Tank Waste Retrieval Lessons Learned at the Hanford Site

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ABSTRACT

One of the environmental remediation challenges facing the nation is the retrieval and permanent disposal of approximately 90 million gallons of radioactive waste stored in underground tanks at the U. S. Department of Energy (DOE) facilities. The Hanford Site is located in southeastern Washington State and stores roughly 60 percent of this waste.

An estimated 53 million gallons of high-level, transuranic, and low-level radioactive waste is stored underground in 149 single-shell tanks (SSTs) and 28 newer double-shell tanks (DSTs) at the Hanford Site. These SSTs range in size from 55,000 gallons to 1,000,000-gallon capacity. Approximately 30 million gallons of this waste is stored in SSTs. The SSTs were constructed between 1943 and 1964 and all have exceeded the nominal 20-year design life. Sixty-seven SSTs are known or suspected to have leaked an estimated 1,000,000 gallons of waste. The risk of additional SST leakage has been greatly reduced by removing more than 3 million gallons of interstitial liquids and supernatant and transferring the waste to the DST system since 1997 as part of the interim stabilization program. Retrieval of SST saltcake and sludge waste is underway to further reduce risks and stage feed materials for the Hanford Site Waste Treatment Plant.

Regulatory requirements for SST waste retrieval and tank farm closure are established in the Hanford Federal Facility Agreement and Consent Order (HFFACO). The HFFACO was signed by the DOE, the State of Washington Department of Ecology (Ecology), and the U. S. Environmental Protection Agency (EPA) and requires retrieval of as much waste as technically possible, with waste residues not to exceed 360 ft^3 in 530,000 gallon or larger tanks; 30 ft^3 in 55,000 gallon or smaller tanks; or the limit of waste retrieval technology, whichever is less. If residual waste volume requirements cannot be achieved, then HFFACO Appendix H provisions can be invoked to request Ecology and EPA approval of an exception to the waste retrieval criteria for a specific tank.

Tank waste retrieval has been conducted at the Hanford Site over the last few decades using a method referred to as Past Practice Hydraulic Sluicing. Past Practice Hydraulic Sluicing employs large volumes of high-pressure supernatant and water to dislodge, dissolve, mobilize, and retrieve tank waste. Concern over the leak integrity of SSTs resulted in the need for tank waste retrieval methods capable of using smaller volumes of liquid in a more controlled manner.

Retrieval of SST waste in accordance with HFFACO requirements was initiated at the Hanford Site in April 2003. New and innovative tank waste retrieval methods that minimize and control the use of liquids are being implemented for the first time. These tank waste retrieval methods replace Past Practice Hydraulic Sluicing and employ modified sluicing, vacuum retrieval, and in-tank vehicle techniques. Waste retrieval has been completed in three Hanford Site SSTs (C-106, C-202, and C-203) in accordance with HFFACO requirements. A fourth SST (S-112) was retrieved to the “limits of technology” as part of a retrieval demonstration, and retrieval of three more SSTs (S-102, C-201, and C-103) is underway. Preparation for retrieval of two additional SSTs (C-108 and C-204) is ongoing with retrieval operations forecasted to start in calendar year 2006. An additional Remote Water Lance demonstration has also been initiated in tank S-112.

Tank C-106 was retrieved to a residual waste volume of 364 ft^3 using oxalic acid dissolution and modified sluicing. An Appendix H exception request for Tank C-106 is undergoing review and approval by Ecology and EPA. The U. S. Nuclear Regulatory Commission has also reviewed the Tank C-106 exception request. Tanks C-202 and C-203 are smaller (55,000 gallon) tanks and waste removal was completed in accordance with HFFACO requirements using a vacuum retrieval system. Residual waste volumes in Tanks C-202 and C-203 are both less than 20 ft^3. Tank S-112 was retrieved to the “limits of technology” using saltcake dissolution and modified sluicing. The residual waste volume requirements specified in the HFFACO were not met in Tank S-112 and a method to break-up and retrieve the 29,000 gallon hard saltcake heel has been implemented. Retrieval of Tank S-102 is about 50 percent complete and forecast for completion in February 2007.

Lessons learned from application of new tank waste retrieval methods are being documented and incorporated into future retrieval operations. They address all phases of retrieval, including process design, equipment procurement and installation, supporting documentation, and system operations. Information is obtained through interviews with retrieval project personnel, focused workshops, review of problem evaluation requests, and evaluation of retrieval performance data.

This paper presents lessons learned from retrieval of tank waste at the Hanford Site and discusses how this information is used to optimize retrieval system efficiency, improve overall cost effectiveness of retrieval operations, and ensure that HFFACO requirements are met.

INTRODUCTION

The Hanford Site covers approximately 560 square miles in southeastern Washington State. The radiochemical processing of spent nuclear fuels and other waste management operations conducted over the past six decades resulted in the generation of roughly 53 million gallons of radioactive waste. This waste is currently stored in 149 SSTs and 28 DSTs located in the 200 East and 200 West Areas of the Hanford Site (commonly referred to as the Central Plateau.) The SSTs were constructed from 1943 to 1964 and contain roughly 30 million gallons of waste. All of the SSTs have exceeded their 20-year design life by several decades.

The SSTs were constructed with steel-reinforced concrete outer shells and carbon steel liners along the sidewalls and tank bottoms. The SSTs are located in 12 tank farms containing 4 to 18 tanks each. Sixteen SSTs are 200-Series tanks with capacities of 55,000 gallons each. The remaining 133 SSTs are 100-Series tanks with capacities ranging from 530,000 gallons to 1 million gallons each. Many of the tanks were built in cascades of three or four tanks. The cascading tank configuration allowed solids to separate and settle while less radioactive liquids flowed from one tank to another.

The SSTs contain mostly radioactive saltcake and sludge waste. The waste is primarily sodium nitrate and sodium nitrate salts; and metal phosphate, carbonates, oxides, hydroxides, and sulfates. About 75 percent of the radioactivity is attributed to Strontium-90, while 24 percent of the radioactivity is associated with Cesium-137. The remaining 1 percent of the waste is a mixture of other radionuclides (primarily actinides) and chemicals. The majority of the Strontium-90 is found in the sludge, while Cesium-137 tends to concentrate in the saltcake and interstitial liquids.

Sixty-seven of the 149 SSTs are known or suspected to have leaked an estimated 1 million gallons of waste into the surrounding soil. The number of tanks that actually leaked is estimated to be 50 percent less based on results of recent investigations attributing some suspected tank leaks to pipeline ruptures and near-surface spills.

In March 2004 the Hanford Site completed the interim stabilization saltwell pumping in all 149 SSTs in accordance with HFFACO requirements. Roughly 3 million gallons of drainable and pumpable liquid waste were removed from the SSTs and transferred into the environmentally sound DSTs between 1997 and 2004. Completion of interim stabilization salt-well pumping was an important first step in retrieving waste from the SSTs and greatly reduces the potential risk associated with leakage of waste while the SSTs await completion of retrieval operations.

Considerations in Choosing a SST Retrieval Method

Through teaming with Ecology, the U. S. Department of Energy, Office of River Protection (ORP), and CH2M HILL Hanford Group, Inc. (CH2M HILL), and negotiated in the HFFACO, four basic retrieval techniques have recently been selected for deployment in the Hanford tanks for retrieval: Saltcake Dissolution, Modified Sluicing, Vacuum Retrieval System (VRS), and Mobile Retrieval System (MRS). Each of these systems has advantages in achieving the retrieval goals set forth in the HFFACO for the differing waste types and tank configurations.

The first discriminator in selecting the retrieval system for deployment in a tank is the suspected integrity of the SST to be retrieved. For tanks that are suspected to have leaked in the past, the vacuum retrieval system has been selected for retrieval. This system utilizes an Articulating Mast System (AMS) with a vacuum head, a vacuum pump, a slurry vessel, and a number of slurry pumps to retrieve waste from the SST. This system minimizes the amount of liquids introduced to the tank during the retrieval process, thereby minimizing the environmental impact of any leakage during the retrieval process. The AMS can reach a 20 ft diameter region of the tank floor. For the 200 Series tanks with an inside diameter of 20 ft, the Vacuum Retrieval System (VRS) can reach the entire tank floor to complete retrieval. The MRS is planned for use in 100 series SSTs with questionable integrity.

The MRS couples the VRS with a hydraulic driven vehicle to push waste from the outer edges of the tank floor to the articulating mast in the tank. Although this retrieval system has not been used for actual tank retrieval, it has demonstrated its capabilities in the Hanford Cold Test Facility (CTF) and is intended to be used for tank retrieval in the near future.

The second important discriminator in choosing the retrieval system is the waste characteristics. Waste being retrieved from the SSTs is generally categorized as saltcake, sludge, or a combination of both. Saltcake waste is predominately sodium salts, sodium nitrates and sodium carbonates. These solids are considered soluble in water and were deposited in the SSTs through past evaporation processes intended to minimize the waste volume storage demands. For the retrieval of saltcake waste, a process of saltcake dissolution has been utilized. This process consists of water jets and sluicers, a progressive cavity pump and recirculation system. Water is introduced and re-circulated within the tank being retrieved, dissolving the slatcake waste until a desired specific gravity is achieved. This minimizes the overall waste being generated during retrieval. The waste is then pumped to the receiving DST.

Sludges consist primarily as metal hydroxides and are largely insoluble in basic tank environments. A process referred to as modified sluicing is used to retrieve sludge material from the SSTs. The modified sluicing system consists of sluice nozzles that suspend the insoluble solids in recycled DST supernatant or water. A slurry pump is then used to transfer the slurry mixture to the receiving DST.

Other important factors in selecting and designing the retrieval system include minimization of the waste volume added to the DST during retrieval and available access to the tank for installation of retrieval systems. Based on past experience with saltcake dissolution, about 3 gallons of waste is generated during retrieval for every 1 gallon of waste retrieved. To minimize the overall waste generated, Saltcake dissolution systems are designed to maximize the ability to recirculate waste within the SST being retrieved so that the maximum amount of waste is dissolved before transfer to the receiving DST. Modified Sluicing Systems have been designed to use existing dilute DST waste as the sluicing media for SST retrieval. In this way, dilute waste is pumped from the DST to the SST, sprayed through the sluice nozzles into the SST, the insoluble solids are mobilized, and the slurry is pumped back to the DST. Both of these techniques have been very effective at reducing the waste volume generated during retrieval.

One important limiting factor to the installation and placement of the retrieval systems into the tank is the availability of access points into the tanks. Many of the SSTs have limited access points (risers) that extend from grade level into the tank allowing the installation of equipment. This limits the size and amount of equipment that can be deployed in the tank.

Each of the tanks that have been or are currently being retrieved, has represented various challenges. In addition to the four basic retrieval techniques (Saltcake Dissolution, Modified Sluicing, VRS, and MRS), various additional techniques have been used with these systems to facilitate waste retrieval and minimize waste generation.

Retrieval of Tank C-106 Waste

Tank C-106 was constructed during 1943 and 1944 with a nominal capacity of 530,000 gallons. In 1971, sludge temperatures in the tank increased to above 212 degrees Farenheit due to the quantities of Strontium-90 that had been transferred to the tank. Since Tank C-106 was not equipped for storage of high heat material, waste additions to the tank were discontinued and the tank was placed on active ventilation. Raw water was periodically added to the tank to facilitate evaporative cooling. As a result of high-heat safety issues and concerns over addition of raw water to control waste temperatures, the decision was made to retrieve the waste from Tank C-106. The first retrieval method, termed “past-practice” hydraulic sluicing, was initiated in November 1998 and completed in October 1999. This method introduced high-pressure, high-volume DST supernatant in the tank to dislodge, dissolve, and mobilize the waste for removal by the retrieval pumping system. This system was successful at retrieval of about 187,000 gallons of sludge and resolving high-heat safety concerns with Tank C-106. About 36,000 gallons of supernatant and hard sludge were left in the tank following this initial retrieval campaign.

Subsequent retrieval operations were performed in Tank C-106 in 2003 using a combination of modified sluicing with oxalic acid dissolution. During this retrieval, a total of 142,000 gallons of 0.9 molar Oxalic Acid were added to Tank C-106 in 6 batches. After each batch, the Acid was allowed to fully react with the sludge material, pumped to the receiving DST, and sluicing operations were performed to remove the loosened sludge. This process was repeated until no additional waste was being removed. [1]

At the conclusion of these retrieval operations, the residual waste volume on the C-106 tank bottom was estimated to be 348.2 cu-ft using the Video Camera/Computer-aided design (CAD) Core Component Modeling System (CCMS). For Tank C-106 the 95 percent confidence interval was an upper bound, yielding a 27 percent residual waste volume of 442.2 cu-ft. This 27 percent error determination was based on 9 data points obtained from initial testing conducted at the CTF and modeled using the CCMS method with known simulant waste volumes. As part of a lessons learned review, the methodologies employed in the error determination were re-evaluated. The review resulted in additional improvements in residual volume estimating.

To obtain a larger data set, additional testing at the CTF using the CCMS method and an additional estimate of “actual” residual waste volume using the ENRAF displacement/submergence method in Tank C-106 was used. The new data (19 data points) coupled with the alternative statistical analysis method yielded a much lower volume estimate with a 95 percent confidence level, namely 364 cu-ft.

The Lessons Learned from this retrieval operation included:

- The slurry pump is best located in the center of the tank if risers are available for access. In this manner, the dish-shape tank bottom can be used most effectively to allow pumping to the lowest point in the tank and minimize residuals.

- Permanently installed stainless steel pipe-in-pipe transfer piping was used for transferring waste from Tank C-106 to the DST receiver during past practice sluicing operations.

While it was effective for use, materials and installation were very expensive in this application. During oxalic acid dissolution and modified sluicing, a Hose-in-Hose Transfer Line was utilized which provided adequate performance at a significantly reduced cost.

- During the bulk retrieval operations in the late 1990's, DST supernatant was recycled during the retrieval operations and used as the sluicing media. This was very effective at mobilizing the tank sludge and reducing the total waste generated during the retrieval operations.

- The initial methods for determining the residual volumes at a 95 percent confidence interval resulted in very large upper bounds and largely overstated the residual volumes. This methodology was revised, resulting in a smaller residual volume estimate at a 95 percent confidence.

Retrieval of Tank S-112 Waste

Tank S-112 is a 100 series SST located in S-Farm in the 200 West Area of the Central Plateau. At the start of retrieval, Tank S-112 was estimated to contain about 614,000 gallons of Saltcake waste. Saltcake dissolution was chosen as the retrieval method to be used for this tank waste. Water was injected into the tank through sluicer type nozzles and recirculated within the tank until a desired specific gravity of 1.3-1.35 was achieved. The waste solution was transferred to a DST. From the start of retrieval in September 2003 to May 2005, more than 585,000 gallons of waste were transferred from
Tank S-112. In May of 2005, the demonstration of Saltcake dissolution was halted when this method was deemed no longer effective at retrieval of the waste. A hard monolithic layer was found on the bottom of the tank that accounted for about 29,000 gallons of waste that would not readily dissolve nor mobilize with the installed system.

A Remote Water Lance Rapid Demonstration project was initiated to evaluate the use of high-pressure water stream to breakup or dissolve this layer. CH2M HILL enlisted the help of Technical Mechanical Resources (TMR) Associates and their "Salt Mantis" water lance for use in this demonstration. The Salt Mantis can be lowered into the tank through a 12-inch riser and deliver a high pressure water stream (35,000 psi) to the surface of the hard waste at various locations in the tank. The demonstration of this technique started on November 18, 2005 and has yielded very positive results so far. Within the first 19 days of operation, 100 percent of the hard-heel waste was broken up and 61 percent of the waste was retrieved using the existing retrieval pump.

Tank S-112 was the first tank to demonstrate retrieval using saltcake dissolution. In this demonstration a number of important lessons have been learned. These lessons learned include:

- The rate of retrieval of waste from Tank S-112 during the saltcake dissolution demonstration was slower than predicted. Fig. 1 below identifies the planned retrieval rate vs. the actual retrieval rates observed. Optimistic planning assumed the process would be limited by the ability to add and remove water from the tank. In practice, after the first 30 percent of the waste was retrieved, the rate of dissolution limited the process.

- The waste residuals remaining after the dissolution had a higher than predicted percentage of insoluble materials. This partially explains the slower retrieval rates at the end of the dissolution demonstration.

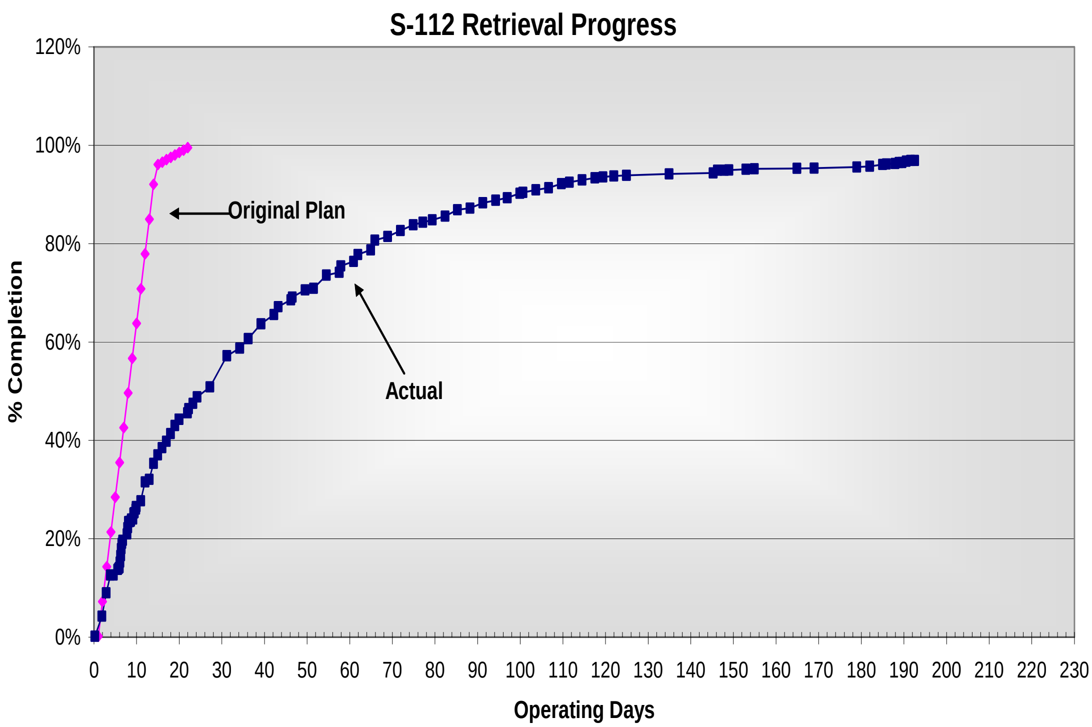

Fig. 1. Planned retrieval rate versus actual retrieval rate

- The initial operating strategy for this retrieval was to mine a hole around the pump, allowing waste to be both pushed to the pump suction as well as dissolved. This strategy was abandoned for one in which layers of waste were removed across the tank which allowed greater waste contact time and yielded a higher specific gravity, thereby reducing the waste volume generated.
- Multiple and moveable discharge points for recirculated waste within the SST would have improved the dissolution of waste. Tank S-112 system had a single recirculation discharge point into the tank.
- The temperature of dissolution water also greatly affected the retrieval rate. Higher temperature water increased the initial dissolution of waste as well as compensated for the heat lost due to the endothermic dissolution of salts such as $NaN0_3$ and Na_3PO_4. The higher temperature water was limited, however, by the thermal requirements of the retrieval system and created a fog, which limited the visibility in the tank.
- The operational convenience of a Human Machine Interface for control and monitoring of the retrieval system must be weighed against the added complexities in training, software configuration control, and computer related downtime.

- A hose-in-hose temporary transfer system installation from Tank S-112 to the receiver DST reduced the overall cost of installation of the system.
- The recirculation of waste within the SST until a desired specific gravity is met was successful in achieving waste minimization goals during the early stages of retrieval. Fig. 2 below plots the projected percent waste retrieved/volume generated, versus actual.
- During the later stages of retrieval, soaking the waste for several days between operations made it easier to maintain adequate specific gravity values before transferring to the DST.
- A higher than anticipated volume of insoluble sludge was contained in Tank S-112. This potential exists in other tanks believed to contain saltcake waste. Additional provisions for retrieving the potential sludge with either a remote water lance or the use of a supernatant recycle system should be considered.

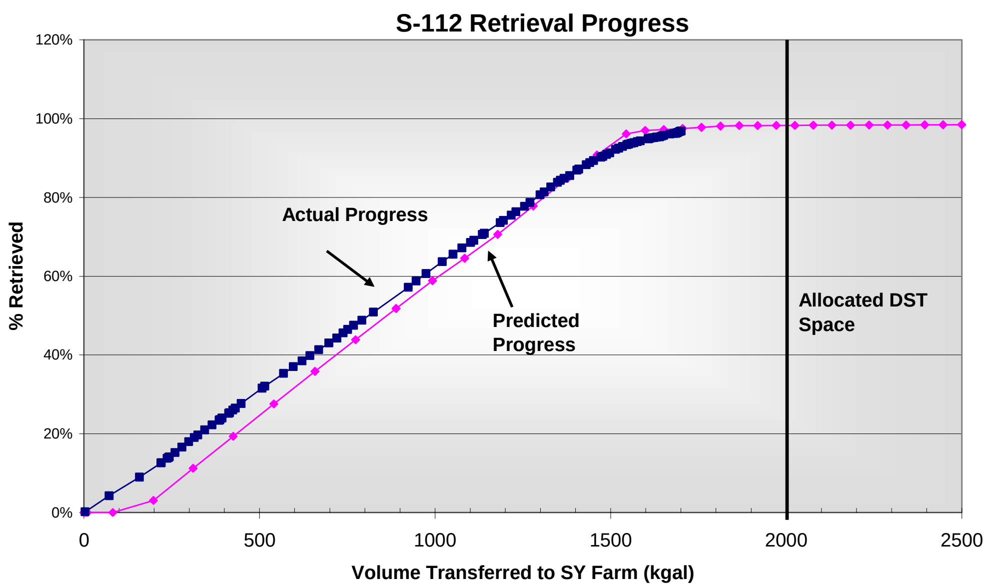

Fig. 2. Projected percent waste retrieved/volume generated, versus actual

Retrieval of Tank S-102

Tank S-102 is a 100 series SST located in S-Farm in the 200 West Area of the Central Plateau. Nearly 440,000 gallons of sludge and saltcake were contained in the tank at the start of retrieval. This waste matrix contained an upper layer of sodium nitrate salt (white salt), a middle layer of sodium fluoride phosphate double salt (black salt), and a lower layer of 38,000 gallons of insoluble sludge. This waste presented a number of challenges to retrieval operations. It was determined through laboratory testing that the black salt would, if subjected to temperatures above 135 Fahrenheit and allowed to cool, form a gel under certain conditions. This gel substance could cause severe problems with pump and transfer line plugging, as well as future challenges retrieving this waste from the DST.

Thus, a process strategy was developed which limited the temperature of water added to the tank to 130 degrees Fahrenheit and controlled the waste liquid density. The second problem encountered with the retrieval of the waste was that the black salt and sludge layers behaved much more like a thick mud layer than the slatcake had and did not dissolve or suspend, nor did it allow dilute waste to flow through it to the progressive cavity pump intake at the bottom of the tank. Water flushes of the pump, as well as air and nitrogen sparging through the pump column, were successful at agitating the waste around the pump column; however, once the sparging ceased and pumping operations were initiated, the waste again slumped around the pump in-take. For these reasons, an additional variable height pump suspended on a cable was installed which would allows retrieval from the top salt layer down. It is anticipated that once the bulk salt waste is retrieved from the tank, the original progressive cavity pump will again be needed to retrieve the remaining waste from the tank. About 250,000 gallons of waste have been retrieved from Tank S-102 thus far using these techniques. As shown below in Fig. 3 and Fig. 4, although the rate of retrieval has been somewhat less than expected, through careful control of the specific gravity, the overall waste generated is close to the projection.

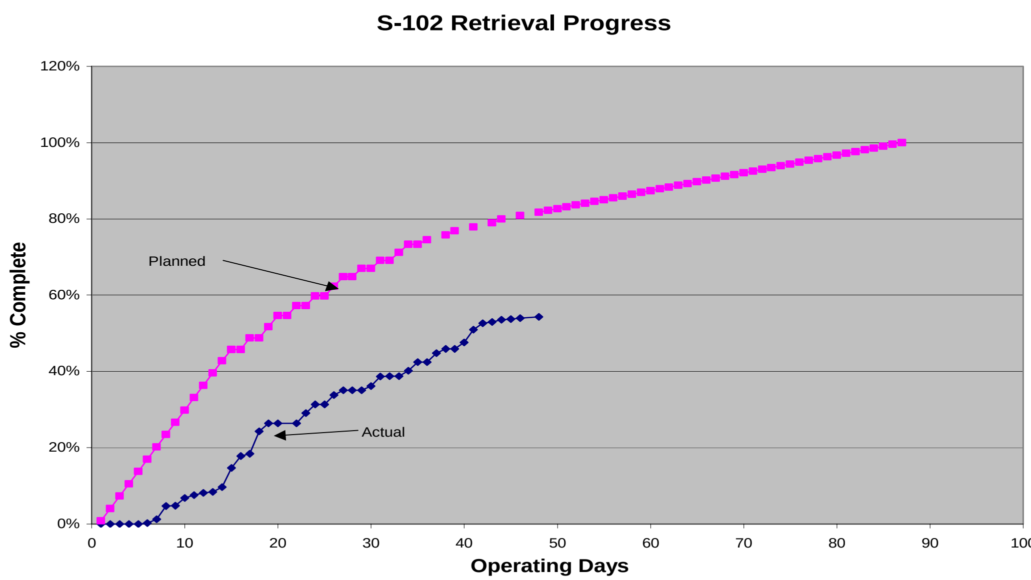

Fig. 3. S-102 Retrieval Progress (% complete)

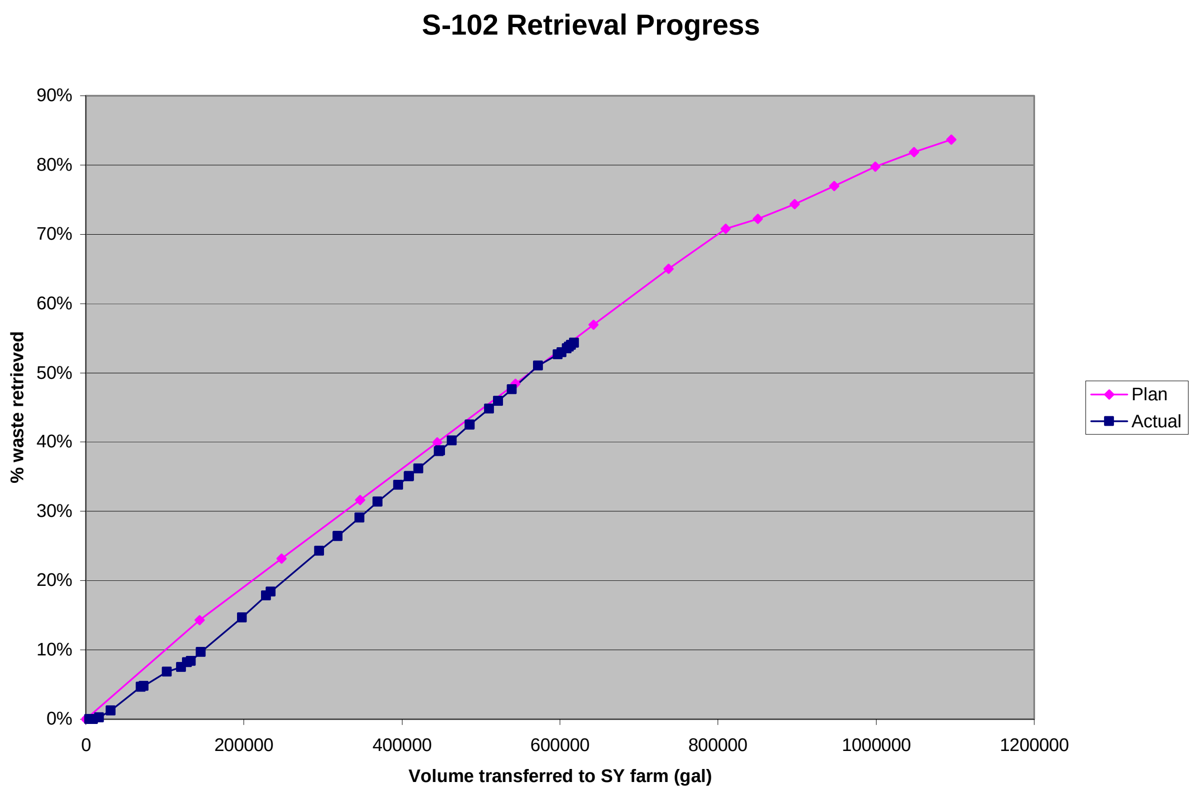

Fig. 4. S-102 retrieval process (% waste retrieved)

Several very important lessons have been learned from the retrieval operations in Tank S-102. These include:

- The importance of tank chemistry data in determining the equipment design and the process strategy. The waste properties in Tank S-102 were different than originally anticipated and, if not carefully examined, could have led to pump or transfer line plugging issues as well as future retrieval issues.

- The ability to flush and back flush the transfer pump suction screen is very important during the retrieval operations to free up plugging that occurs. Additional spray, flushing, and mechanical scraping capabilities outside the pump suction screen would enhance the retrieval rates and further reduce the pump plugging issues. Additionally, the pump suction inlet screen pore size must be re-evaluated for future operations to improve overall operating efficiency.

- The use of a variable height pump may be required when retrieving thick, mud-like waste to allow retrieval from the top of the tank down and reduce pump plugging issues

- Although not effective in Tank S-102, the pump back flush and sparging actions did appear to agitate the waste around the pump column and may be an effective tool in future retrieval activities.

Retrieval of C-200 Series Tanks

SST C-203 is a 55,000-gal SST that is one of four 20-ft diameter tanks built in C Tank Farm from 1944 to 1945. The tank was first put into service in 1947 and filled with waste. This waste was removed in 1954, and the tank received more waste from the hot semi-works in 1955 and 1956. Most of the hot semi-works waste was removed in 1970, and the tank was removed from service in 1976. Interim stabilization was complete in 1982. Due to liquid level decreases, the tank was assumed to be a leaking tank in 1984.

The waste in SST C-203 was retrieved using a VRS consisting of an articulating mast with a vacuum head, vacuum pump, slurry vessel and slurry transfer pump. A ventilation system, control trailers and associated piping and utilities make up the remaining system. Figure 5 shows the configuration of this system. The retrieval system and its operation are described in RPP-16945, *Process Control Plan for the 241-C-200 Series Waste Retrieval System.*

The retrieval of waste from Tank C-203 started in June 2004 and continued through March 2005. The pre-retrieval estimate of waste contained in the tank was 2,600 gallons. When retrieval completed in March 2005, approximately 3,050 gallons of waste had been retrieved from Tank C-203. The total volume of post-retrieval waste in SST C-203 and the waste volume associated with the various waste components are given in Table I. The total post-retrieval waste volume in SST C-203 is estimated to be 18.55 cu.ft (139 gallons). For the purpose of meeting the HFFACO, the total residual waste volume is the residual waste volume on the tank bottom (both liquid and solid) at the 95 percent upper control limit (14.8 cu ft) plus the residual waste volume on the stiffner rings, equipment void space, and tank walls (5.11 cu ft). Using this definition, the total post-retrieval waste volume in Tank C-203 is estimated to be 19.9 cu ft (149 gallons), thus meeting the criteria of less than 30 cu ft. A comparison of the pre-retrieval estimates and post retrieval actual values is provided below in Table I. [2,3]

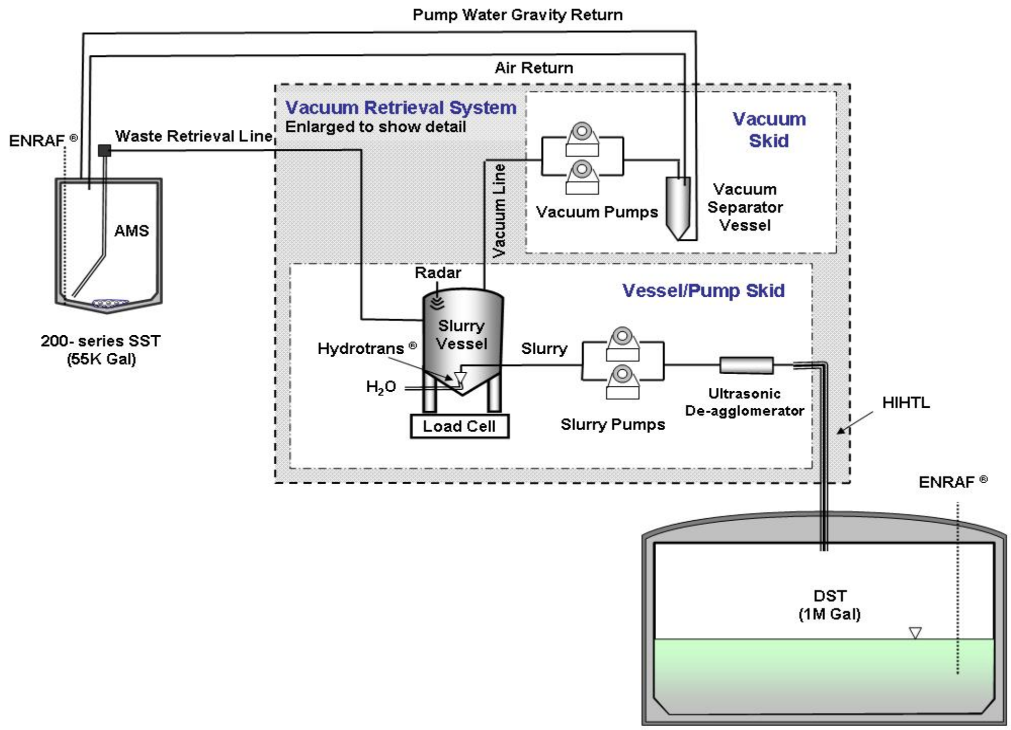

Fig. 5. Vacuum retrieval system configuration

Table I.

Measurement	Predicted	Actual	Achieved Expectations?
Remaining tank waste residues volume (ft^3)	<<30	18.5	Yes
Volume of waste retrieved (gallon)	~2,600	3,047	Yes
Retrieval time (days)	7	34	No
Retrieval rate (gallon per batch)	40 to 60	16	No
Total water usage (gallon)	14,000 to 42,000	62,664	No

Reference 2

SST C-203 retrieval was the first use of the in a radiological environment for recovery of tank solids. Many lessons were learned which will improve pre-retrieval predictions and overall system performance [3]. These lessons include:

- The HFFACO established method of estimating the remaining waste volume using 3-D imaging and computer aided as-built drawings was effective in determining the waste remaining in the tank after completion of retrieval operations.
- Material balance calculations for estimating volume of waste retrieved proved useful as a general indicator of retrieval progress. The trend line in Figure 6 dips below the zero residual waste volume, which is clearly not the case, since the HFFACO established residual waste volume measurement indicated that 18.5 ft^3 (~138 gallons) remained in the tank. This is the result of uncertainties in the pre-retrieval estimates and material balance calculations during retrieval.

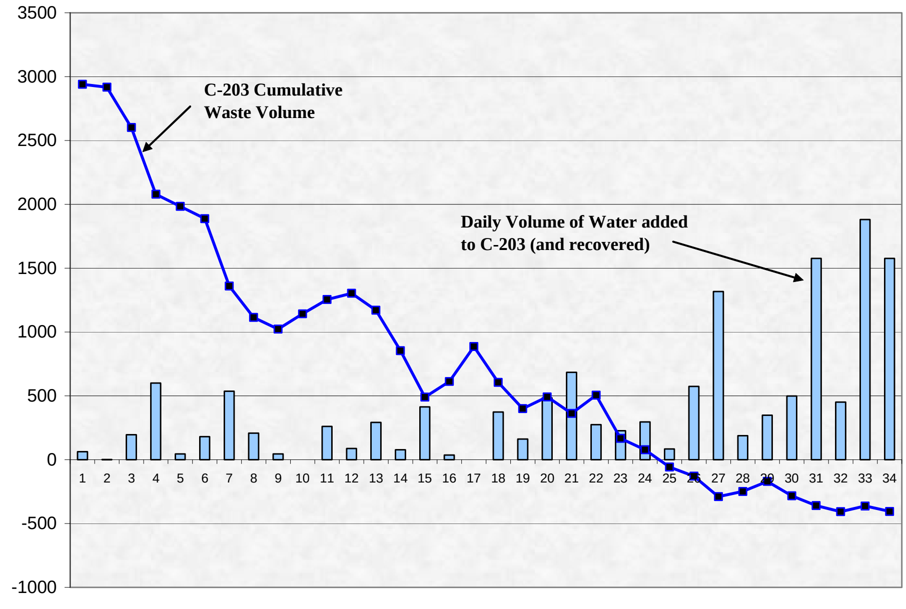

Fig. 6. Day of activity

- The pre-retrieval estimate of 7 days was overly optimistic, though a considerable amount of waste was retrieved in the first 7 days of operation. The pre-retrieval predictions were based on performance data observed during CTF simulations prior to startup. The simulations were conducted at the CH2M HILL CTF using waste simulants derived from generator knowledge contained in RPP-14627, *Characteristics of Waste in the C-200 Series of Hanford Underground Waste Tanks*. The waste simulant resembled the sticky viscous material identified in the report. The mock retrieval system was able to suction the waste out of the tank by adding limited quantities of water to change its consistency to a non-cohesive mud-like substance.

- Initially the waste behaved in a similar manner as observed at the CTF. As the campaign progressed, however, the waste characteristics became less favorable to retrieval. The waste, rather than resembling a mud-like substance after addition of water, broke into chunks having a gravelly appearance. This material required considerably more effort to be lifted out of the tank and remain suspended through the retrieval system process. The material had a tendency to settle quickly, requiring more water and greater agitation to suspend the particles and subsequently longer time to complete retrieval.

- The retrieval campaign used approximately 62,664 gallons of water. Water use increased during the retrieval duration as the waste behavior became more gravel-like and less mud-like. This required greater amounts of water to effectively mobilize, retrieve and flush the system.

- The length and configuration of the hose connecting the AMS to the vacuum vessel was determined to be an important factor to having adequate vacuum for retrieval operations. During the retrieval activities on Tank C-203, significantly less vacuum was observed in the AMS and vacuum head than had been demonstrated during testing at the CTF. Additional mockup operations at the CTF showed considerable improvements in vacuum by shortening the hose lengths and reducing the number and angle of bends in the piping system.

- The screen mesh size on the intake to the AMS was sized smaller than need be (3/8 in.) to protect the slurring pump and vessel equipment. This led to unnecessary plugging problems that severely slowed the vacuum retrieval rates with this system. Similar to saltcake dissolution and sluice retrieval pumps, the intake screen should be sized as large as possible to protect the pump from damage and also as large as possible to minimize plugging.

Retrieval of Tank C-202

The second of the C-200 series tanks to retrieve was Tank C-202, which bears similarity to C-203. Tank C-202 is a 55,000-gallon tank built in 241-C Tank Farm in 1944 to 1945. The tank was first put into service in 1947 and filled with waste. This waste was removed in 1954 and the tank received additional waste from the hot semi-works in 1955 and 1956. Most of the waste was removed in 1970 and the tank was removed from service in 1976. Interim stabilization was completed in 1982. Due to level decreases, the tank was assumed to be a leaking tank in 1988.

Like C-203, Tank C-202 utilized the vacuum retrieval system consisting of an articulating mast with a vacuum head, vacuum pump, slurry vessel and slurry transfer pump. Key lessons learned from C-203 retrieval were incorporated into the operation of C-202. These included:

- Shorter hose lengths were used between the AMS and the vacuum vessel.
- Sharp bends between the vacuum line and the top of the AMS were removed.
- Transfer line flushes were reduced from being performed after each batch to being performed at the end of each operating day.
- Reduced water usage and air injection at the vacuum head resulted in higher vacuum and increased retrieval rates.

The retrieval efficiency was increased from 0.05 gallon waste retrieved per gallon of DST waste created for Tank C-203 to 0.07 for Tank C-202. This resulted in a 34 percent reduction in the DST space required for retrieval. [4]

Retrieval of Tank waste from tank C-202 was completed on August 11, 2005, requiring just eighteen shifts of operation. At the completion of retrieval, an estimated 20.9 cu. ft. of residuals remained in the tank, including 5.1 cu. ft. on the tank walls, 6.1 cu. ft. in abandoned equipment and 9.7 cu. ft on the floor.

Retrieval of Tank C-201 Waste

Waste retrieval operations were initiated on Tank C-201, the third of four C-200 series tanks, in October 2005. Tank C-201, like the other C-200 series tanks is a 55,000 gallon tank built in the 1940s containing approximately 750 gallons of solid waste prior to VRS operations. To date, approximately 70 percent of the waste has been removed from Tank C-201 and transferred to the DST system. Many of the lessons learned from the Tank C-203 retrieval effort and applied to Tank C-202 waste retrieval have also been successfully applied to Tank C-201 waste retrieval.

Retrieval of Tank C-103 Waste

Tank C-103 was constructed during 1943 and 1944 with a nominal capacity of 530,000 gallons. Approximately 72,000 gallons of sludge waste and 5000 gallons of water were present in the tank at the beginning of sluicing operations. Due to the tank status (non-leak designation) and waste form (sludge), Tank C-103 retrieval utilizes the modified sluicing technology, and is designed to allow DST supernatant to be recycled and employed as the sluicing medium. This significantly reduces the amount of DST space required for the retrieval of tank contents by several million gallons, providing significant cost reduction associated with the storage of DST tank waste and evaporator reductions of stored DST liquids. Tank C-103 retrieval operations were initiated in November 2005, and during the first week of retrieval surpassed assumed retrieval rates. To date, approximately 12 percent (~9900 gallons) of the waste has been successfully removed from Tank C-103 and transferred to the DST system.

Lessons learned, which have been incorporated into the C-103 retrieval, include:

- Due to limited access, removed as many items requiring maintenance to a more accessible above grade valve pit. If mechanical or electrical equipment in the piping system fails, time and cost associated with repairs will be minimized.

- Designed the system to utilize recycled DST supernatant as the sluicing media. During the first several sluicing campaigns, this method has proved very effective at mobilizing the tank sludge and reducing the total waste generated during the retrieval operations.

- Designed the system to be operated and surveyed remotely, thereby minimizing potential exposure to operation and surveillance personnel.

- Utilized Commercial off-the-shelf components, significantly minimizing procurement durations and cost.

- Performed upgrades to existing ventilation system with focus on minimizing unplanned shutdowns and maintenance.

General Observations and Lessons Learned

There are several other general lessons that have been learned and applied to subsequent retrieval operations. These include:

- The use of old facility systems and infrastructure should be limited. The cost of upgrading old existing systems and structures and removing contaminated equipment far exceeds the fabrication and installation of new systems when practicable.

- The application of lessons learned from both process data and equipment design has significantly reduced the cost of retrieval from the Tank C-106 retrieval operations to the more recent Tank C-200 retrieval. This is demonstrated in Figure 7 below.

- Significant improvement has been made in the measurement of the post retrieval residual volumes. This allows, at the 95 percent confidence interval, to more accurately depict the final residual volumes for use in future risk assessments and closure plans.

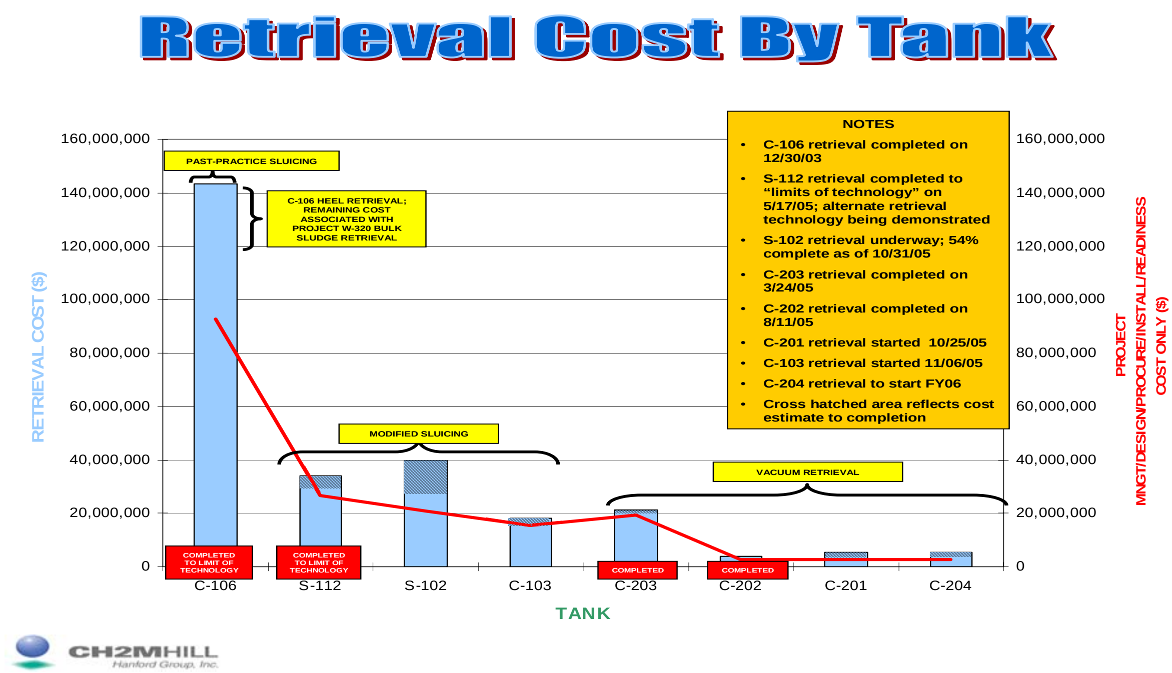

Fig. 7. Retrieval cost by tank

CONCLUSION

Significant accomplishments are being made in the retrieval of waste from the SSTs at Hanford. Three retrieval technologies have been successfully deployed (saltcake dissolution, modified sluicing, and vacuum retrieval) for the retrieval of these sludges and saltcakes. Additional processes of the mobile retrieval system and the salt mantis have been tested at the CTF and the salt mantis has been implemented in the field operations. Additional techniques of oxalic acid dissolution, air/nitrogen sparging, and variable height pumping have also been utilized. Through the application of lessons learned, the cost of retrieval is significantly reduced, and the end state goals for residual volumes are being achieved.

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