORP can mitigate the majority of risk. While these studies have some limitations, they show significant risk reduction at a reasonable cost by removing waste from only those tanks that pose the greatest hazard to the public and environment. Risk is a key factor in identifying and prioritizing the tank waste to be delivered to the privatization contractor for immobilization.

The Office of River Protection's current baseline is to use a crawler-based retrieval strategy for the next SST retrieval technology demonstration in tank 241-C-104. After an extensive technology evaluation test program and a competitive procurement, a team lead by Los Alamos Technical Associates was awarded the contract to design, build, test, and operate a crawler-based retrieval technology in a Hanford tank. The crawler is an update of a design used in the petrochemical industry. The system uses high-pressure water jets in conjunction with a water cannon to clean the tank surfaces. The crawler platform includes a pump—as waste is mobilized, the slurry is quickly pumped out of the tank. The waste retrieved during this demonstration will be vitrified during Phase I.

Following the 241-C-104 activity, the next demonstration will be retrieval of saltcake waste from an SST, likely in the 241-S tank farm. While the crawler described above may be suitable for use on saltcake, there are alternative approaches that could prove to be even better for this specific waste type. The first demonstration technology is called "saltcake dissolution." Sprinklers are installed in the tank to allow wetting of the entire waste surface. A transfer pump is installed in the low point of the tank. As water is added, the saltcake dissolves into a solution suitable for pumping. By carefully monitoring the concentration of the retrieved solution, one can achieve equilibrium where the rate of water added is nearly equivalent to the volume retrieved. This adds the minimum amount of water required to retrieve the saltcake. Currently, this technology is in the early stages of development and the target deployment date is in the post-2008 timeframe, depending on the availability of DST space.

Other retrieval technologies have been developed that have potential use in Hanford's SSTs. The DOE Office of Environmental Management, Tanks Focus Area, is developing and deploying technology systems used at the Oak Ridge National Laboratory and Savannah River Site. The Office of River Protection is an active participant in the Tanks Focus Area and has been partnering with and learning from the other sites as they work through similar issues.

## IMMOBILIZED WASTE STORAGE AND DISPOSAL

The Office of River Protection's Storage and Disposal Project was established to provide for the disposition of the two major products from the treatment of Hanford tank waste: immobilized low-activity waste (ILAW) and immobilized high-level waste (IHLW). Both waste forms will consist of glass monoliths formed by the cooling of molten glass poured into stainless steel containers (ILAW) or canisters (IHLW), which will be sealed, decontaminated, and placed in a lag storage facility in the treatment plant until transported away. The relatively large volume of ILAW will be disposed of in shallow disposal facilities on the Hanford site, and the much smaller volume of IHLW will be held in interim storage facilities pending transportation to a geologic repository currently assumed to be at the Yucca Mountain site in Nevada (5).

## Immobilized Low-Activity Waste Disposal

It is estimated that about 16,000 $m^3$ (565,000 $ft^3$) of ILAW will be generated during Phase I [and an additional 169,000 $m^3$ (6 million $ft^3$) during Phase II] based on privatization Part B-1 contract specifications for treatment of tank waste (6). This corresponds to approximately 6100 packages (filled containers) and receipt rates from two to five packages per day during Phase I based on a cubical container [1.4 m (4.6 ft) on a side] as specified in the current privatization Part B-1 contract. It is expected that the estimated volume of ILAW will be revised as flowsheets are refined. In addition, it is expected that a 1.22-m diameter (4.0 ft) by 2.28-m (7.48 ft) tall upright cylinder will be adopted as the ILAW container due to reduced fabrication cost and improved control of filling. The internal volume of the cylindrical container is 2.55 $m^3$ (8.37 ft), which will slightly increase the number of ILAW waste packages requiring disposal. The Part B-1 contract specifications limit the radiation level of the ILAW packages to 10 mSv (1000 mrem)/hr at the package surface. Based on experience with other types of low-level waste, packages with dose rates above 2 mSv (200 mrem)/hr require remote handling. Estimates of the radiation levels for Phase I ILAW packages indicate that a substantial fraction of the packages will be greater than 2 mSv (200 mrem) and therefore will require remote handling (2).

Until recently, the baseline technical strategy for ILAW disposal was to modify four empty, reinforced-concrete "grout vaults" near the east end of the 200 East Area for interim storage of the first 7000 packages of ILAW from the privatized treatment plant in Phase I. A series of new disposal vaults for all additional ILAW would be constructed on about 90 acres to the south and west of the plutonium uranium extraction (PUREX) plant in the 200 East Area. This technical strategy was selected by DOE after the identification, evaluation, and ranking of alternatives using systems engineering procedures. Other alternatives considered include disposal in individual shielded overpacks and disposal in and/or next to the chemical separations plants, i.e., "canyons" in the 200 East and West Areas during their decommissioning. The individual overpack option was deemed too expensive, and current information on the canyon option was insufficient for a comprehensive evaluation. Therefore, ORP judged that the canyon option would be too risky to pursue as a Phase I disposal alternative. Based on completed conceptual designs, the total project costs (escalated) for modification of the Grout Vaults (Project W-465) and for the new vault facility (Project W-520) are $48.4M and $112.4M, respectively (7). Project W-520 includes one new vault with a capacity for 11,088 cubical ILAW packages, and both projects include new shielded transportation equipment.

However, ORP has evaluated and adopted an alternative technical strategy termed the "remote-handled (RH) trench" concept (8). In this concept, the ILAW packages would be disposed of in a large trench with sloping sides. The packages would be transferred by tractor-trailer from the private vendor's lag storage facility to the trench. An open box with thick sides on the trailer would provide shielding in the lateral direction. At the disposal trench, a crane would lift the package into a shielded "bell." The package inside the bell would be swung into position and the ILAW package released from the bell and crane (Fig. 3). A wall of movable shielding "ecology" blocks between the crane operator and the ILAW packages would reduce dose to the crane operator. As the array of packages advances, a cover of earth would be pushed over the packages using a bulldozer. An analysis of principal radiation sources, R1-R6, shows that doses to operators would remain within acceptable limits. Because the sides of the trench slope upward at a shallow angle, it will be possible to emplace more packages in successive layers. It is expected that each trench would be equipped with RCRA-compliant liners and a leachate collection system. A similar disposal concept has been implemented at Hanford for remote-handled low-level waste with radiation levels much greater than the 10 mSv (1000 mrem) but not on the frequency or scale required for ILAW disposal. The life-cycle cost for this technical strategy is estimated to be \$337.2M versus \$583.3M for the baseline technical strategy, for potential savings of up to \$246.1M.

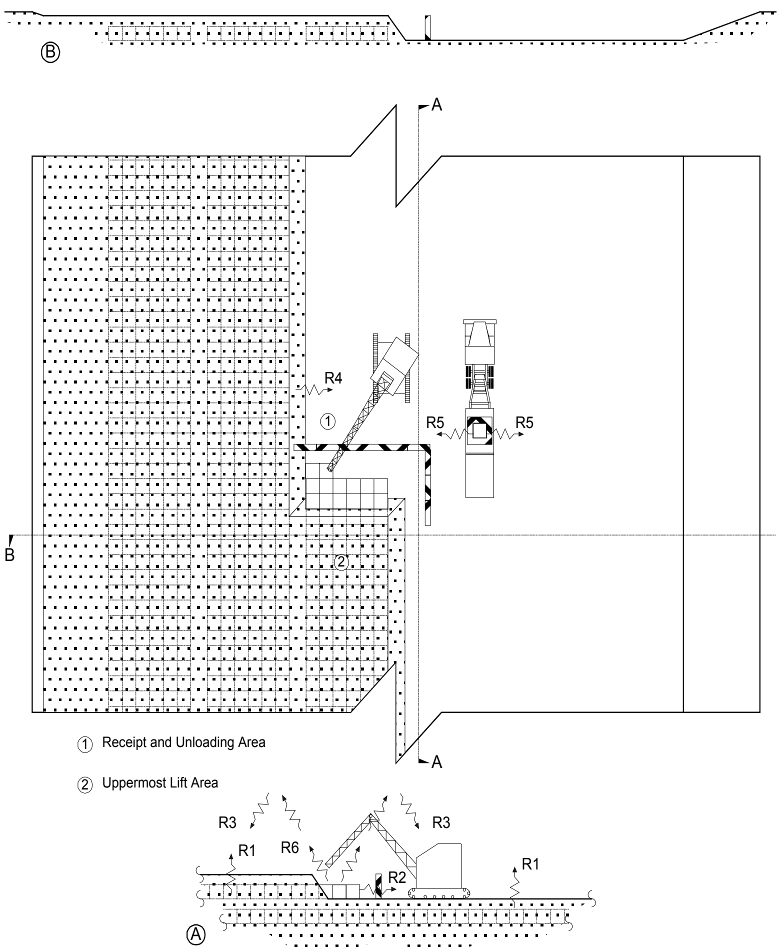


Fig. 3. Remote-Handled Trench Occupied Zones.

The ILAW is being managed by ORP to comply with the recently issued DOE Order 435.1, Radioactive Waste Management requirements for low-level and mixed low-level waste, following Nuclear Regulatory Commission (NRC) staff concurrence that the ILAW could be considered "incidental waste" (9). This determination is of critical importance to ORP because it allows ORP to dispose of ILAW in near-surface disposal facilities that are not subject to NRC licensing (if conditions specified in the NRC letter are met). DOE Order 435.1 includes incidental waste classification criteria that are similar to those from the NRC staff.

DOE Order 435.1 also requires authorization from DOE Headquarters (HQ) prior to construction of any new low-level waste (LLW) disposal facilities. This requirement was met by ORP with the issuance of a Disposal Authorization Statement (DAS) in October 1999 (10) based on review of the ILAW disposal system performance assessment that was submitted to HQ in June 1998 (11). On December 29, 1999 (12), ORP provided a status report, including a data package on representative ILAW glass formulations, which is consistent with requirements that were defined in the 1998 performance assessment. Glass development and testing programs sponsored by ORP and the DOE Office of Science and Technology are underway and are expected to yield results that show practical glass formulations will meet the performance requirements. This data, along with recent geotechnical data, will be used in glass performance calculations to be described in a "white paper," which is scheduled for April 2000 to help support a DOE decision on proceeding with a contract for privatized tank waste treatment and immobilization services. An update of the ILAW performance assessment is scheduled to be issued for review in March 2001.

## Immobilized High-Level Waste Disposal

With respect to interim storage of IHLW, it is estimated that as many as 1320 canisters could be generated in privatized Phase I facilities. The canisters are 0.61 m (2 ft) in diameter x 4.5 m (14.8 ft) tall and hold about 1.15 $m^3$ (40.6 $ft^3$) of HLW glass. The first 600 canisters could be produced from 2007 to 2012, and 720 more canisters could be produced by 2018. An additional 10,880 canisters, or about 13 canisters per week, are projected as a reference case for Phase II, but estimates vary depending on assumptions (13). The baseline technical strategy for IHLW interim storage includes retrofitting Vaults 2 and 3 in the Canister Storage Building (CSB), which is currently under construction in the 200 East Area for interim storage of spent nuclear fuel in multicanister overpacks in Vault 1 (Fig. 4). The capacity of Vaults 2 and 3 is 880 canisters. The canisters would be transferred by tractor-trailer to the interim storage facility in a shielded transportation cask at a rate of about three to five per week. After that the operating sequence includes transferring the cask to a shielded cell, lifting the canister from the cask into a shielded canister transporter, driving the shielded canister transporter with the canister to the designated storage

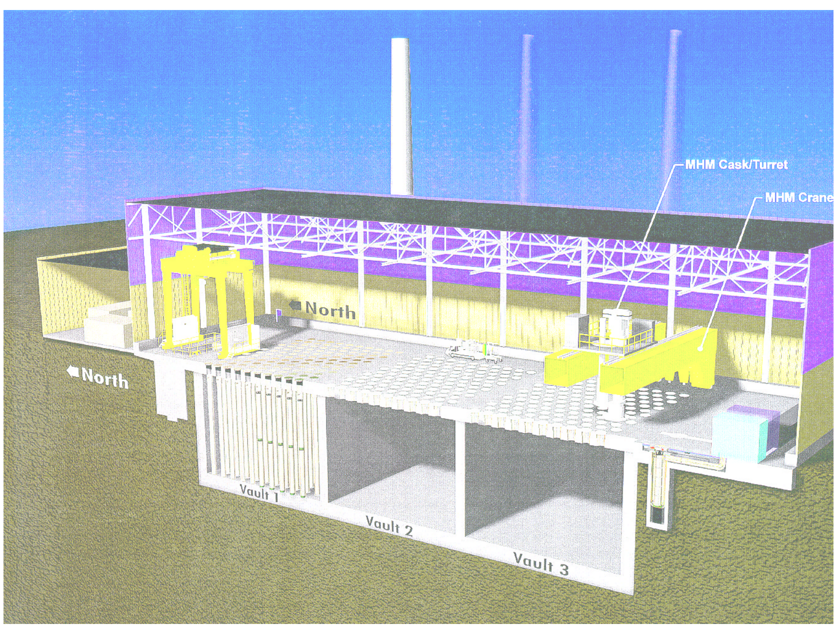


Fig. 4. Canister Storage Building Configuration (Project W-379).

tube, and lowering the canister into position in the tube below the deck. The deck and storage tube plugs provide sufficient shielding to allow manned access in the deck area.

The Office of River Protection has assumed that shipment of IHLW canisters from Hanford to the repository would not begin until 2035, which is after the baseline date of 2028 for completion of IHLW production. Therefore, additional canister storage facilities for the entire output of IHLW canisters would be needed at a cost of approximately $1.8B (in FY 2000 dollars) in addition to a facility for loading canisters into transport casks for shipment by rail to the HLW repository (13). Alternatives that are being evaluated include retrofitting the Fuels and Materials Examination Facility (FMEF) for storage of up to 1008 additional canisters and evaluation of FMEF as a potential load-out facility. Furthermore, preliminary parametric studies of complex-wide storage, shipping, and disposal of both spent nuclear fuel and IHLW show a significant reduction in required canister storage facilities if shipping from Hanford is started in 2010 and production of IHLW canisters is extended beyond the baseline date (2028).

## CONCLUSIONS

The Office of River Protection faces substantial challenges in retrieving and disposing of Hanford's tank wastes. The retrieval program will use long-shaft mixer pumps and deep-well turbine pumps to mobilize and transfer wastes in the DSTs. Single-shell tank waste retrieval is a complex problem that needs to address many different issues to enable the tanks to be cleaned and closed. Upcoming activities will address part of the SST tank retrieval technology requirements and help define the technical basis to support tank closure. The ILAW will be permanently disposed of on the Hanford Site in a remote-handled trench. The remote-handled trench would use cranes and shielding to place immobilized waste packages in a lined trench. The IHLW will be transferred to the CSB for interim storage. Once the HLW geologic repository is opened, the canisters would be transported offsite for final disposal. The Office of River Protection is making real progress toward these challenges and remains committed to taxpayer value and safety as the highest priorities.

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