HIGH-LEVEL WASTE TANK LAY-UP AT THE WEST VALLEY DEMONSTRATION PROJECT

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ABSTRACT

The West Valley Demonstration Project (WVDP) has successfully completed the retrieval and vitrification of radioactive high-level waste (HLW) from its storage tanks and the subsequent lay-up of the two largest tanks in preparation for future closure. Waste recovery of cesium-137 adsorbed on two zeolite medias during waste pretreatment has resulted in over 95 percent of this radioactivity being vitrified. Greater than 99.5 percent of the long-lived sludge/transuranic radioactivity and 99% of the Sr-90 have been retrieved from the tanks and vitrified. Approximately 84 percent of the original $1.1x10^{18}$ becquerels (30 million curies) of radioactivity was efficiently retrieved and vitrified from June 1996 to June 1998 during Phase I HLW processing. Recovery of the last HLW took place from June 1998 to September 2001 and was challenging due to a number of factors. The primary factors were the complex internal support structure within the two main 2.8 million- liter (760,000-gallon) HLW tanks, designated Tanks 8D-1 and 8D-2, and the discovery/mitigation of higher-than-expected radioactive deposits on the walls of Tank 8D-2. Recovery of this last waste was exponentially more difficult, as less and less HLW was available to mobilize and vitrify. The WVDP vitrification system was flushed and its melter shut down permanently on September 5, 2002.

Following completion of vitrification, approximately 490,000 liters (130,000 gallons) of dilute liquid remained in Tanks 8D-1 and 8D-2. This liquid was retrieved from the tanks in January and February 2003 using specially developed remote equipment to minimize the liquid heel left behind. The tanks were then isolated from further waste additions and placed in a safe, minimum surveillance and maintenance lay-up mode on July 31, 2003. Activities completed to accomplish tank lay-up also included deactivation of the Supernatant Treatment System, the pretreatment system for the HLW with most of its process vessels inside Tank 8D-1, and a number of actions to reduce the moisture in the underground vaults and minimize external corrosion of the carbon steel tanks.

This paper contrasts the current status of the former HLW tanks against their status prior to the start of the West Valley Demonstration Project, summarizes the HLW pretreatment processes and HLW retrieval for vitrification, reviews waste residual characterization efforts, and describes in detail the recent emptying of Tanks 8D-1 and 8D-2 and their lay-up into a safe, minimum surveillance and maintenance configuration, awaiting a determination on the method/configuration of final tank closure. Major lessons learned during HLW pretreatment, waste retrieval, residual characterization, and tank lay-up are also presented.

INTRODUCTION

The WVDP is located about 30 miles south of Buffalo, New York, on the site of a former commercial spent fuel reprocessing facility, which operated from 1966 to 1972. Approximately 640 metric tons of commercial and defense fuels were reprocessed at the site using the (PUREX) and (THOREX) processes. The former site operator, Nuclear Fuel Services (NFS), Inc., halted reprocessing operations in 1972 to

evaluate the potential for facility expansion. In 1976, NFS notified New York State that it would withdraw from operating the facility in 1980, when its lease expired.

In 1980, the West Valley Demonstration Project (WVDP) Act was signed, directing the U.S. Department of Energy (DOE) to: solidify and develop suitable containers for the site's high-level radioactive waste; transport the solidified waste to a federal repository; and dispose of the low-level radioactive and transuranic wastes created during reprocessing operations. In 1982, the DOE took control of the site working closely with the New York State Energy Research and Development Authority (NYSERDA). A private company, West Valley Nuclear Services Company (WVNSCO), was awarded the operations contract and has been the primary contractor since February 1982. New York State owns the site. Under the WVDP Act, the DOE is responsible for management of the Project and funds 90 percent of the cleanup costs while working with NYSERDA, which funds the remaining 10 percent.

At the start of the Project, approximately 2.3 million liters (600,000 gallons) of neutralized high-level PUREX radioactive waste remained on the site in an underground carbon steel storage tank designated Tank 8D-2. This waste consisted of insoluble hydroxides and other salts that precipitated out of the solution to form a bottom sludge layer, and a liquid top layer rich in sodium nitrate and nitrite (supernatant). Figure 1 illustrates this tank in its underground vault after the installation of truss-mounted mobilization pumps. In addition, approximately 31,000 liters (8,200 gallons) of acidic THOREX remained in an underground stainless steel storage tank designated Tank 8D-4 (Reference 1).

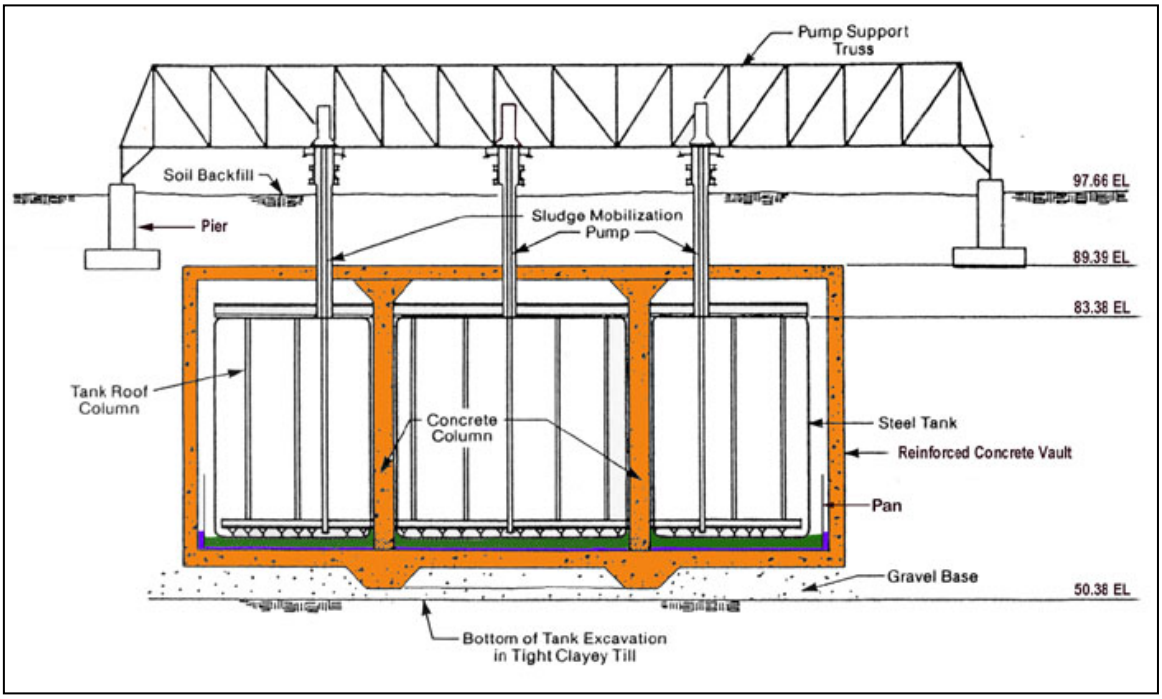

Fig. 1 Underground HLW tank with supporting trusses on top.

HLW PROCESSING SUMMARY

The WVDP HLW underwent several processing steps prior to its ultimate vitrification, as illustrated by the chronology provided in Table I.

HLW Pretreatment

During HLW pretreatment, the liquid portion of the alkaline PUREX supernatant was processed to separate the highly radioactive portion of the waste from the soluble salts. This separation allowed the decontaminated salt solution to be processed into a cement-stabilized waste form meeting the NRC's requirements for low-level radioactive waste as specified in 10 CFR 61. The highly radioactive Cs-137 in the HLW was adsorbed onto UOP (formerly Union Carbide) IE-96 ® zeolite, which was temporarily stored in the spare HLW tank (Tank 8D-1). By removing the soluble salts, the amount of vitrified waste to be produced was greatly reduced. The Supernatant Treatment System (STS) pretreatment system was constructed adjacent to Tank 8D-1 and has nearly all of its process vessels inside this spare HLW tank as shown in Figure 2. The pretreatment of 2.34 million liters (618,000 gallons) of supernatant resulted in 10,393 270-liter (71-gal) drums of solidified liquid LLW and 45,100 kg (99,400 lb) of zeolite containing 1.96E+17 Bq (5.30M curies) of Cs-137.

Table I WVDP HLW Processing Chronology

ACTIVITY	**START**	**FINISH**
HLW Pretreatment		
Supernatant Processing	May 1988	Nov 1990
Sludge Wash 1 and Processing	Oct 1991	May 1994
Sludge Wash 2 and Processing	May 1994	Aug 1994
THOREX Addition	Jan 1995	Jan 1995
Sludge Wash 3 and Processing	Jan 1995	May 1995
Zeolite Mobilization and Retrieval	Jul 1995	Feb 2001
HLW Mobilization, Retrieval and Vitrification	Jun 1996	Sep 2001
HLW Tank Residual Characterization	Jul 2000	Nov 2002
HLW Facility Flushing and Final Vitrification	Nov 2001	Sep 2002
Tank Farm Residual Liquid Processing	Jan 2003	Feb 2003
HLW Tank Lay-up	Jan 2003	Jul 2003

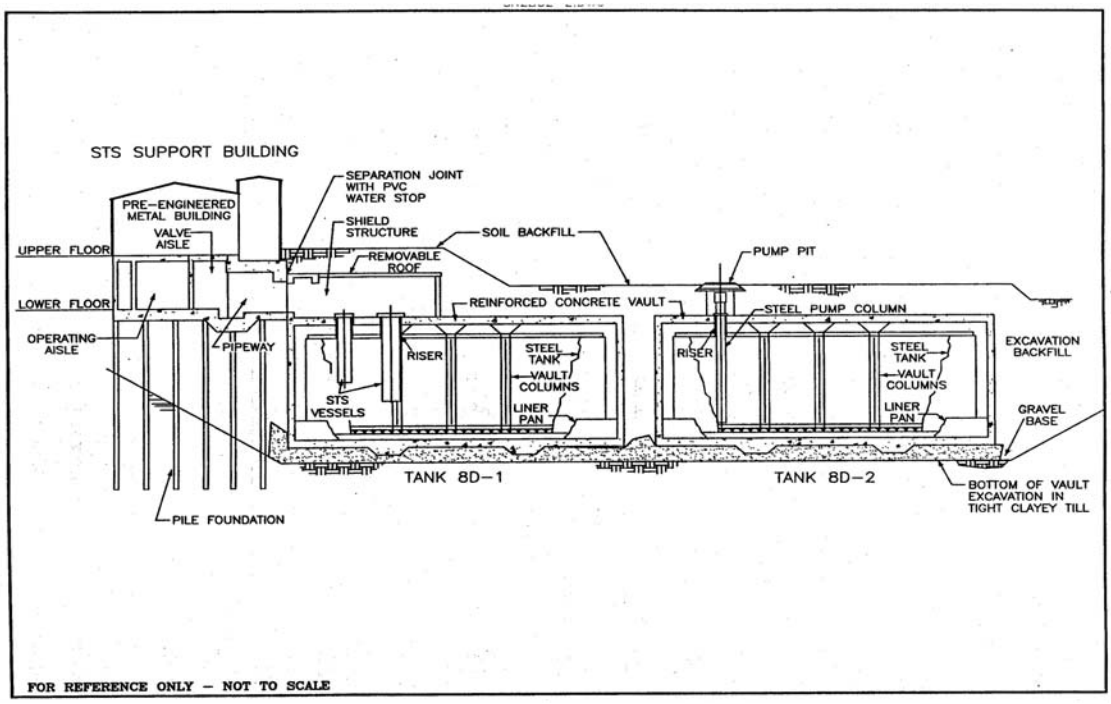

Fig. 2 Major components within Tanks 8D-1, 8D-2, and the Supernatant Treatment System.

Two PUREX sludge washes were performed to further extract soluble salts from this portion of the HLW and further reduce the volume of HLW glass that would be produced. The sludge washing was accomplished by adding alkaline-adjusted water to the PUREX waste and agitation of the sludge and its interstitial liquid using five mobilization pumps installed in new tank risers. Following washing operations and subsequent sludge settlement, each of the two sludge wash solutions was processed through the pretreatment system as was done with the PUREX supernatant. This sludge wash pretreatment of 2.9 million liters (766,000 gallons) of solution resulted in 8,033 270-liter (71-gal) drums of solid LLW and 13,300 kg (29,300 lb) of IE-96 ® and TIE-96 ® zeolite containing 3.82E+16 Bq (1.03M curies) of Cs-137. Individual statistics for each sludge wash are presented in Table II.

Table II WVDP HLW Pretreatment Statistics

Pretreatment Process	**Waste Volume Processed (liters) [gallons]**	**Cs-137 Radioactivity* Removed (Bq) [curies]**	**Zeolite Used (kg) [pounds]**	**LLW Cement Waste Drums**
Supernatant	2.34M [618,000]	1.96E+17 [5.30M]	45,100 [99,400]	10,393
PUREX Sludge Wash #1	1.55 M [410,000]	3.36E+16 [0.909M]	11,700 [25,800]	7,219
PUREX Sludge Wash #2	1.35M [356,000]	4.6E+15 [0.125M]	1,600 [3,600]	814
PUREX/THOREX Sludge Wash #3	1.19M [316,000]	1.13E+16 [0.304M]	4,900 [10,800]	1,451
TOTAL	6.43M [1,700,000]	24.6E+17 [6.638M]	63,300 [139,600]	19,877

*Radioactivity measured at time of processing

The acidic THOREX waste was then added and neutralized within the primary HLW tank, together with water flushes of the THOREX storage tank. Mobilization pumps were again used to agitate the PUREX sludge and the precipitate formed from the THOREX addition. This final sludge wash was processed through the pretreatment system to again remove soluble salts deleterious to the vitrification waste product and minimize the volume of the vitrified waste. A total of 1.19 million liters (316,000 gallons) of this third sludge wash were processed into 1,451 270-liter (71-gal) drums of solid LLW and 4,900 kg (10,800 lb) of IE-96 ® and TIE-96 ® zeolite containing 1.13E+16 Bq (304,000 curies) of Cs-137.

Pretreatment of the HLW was successful in reducing the amount of vitrified waste by approximately a factor of 10. The zeolite removed over 99.99 percent of the Cs-137 from the liquids processed, resulting in an average contact dose on the LLW drums of 0.23 mSv/hr (23 mrem/hr). Reference 2 provides additional detail on the pretreatment of the WVDP HLW in the Integrated Radwaste Treatment System.

Zeolite Mobilization and Retrieval

Following HLW pretreatment, the Cs-137 laden zeolite stored in the spare HLW tank was transferred back into the primary HLW tank (8D-2) and mixed with the washed sludge to provide the feed material for vitrification. The zeolite was mobilized in the spare HLW tank using five mobilization pumps, identical to those used for sludge washing. These pumps and a transfer pump were all installed in new tank risers. During the transfers, the zeolite was size-reduced to less than 50 microns utilizing an in-line grinder so that the zeolite particles would form a more homogenous mix with similar-sized sludge particles, make the zeolite easier to retrieve from HLW Tank 8D-2, and simplify operations during vitrification processing. Retrieval of the zeolite proved to be more difficult than 1/6-scale model testing (Reference 3) indicated.

As shown in the zeolite retrieval graph (Figure 3), over 5.6E+16Bq (1.5 million curies) of Cs-137 representing approximately 22 percent of the stored zeolite were removed from the storage tank during the first transfer. After the zeolite solids settled to the bottom of the primary HLW tank (Tank 8D-2) with the washed sludge, the clarified liquid was decanted back to the zeolite storage tank (Tank 8D-1) to aid in further zeolite removal. As indicated in Figure 3, subsequent mobilization and retrieval of the zeolite slurry became much more difficult. This was attributed primarily to the retrieval of the smaller, more easily mobilized zeolite particles during the initial transfer, leaving the larger zeolite particles behind. Other factors that limited more effective retrieval included HLW dilution with mobilization pump seal water, the complex internal tank bottom structure, and solids plugging both mobilization and zeolite removal pump suctions. Due to the difficulty in zeolite retrieval, vitrification of the sludge/zeolite was initiated after approximately 85 percent of the stored zeolite was combined with the HLW sludge.

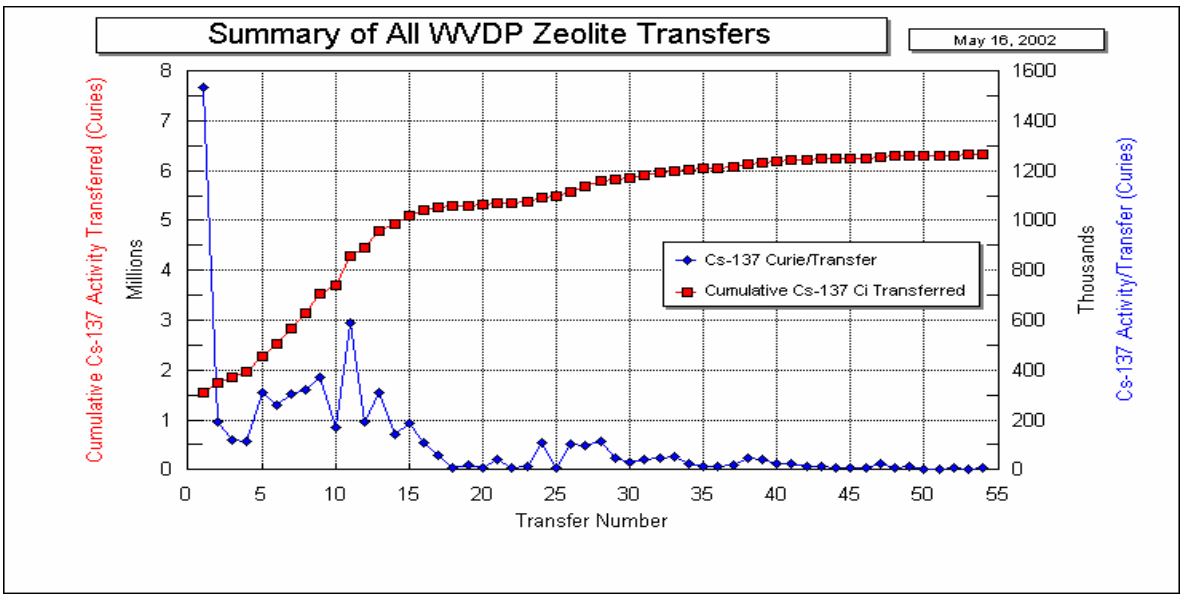

Fig. 3 Zeolite retrieval results

Additional zeolite was retrieved and mixed with the HLW sludge and zeolite vitrification feed in parallel with ongoing HLW glass production. The continued use of the pretreatment system to process excess liquid resulting from both zeolite and sludge mobilization pump seal leakage produced more Cs-137 laden zeolite during vitrification processing that, in turn, needed to be retrieved from the spare HLW storage tank. As Figure 3 illustrates, retrieval of spent zeolite from the storage tank had reached very diminishing returns toward the end of vitrification operations. Since it was determined to be no longer operationally or economically practical to continue zeolite retrieval as vitrification feed, zeolite transfers were concluded with the 54th transfer on February 6, 2001. In all, 33 million liters (8.7 million gallons) of ever-more dilute zeolite slurry were removed from the zeolite storage tank to support retrieval of 96 percent of Cs-137 laden zeolite. During these operations, over 2 million liters (530,000 gallons) of clean mobilization pump seal water were added to the HLW volume. References 4 and 5 provide additional detail on zeolite retrieval activities.

HLW Mobilization, Retrieval and Vitrification

The first HLW transfer to the Vitrification Facility of 7,200 liters (1,900 gallons) was performed on June 25, 1996, with approximately 950,000 liters (250,000 gallons) of slurry in the HLW Tank 8D-2 and four mobilization pumps operating. The HLW consisted of washed PUREX and THOREX sludge commingled with the size-reduced zeolite. Vitrified waste from the first HLW melter feed batch was produced on July 2, 1996. Subsequent HLW transfers were performed with four to six, 112 kW (150 Hp), mobilization pumps operating and transfer volumes as high as 20,000 liters (5,200 gallons) to produce a single vitrification batch: typically four canisters or 8,000 kg (18,000 lb) of HLW glass. The excess liquid in the HLW tank was reduced in stages and stored in spare HLW Tank 8D-1 to maintain a concentrated HLW feed to the Vitrification Facility. Following the 44th transfer of HLW feed to the Vitrification Facility on November 10, 1997, with 270,000 liters (71,000 gallons) remaining in the HLW tank, multiple transfers of

the increasingly dilute HLW were necessary to produce a full vitrification feed batch. Figure 4 illustrates the cumulative retrieval of the Sr-90 (sludge component) and Cs-137 (zeolite component) radioactive constituents, together with the number of HLW transfers performed. Various methods were employed to aggressively expedite retrieval of the remaining HLW: lowering all mobilization pumps closer to the tank bottom, indexing pump jets at deposits observed with in-tank video cameras, providing variable speed/programmable controls on mobilization pump rotary positioners, and washing tank bottom structures with in-tank sluicers and the wave action resulting from specific mobilization pump operations.

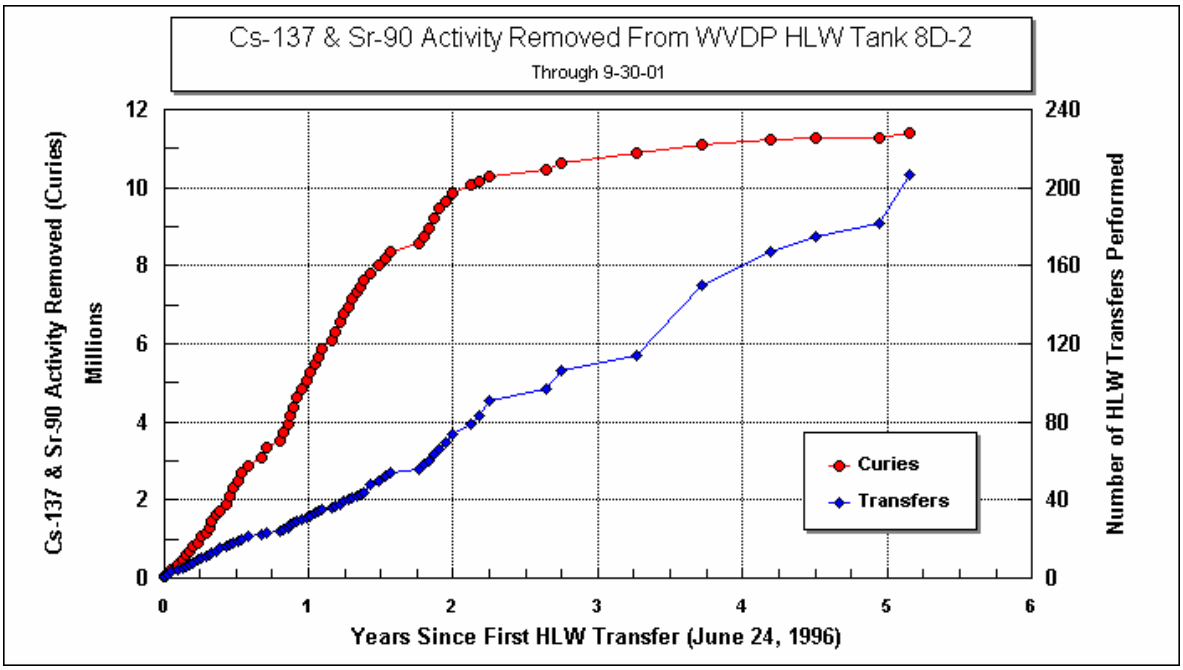

Fig. 4 Cumulative retrieval of the Sr-90 and Cs-137

Based on the greatly diminished amount of radioactivity being removed from the HLW tank, economic modeling and approaching the design life of the melter, HLW transfers to vitrification were terminated on September 26, 2001, with completion of the 207th transfer, which finished the 66th HLW melter feed batch. Reference 5 provides a more in-depth description of WVDP HLW retrieval.

HLW Tank Residual Characterization

In parallel with the final retrieval of WVDP HLW, efforts were initiated to determine the amount of key radionuclides remaining in the three tanks that contained HLW. This data was necessary to help establish when waste retrieval activities could cease and vitrification processing finish. Characterization techniques employed included visual inspection via radiation-resistant black-and-white and color video cameras in the two larger tanks, beta-gamma general field radiation probes and modeling, shielded beta-gamma measurements obtained from internal surfaces of the primary HLW tank, gamma camera imaging utilizing AIL's Gamma Cam® M31 system modified to WVDP requirements, physical sampling of the residual waste remaining, and sampling surface deposits from inside the primary HLW tank. Additional detail on the characterization of WVDP HLW tank residuals is provided in Reference 6.

Early characterization efforts inside the primary HLW tank (Tank 8D-2) performed in July 2000 revealed significantly more Sr-90 and alpha-TRU nuclides on the upper wall surfaces than projected. This

discovery led to the actual sampling of internal surface deposits and the installation of two sluicers to wash these surfaces using the diluted waste liquid in the tank. One of the six mobilization pumps had to be removed to provide access for installation of a second sluicer. Following the extensive washing of the tanks' surfaces, additional characterization activities were conducted to establish the radioisotope inventory remaining.

HLW Facility Flushing and Final Vitrification

Flushing of the HLW storage and processing systems was initiated in conjunction with final HLW retrieval. Although the continued use of these HLW facilities with increasing more dilute waste provided significant flushing, additional water and nitric acid flushes were identified for the various systems. The effectiveness of the flushing and the determination of when the flushing could cease were indicated by either radiation probes adjacent to the systems or by sampling. The Supernatant Treatment System, used since 1988 to adsorb Cs-137 from the HLW onto zeolite, was selectively flushed with water and nitric acid, depending on the specific flush path. The stainless steel tank (8D-4), which originally stored the acidic THOREX waste and then held various Vitrification Facility waste, was flushed multiple times with nitric acid and then water. The HLW transfer system connecting the Tank Farm to the Vitrification Facility was flushed multiple times with the acid solutions from Tank 8D-4 and water.

In the Vitrification Facility, the submerged bed scrubber on the off-gas ventilation system was flushed with nitric acid and water, as were other smaller vessels. The radioactivity remaining in the batch concentrator make-up and melter feed tanks, and the melter itself, was minimized by processing two additional batches of glass-former material through these components, producing lower and lower radioactive glass. The final molten radioactive glass remaining in the melter was removed by vacuum into two specially outfitted canisters on September 5, 2002, marking the end of the successful WVDP HLW retrieval and vitrification program.

TANK LAY-UP

Tank lay-up consisted of placing the tanks into a safe, minimum surveillance and maintenance configuration. This necessitated the retrieval of the remaining dilute liquids and isolation of the tanks from further waste additions. Activities completed to accomplish tank lay-up also included deactivation of the Supernatant Treatment System, the pretreatment system for the HLW with most of its process vessels inside Tank 8D-1, and a number of actions to reduce the moisture in the underground vaults and the resulting external corrosion of the carbon steel tanks.

Residual Liquid Processing

Following completion of HLW retrieval, system flushing, and vitrification of the wastes, approximately 490,000 liters (130,000 gallons) of very dilute waste liquid remained in the two large HLW tanks. Table III contrasts the concentration of key radionuclides and chemical constituents in the original supernatant (1986) to those present in this diluted sodium bearing liquid in 2002. The low concentration of radionuclides: 7.4E+05 Bq/ml (20 Ci/ml) Cs-137, 1.1E+04 Bq/ml (0.3 Ci/ml) Sr-90, and 3.0E+01 Bq/ml (0.00080 Ci/ml) alpha-Pu, as well as the high sodium content of the liquid from corrosion inhibitors, made processing of this liquid into glass uneconomical. Based on the sodium limit in the vitrification feed, an additional 60 canisters of glass would have been produced. Instead, this liquid was processed through the STS to strip out the Cs-137 onto existing, partially spent zeolite remaining in two columns, allowing the decontaminated liquid to be subsequently concentrated in the Liquid Waste Treatment System (LWTS) evaporator and held in the two concentrate tanks as was done during pretreatment processing. The WVDP has secured a subcontractor to process this mixed waste liquid into a cement-stabilized LLW during CY2004.

Specialized remote equipment was developed at the WVDP to process the dilute liquid waste through the pretreatment system and minimize the liquid heels remaining in both tanks; previously, pumps could only process the liquid down to a 100-cm (39-inch) heel. The remote equipment developed, deployed and successfully operated in the bottom of the primary HLW tank 12 meters (40 feet) below ground level included an articulated arm with a saw end-effector to cut off the floating suction from the turbine pump previously used for pretreatment processing. Once the suction was severed, a different end-effector deployed a submersible pump into the tank and remotely attached the new pump's discharge line to the existing pump's suction line. This installation permitted existing underground lines to be used to process this liquid to the STS. Liquid from the spare HLW tank (8D-1) was transferred to the primary HLW tank (8D-2) with the existing zeolite transfer pump leaving 30,000 liters (7,900 gallons) of liquid behind, due primarily to the 36-cm (14-inch) tilt across the bottom of tank. The newly installed submersible pump emptied the liquid out of the primary HLW tank while supplying it to the STS process. The primary tank was emptied of all but 20,000 liters (5,300 gallons) of liquid or about a 5-cm (2-inch) depth. All liquid waste retrieval activities were completed on February 5, 2003.

Table III Waste concentration and volume at start of respective processing

Pretreatment Waste Stream	**Supernatant**	**PUREX Sludge Wash #1**	**PUREX Sludge Wash #2**	**PUREX/THOREX Sludge Wash #3**	**Final Sodium Bearing Liquid**
Waste Volume (liters) [gallons]	2.57M [680,000]	1.25M [331,000]	1.62M [427,000]	1.56M [413,000]	0.490M [130,000]
Cs-137 (Bq/ml) [µCi/ml]	1.06E+08 [2,860]	2.96E+07 [800]	3.55E+06 [96]	1.01E+07 [274]	7.4E+05 [20]
Sr-90 (Bq/ml) [µCi/ml]	3.5E+04 [0.96]	9.32E+03 [0.252]	1.8E+03 [0.048]	2.02E+04 [0.546]	1.1E+04 [0.30]
Alpha-Pu (Bq/ml) [µCi/ml]	2.5E+03 [0.068]	6.3E+02 [0.017]	8.1E+01 [0.0022]	1.0E+00 [0.000028]	3.0E+01 [0.00080]
Sulfate (µg/ml)	20,000	19,700	3,000	880	640
Sodium (µg/ml)	130,000	77,800	9,160	16,600	14,900
Density (g/ml)	1.290	1.161	1.020	1.037	1.025
Total Dissolved Solids (wt %)	36.5	20.8	2.97	5.61	4.06
pH (SU)	10.0	12.6	11.7 @33E C	11.6 @26E C	9.7 @ 26EC
Chromium (µg/ml)	530	220	27	126	96.8

Safe Tank Lay-up

After retrieval of the dilute liquid remaining in the HLW tanks, the two 39-year-old carbon steel tanks were placed into a safe, minimum maintenance lay-up mode. There was no desire to continue to utilize the aging tanks for waste storage. Long-term closure decisions have not yet been made on the ultimate

disposition of these tanks and the residual radioactivity remaining, so in the interim, a lay-up plan was adopted to preserve tank integrity, minimize surveillance and maintenance activities, and isolate the tanks from further waste additions. All lay-up actions do not compromise potential long-term closure alternatives under consideration.

Preserve Tank Integrity

Preservation of tank integrity is of prime importance to continue to contain the residual waste remaining and keep options open for various closure alternatives. As part of the lay-up plan, actions were taken to reduce the groundwater infiltration into the underground concrete vault containing the primary HLW tank.

This was done to reduce external tank corrosion. A portland cement/bentonite grout mixture was injected under pressure into the vault overburden around vault penetrations such as tank risers and pump pits. A video camera within the vault was used to identify in-leakage sources and establish the effectiveness of the injection grouting process. Another action that was taken to reduce groundwater infiltration into both underground vaults was to lower the groundwater pressure under the vaults. The reduced pressure lessened the quantity of groundwater migrating into the underground vaults through cracks and imperfect construction joints. The reduction in groundwater pressure was accomplished by the replacement of the dewatering well pump and setting the pump lower in the well between both vaults. This action reduced the typical groundwater pressure on the vault bottoms from 69-90 kPa (10-13 psig) to 34-55 kPa (5-8 psig). With this change, the dewatering well is still pumped approximately once per week as it was before and the volume pumped is comparable with previous values.

Groundwater that infiltrates the vault of the primary HLW tank must be periodically pumped out to limit the moisture at the tank bottom exterior. To better protect the bottom of the primary HLW tank, a new pump was installed within the vault to minimize the liquid level within the perlite-cement blocks and pea gravel separating the tank bottom from vault surface. By reducing the liquid level maintained within the vault, it became more difficult for this water to wick up through the pea gravel and perlite-cement blocks to the carbon steel tank bottom. This should act to reduce external corrosion of the tank bottom. This action was not required for the adjacent HLW tank (8D-1) since it has a much smaller groundwater infiltration rate as a result of selective grout injection above its vault in 1999. With the nitrogen purge into both vaults to reduce exterior corrosion, the small amount of groundwater that periodically infiltrates into the 8D-1 vault is slowly evaporated such that no liquid pumping from this vault/pan is necessary.

Minimize Surveillance and Maintenance

An objective of the safe tank lay-up was to reduce the resources required to monitor and maintain systems, equipment and instruments that no longer were needed. Although active ventilation of the emptied tanks was desired to better contain the internal contamination and the nitrogen purge to the underground vaults remained to reduce tank external corrosion, many of the other systems were secured in a safe configuration. Mobilization pumps were left in place, but isolated from their electrical and seal water supplies, and all preventive maintenance was suspended. The Supernatant Treatment System, which has nearly all of its vessels inside HLW tank 8D-1, was deactivated since no future processing was practical. This resulted in huge resource savings by elimination of preventive maintenance activities, instrument calibrations, round sheet readings, etc. The HLW Transfer System was left operable with isolation valves closed and locked, and power to each tank removal pump locked out. Although the small liquid heels remaining in the two tanks are inadequate to prime the pumps, it was thought prudent to maintain this removal capability in the event of some inadvertent liquid addition to the tanks. The twice-daily monitoring of critical data such as tank and secondary containment levels, tank pressures,

ventilation system operating parameters, and nitrogen flow to each vault continues although the quantity of data recorded has been greatly reduced.

A new Digital Acquisition System (DAS) is currently being installed and will be operational in April 2004. The system collects all the critical data outlined above and also includes data from new relative humidity probes installed in each vault to gather data to better reduce tank external corrosion. The new DAS is expected to further reduce surveillance and monitoring costs.

Tank Isolation

A critical aspect of the lay-up plan was the elimination of further waste additions and water additions to the tanks. Since fuel reprocessing operations began in 1966, and until January 2003, most wastes produced by the WVDP Analytical Chemistry Laboratory and Main Plant liquid wastes were returned to the primary HLW tank (8D-2). Now that this tank was placed in an interim closure state, other destinations for these continuing waste streams had to be provided and all previous waste addition lines had to be securely isolated. This required an extensive review of the various piping networks and resulted in piping modifications to send these ongoing plant wastes to the LWTS for potential evaporation/volume reduction and subsequent cement stabilization using a semi-remote process.

In addition to precluding future waste additions to HLW Tanks 8D-1 and 8D-2, the many water lines that supply systems that supported tank operations and pretreatment processing had to be permanently isolated to prevent inadvertent additions to the tanks. One unexpected source of water did add considerable volume to the heel remaining in Tank 8D-1 after it was emptied. The 39-year-old carbon steel underground ventilation line for the two HLW tanks developed a breach, and when groundwater built up to this level, it entered Tank 8D-1 through its ventilation nozzle in the tank top. This water infiltration has been halted by the installation and operation of a pumping system with level monitoring/alarm in an excavation around the underground ventilation line. During the five months of investigation as to the source of the infiltration and the resulting remediation activities, this groundwater added approximately 24,000 liters (6,300 gallons) to the waste heel remaining in Tank 8D-1 after it was emptied in January 2003.

CURRENT STATUS OF TANKS 8D-1 AND 8D-2

Both tanks continue to be actively ventilated by a relatively new 16-year-old, permanent HEPA-filtered system. The system is constructed of primarily stainless steel, except for the original carbon steel underground piping, and has its own stack and monitoring instruments. The system has two separate trains with automatic switch-over capability. Tanks are typically maintained at a negative pressure of -8 cm (-3 inch) of water, with a combined ventilation flow rate of approximately 28,000 liters/min (1000 cfm). The vault and tank temperatures vary seasonally from 10 to 24 C (50 to 75 F). Tank, secondary containment and vault levels are monitored with high alarms. Approximately 10,000 liters (2,600 gallons) of infiltration water into the containment pan under Tank 8D-2 is pumped 6 to 8 times a year. A nitrogen purge of 100 to 200 liters/min (4 to 8 cfm) is supplied to each concrete vault to reduce external tank corrosion by drying out moisture in the vault and reducing the oxygen concentration. Relative humidity and temperature probes in each vault monitor the environmental conditions around the tanks. The groundwater pressure underneath the vaults is limited by typically pumping the localized perched water table once a week. There is no evidence of any breach in either tank that would release waste into the secondary containment. Liquid samples from the secondary containment pan of Tank 8D-1 have shown only background levels of radioactivity, whereas the liquid in the containment pan and vault of Tank 8D-2 has shown somewhat elevated alpha and beta levels. This has been attributed to a small leak in a now out-of-service line between the tank top and vault roof. The water pumped from the dewatering

well between the two vaults over the last 20 years has consistently shown very low background levels of radioactivity.

When the new Tank Farm data acquisition system becomes operational in April 2004, nearly all of the above parameters will be continuously monitored on the new DAS in addition to being recorded by hand during twice-per-day rounds. As confidence in the DAS data matures, it is envisioned that the frequency of the rounds readings will be reduced.

LESSONS LEARNED

During the course of HLW pretreatment, mobilization, retrieval and vitrification; residual waste characterization; and tank lay-up, much was learned about the processes that may benefit other sites proceeding with waste pretreatment and/or retrieval. The following are the more significant lessons learned during these phases of the WVDP.

Pretreatment of the HLW supernatant and sludge wash liquids was effective in removing sufficient salts from the HLW such that the number of glass canisters was able to be reduced approximately tenfold to 275 canisters. The pretreatment resulted in 63,300 kg (139,600 lbs) of cesium-137 laden zeolite and 19,877 270-liter (71-gallon) drums of cement-stabilized decontaminated salt solution concentrate (20 to 42 wt% total dissolved solids). The average Cs-137 decontamination factor (DF) obtained with the UOP IE-96 ® and TIE-96 ® zeolites averaged 10,000. In addition, the TIE-96 ® zeolite typically resulted in overall decontamination factors of 10 to 100 for Sr-90 and plutonium.
The zeolites' 20 x 50 mesh (300 to 840 micron) size and rapid settling nature made it more difficult to fluidize and retrieve from the large spare HLW tank (8D-1) than prior 1/6-scale testing indicated. That is the primary reason for the lower 96 percent recovery of Cs-137 from the HLW tanks versus the larger 99.5 percent retrieval of sludge solids that typically are sized no more than 50 microns, and consequently more easily fluidized.

Once retrieved from the spare HLW tank, the radioactively laden zeolite was size-reduced in an in-line grinder prior to mixing it with the PUREX and THOREX HLW sludge as feed for the Vitrification Facility. The size-reduction to less than 50 microns and the commingling with the sludge made the zeolite much more easily retrievable from the primary HLW tank (8D-2). The size-reduction of the zeolite didn't cause the molecular sieve structure to release any appreciable amount of the Cs-137 back into the liquid.

Since the WVDP melter used glass-former chemicals with the HLW to produce the desired feed composition and the silica-based composition of the zeolite is a major feed ingredient, the size-reduced zeolite proved to be a very successful melter feed component. The ground zeolite size facilitated representative melter feed slurry sampling and expedited the chemical analyses of the slurry in the laboratory.

One of the largest unplanned activities that required extensive resources was managing the ever-increasing volume of the HLW during zeolite and HLW mobilization/retrieval. The four to six mobilization pumps used to mobilize and suspend the solids in advance of and during waste retrieval batch transfers developed ever-increasing leaks through their lower mechanical seals. This allowed the clean pressurized water (used to lubricate and cool the pump drive-line bearings) in the pump columns to enter the HLW tank and both increase the waste volume and dilute the waste concentration, which acted to slow the retrieval and vitrification processes. In response to this, the WVDP had to continue to utilize the STS to decontaminate the Cs-137 in the liquid sufficiently to volume reduce the solution in the LWTS evaporator before returning the concentrate to the HLW tanks. These systems still remained operable from pretreatment processing.

The WVDP aggressively pursued viable options to minimize the volume of mobilization pump seal water mixing with the HLW. Design changes were specified on two additional mobilization pumps that were procured and deployed into the HLW tanks. These modifications were successful; neither of these pumps developed lower seal leakage throughout their continued usage. Specialized bearing spray systems were developed and installed into four mobilization pumps to limit seal in-leakage and restore operability to mobilization pumps with catastrophic seal failure that resulted in the inability of the pump columns to hold water. These spray systems sprayed a small amount of water at each drive-line bearing resulting in a 12 to 20 liter/min (3 to 5 gpm) water addition per outfitted mobilization pump into the waste instead of a typical large mechanical seal leakage rate of 32 to 60+ liter/min (8 to 15+ gpm). The use of these spray systems avoided the addition and subsequent processing of 760,000 liters (200,000 gallons) of water to the waste and restored operability to two mobilization pumps that otherwise would have needed to be replaced.

The WVDP developed methods to optimize the retrieval of the HLW and measure in real time the amount of gamma radioactivity being removed. Variable frequency drives were installed on all mobilization and transfer/retrieval pumps, as well as on the gear motors that facilitate the rotation of the entire mobilization pumps. This allowed speed adjustment and phasing of all this equipment to settings that maximized the gamma radioactivity indicator. In-tank video cameras were periodically used to adjust mobilization parameters to aid in the retrieval of solids from more difficult regions of the tank bottom.

Another technique that was employed during zeolite retrieval was the simultaneous retrieval of waste slurry from tank with the concurrent decant of the liquid back into the sending tank. This permitted the tank level to be held constant, increased or decreased as the zeolite slurry was being removed. The use of this simultaneous decant-and-transfer resulted in much more efficient retrieval of spent zeolite than a series of batch transfers. In addition, it was discovered that zeolite retrieval was more productive at certain tank liquid levels. The above technique was used to maintain constant tank levels, which resulted in good solids removal, while pumping the slurry from the tank.

Characterization of HLW tank internal surfaces to determine the amount and type of radioactivity present was initiated in Tank 8D-2 in parallel during later HLW retrieval. Based on ongoing black-and-white video inspection of these surfaces, the expectation was to demonstrate low concentrations of insoluble radionuclides on tank vertical surfaces above the 1-meter (3-foot) depth of waste remaining, as well as in the residual waste in the tank bottom. Instead, the radiation wall surveys indicated a significant build-up of both beta and gamma radioactivity 4.3 to 6.1 meters (14 to 20 feet) above the tank bottom. After deployment of a remote surface sampling system (burnishing sampler) and radiochemical analysis of many tank samples, it was determined that there was more radioactive material deposited on tank surfaces than remained in the waste slurry in the bottom of the tank. This revelation necessitated major changes in final waste retrieval activities to focus on washing interior tank surfaces. The ring of elevated radioactivity inside the tank was thought to be the result of maintaining the tank waste levels between these elevations during fuel reprocessing operations; a steam-fired heat exchanger installed in the tank was used to aid in-tank volume reduction, which provided extra capacity for further HLW additions. The lesson learned here is that tank surfaces other than the bottom may contain very significant waste inventories and should not be ignored, despite a clean appearance.

As expected, retrieval of the last HLW was much more difficult and time consuming than initial retrieval activities. Initially, one HLW transfer of 17,000 liters (4,500 gallons) from Tank 8D-2 was sufficient to produce one batch of glass, or approximately four canisters. After 44 HLW batches of glass produced (67 percent of total batches encompassing 65 percent of the initial radioactivity), the remaining waste in the HLW storage tank was diluted to the point that multiple HLW transfers were required to produce a single batch of glass canisters. Dilution was caused by mobilization pump seal water in-leakage. This dilution

was mitigated by decanting excess liquid into spare Tank 8D-1; however, the need to maintain enough liquid in HLW Tank 8D-2 to safely operate the mobilization pumps began to reduce the solids being removed in each successive transfer to vitrification. By vitrification Batch 55, it took five transfers of HLW from Tank 8D-2 to make up a melter feed batch. Batch 62 needed 36 transfers, the largest number for any vitrification batch. The last vitrification batch of HLW from the Tank Farm required 25 transfers of the ever-more dilute waste from Tank 8D-2. This diminishing retrieval of waste from the HLW tank is shown graphically in Fig. 4.

CONCLUSIONS

The WVDP has successfully completed the retrieval and vitrification of radioactive HLW from its storage tanks and the subsequent lay-up of the two largest tanks in preparation for future closure. Waste recovery of cesium-137 adsorbed on two zeolite medias during waste pretreatment has resulted in greater than 95 percent of this radioactivity being vitrified. Over 99.5 percent of the long-lived sludge/transuranic radioactivity and 99% of the Sr-90 have been retrieved from the tanks and vitrified. Approximately 84 percent of the original $1.1x10^{18}$ becquerels (30 million curies) of radioactivity was efficiently retrieved and vitrified from June 1996 to June 1998 during Phase I HLW processing. Recovery of the last HLW took place from June 1998 to September 2001 and was challenging due to a number of factors, primarily the complex internal support structure within the two main 2.8 million-liter (760,000-gallon) HLW tanks, designated Tanks 8D-1 and 8D-2, and the discovery/mitigation of higher-than-expected radioactive deposits on the walls of Tank 8D-2. Recovery of this last waste was exponentially more difficult as less and less HLW was available to mobilize and vitrify.

The WVDP vitrification system was flushed and its melter shut down permanently on September 5, 2002. Following completion of vitrification, approximately 490,000 liters (130,000 gallons) of dilute liquid remained in Tanks 8D-1 and 8D-2. This liquid was retrieved from the tanks in January and February 2003 using specially developed remote equipment to minimize the liquid heel left behind. The tanks were then isolated from further waste additions and placed in a safe, minimum surveillance and maintenance lay-up mode on July 31, 2003. Activities completed to accomplish tank lay-up also included deactivation of the Supernatant Treatment System, the HLW pretreatment system, most of which is inside Tank 8D-1 and a number of actions to reduce the moisture in the underground vaults and the resulting external corrosion of the carbon steel tanks.

It is envisioned that the two tanks will remain in this lay-up state until a final closure plan for the WVDP is approved and a Record of Decision issued. During the pretreatment and retrieval of the HLW, much was learned that might aid other sites in similar activities. The major lessons learned during HLW pretreatment, waste retrieval, residual characterization, and tank lay-up are included above.

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FOOTNOTES