Retrieval and Treatment of Hanford Tank Waste

M.S. Spears, J.A. Eacker, P.E. and M.H. Sturges, P.E.
CH2M HILL Hanford Group, Inc.
P.O. Box 1500, MSIN H6-03
Richland, WA 99352

Billie M. Mauss
U.S. Department of Energy – Office of River Protection
2440 Stevens Drive
Richland, WA 99352

ABSTRACT

The Hanford Tank Farms contain 53 million gal of radioactive waste accumulated during over 50 years of operations. The waste is stored in 177 single-shell and double-shell tanks in the Hanford 200 Areas. The single-shell tanks were put into operation from the early 1940s through the 1960s with wastes received from several generations of processing facilities for the recovery of plutonium and uranium, and from laboratories and other ancillary facilities. The overall Hanford Tank Farm system represents one of the largest nuclear legacies in the world driving towards completion of retrieval and treatment in 2028 and the associated closure activity completion by 2035. Remote operations, significant radiation/contamination levels, limited access, and old facilities are just some of the challenges faced by retrieval and treatment systems. These systems also need to be able to successfully remove 99% or more of the waste, and support waste treatment, and tank closure.

The Tank Farm retrieval program has ramped up dramatically in the past three years with design, fabrication, installation, testing, and operations ongoing on over 20 of the 149 single-shell tanks. A variety of technologies are currently being pursued to retrieve different waste types, applications, and to help establish a baseline for recovery/operational efficiencies. The paper/presentation describes the current status of retrieval system design, fabrication, installation, testing, readiness, and operations, including:

- Saltcake removal progress in Tanks S-102, S-109, and S-112 using saltcake dissolution, modified sluicing, and high pressure water lancing techniques,
- Sludge vacuum retrieval experience from Tanks C-201, C-202, C-203, and C-204,
- Modified sluicing experience in Tank C-103,
- Progress on design and installation of the mobile retrieval system for sludge in potentially leaking single-shell tanks, particularly Tank C-101, and
- Ongoing installation of various systems in the next generation of tanks to be retrieved.

Several of these systems are first-of-a-kind applications, including the vacuum retrieval and mobile retrieval system. Others are modifications of existing proven systems that build on

previous successes in the nuclear environment and/or incorporate lessons learned from previous similar operations.

The treatment program for the removed tank waste is aimed at applying the right technology for the right waste type since there are significant variances in the waste forms. The Waste Treatment Plant represents the focal point of this program, but is being supplemented by a Demonstration Bulk Vitrification System, supplemental pretreatment in the tank farms, and optimization activities that can take place in the tanks themselves. The paper will include a discussion of:

- Optimization studies that have been performed including waste blending, wash/leach, and physical separation that could be used to supplement WTP operations,

- Supplemental pre-treatment options including fractional crystallization, ion exchange, and other approaches considered that could be performed in the tank farms to either supplement the WTP pre-treatment capability or be used prior to its availability, and

- Progress and lessons learned from testing, design, and construction of the DBVS.

INTRODUCTION

The Hanford Tank Farms contain 53 million gal of radioactive waste accumulated with over 50 years of operation. The waste is stored in 177 single- (SST) and double-shell tanks (DSTs) located within a number of farms and spread geographically over many square miles of the Hanford Site.

Treatment and disposal of the tank waste, followed by closure of the tank farm facilities, is the critical path to closure of the Hanford 200 Areas with a current baseline end date of 2035. Retrieval of waste into the newer DSTs is the first major step in this process to stage the waste for treatment in either the Hanford Waste Treatment Plant (WTP) or a supplemental treatment technology facility that is currently under development. The Hanford Federal Facility Agreement and Consent Order (HFFACO) [1] with the State of Washington and the Environmental Protection Agency requires that waste in single-shell tanks be removed to below 1% of volume of the tank and to the limits of the retrieval technology. This retrieval effort has transitioned over the last two years from a demonstration scale intended to have one tank retrieved by the end of fiscal year 2006, to the following current status:

- Three tanks retrieved (Tanks C-106, C-202, and C-203)
- Four tanks currently in retrieval operations (Tanks C-201, C-103, S-102 and S-112)
- Two additional tanks with retrieval systems being installed (Tanks C-108 and C-204)
- Several additional tank retrieval systems at various stages of design, fabrication and construction.

GENERAL SST INFORMATION RELEVANT TO RETRIEVAL

General information about the SSTs includes tank dimensions, composition, and characteristics.

General tank dimensions of concern for retrieval operations are:

- Overall diameter of an SST which is either 75 feet (100 Series tank) or 20 feet (200 Series tank)
- Available access points vary from 3 to >20 per tank with diameters varying from 4" to 42"
- Distance from the surface to the base of the tank ranges from ~38 to 53 feet for the 100 and 200 Series tanks.

The SSTs were constructed at various phases of the Hanford Site operations and generally co-located with one or more major waste generators accomplishing the nuclear materials production mission. Table I describes the various tank sizes and age of the tanks involved.

Table I. Hanford Tank Farms SST Data

Tank Farm	Number of Tanks	Tank Capacity	Construction Date
A	6 - 100 Series	1,000,000 gal	1954-55
AX	4 – 100 Series	1,000,000 gal	1963-64
B	12 - 100 Series 4 - 200 Series	533,000 gal 55,000 gal	1943-44
BX	12 – 100 Series	533,000 gal	1946-47
BY	12 – 100 Series	758,000 gal	1948-49
C	12 - 100 Series 4 - 200 Series	533,000 gal 55,000 gal	1943-44
S	12 – 100 Series	758,000 gal	1950-51
SX	15 – 100 Series	1,000,000 gal	1953-54
T	12 - 100 Series 4 - 200 Series	533,000 gal 55,000 gal	1943-44
TX	18 – 100 Series	758,000 gal	1947-48
TY	6 – 100 Series	758,000 gal	1951-52
U	12 - 100 Series 4 - 200 Series	533,000 gal 55,000 gal	1943-44

A wide variety of chemicals and radionuclide compositions are present in the tanks from the various generations of processing facilities for the recovery of plutonium and uranium, along with laboratories and other support site support facilities. Tank chemical composition and physical composition have also been altered by various chemical processing activities within the tanks, evaporation and operational methods to promote waste volume reduction, and tank-to-tank transfers.

There are two primary waste forms stored in the SSTs - sludge and saltcake. Physical properties generally conform to the characteristics described in Table II.

Table II. SST Waste Form General Physical Characteristics

	Primary Constituents	Shear Strength	Moisture Content	Primary Particle Size	Bulk Density
Sludge	Metal Hydroxides	100 Pa – 6kPa	8 to 60% by wt.	5 micron to large agglomerates	1.4 – 2.0
Saltcake	Sodium Salts, Sodium Nitrates, Sodium Carbonates	200 Pa – 10kPa	8 to 60% by wt.	Sub-micron to large crystals	1.6 – 1.9

Table III describes the significant chemical and isotopic constituents present within the SSTs.

Table III. General SST Waste Characteristics

Analyte	Units	Minimum	Maximum
137Cs	uCi/g	2.79E-03	9.88E+02
239Pu	uCi/g	< 3.53E-06	1.67E+01
240Pu	uCi/g	< 6.70E-07	3.77E+00
90Sr	uCi/g	1.77E-04	4.07E+04
99Tc	uCi/g	1.04E-05	1.86E+00
Al	ug/g	6.32E+00	2.23E+05
Na	ug/g	6.19E+02	3.26E+05
NO2	ug/g	< 4.63E+01	1.15E+05
NO3	ug/g	< 5.89E+01	6.00E+05
PO4	ug/g	1.79E+01	2.50E+05
TOC	ug/g	4.29E+01	1.04E+05
UTOTAL	ug/g	9.19E-02	1.57E+05

Source: TWINS, Best Basis, Calculation Detail, http://twins.pnl.gov/data/datamenu.htm, queried 11/15/04. Results are Best Basis Inventory minimum and maximum sample-based concentrations for each waste phase/waste type in the SSTs.

SLUICING RETRIEVALS OF SLUDGE TANKS (C-103/C-108)

Retrieval of sludge from tanks that are believed to be sound has traditionally been performed with a system that sluices the material and transfers it from the SST being retrieved to a DST. The tank retrieval in SST C-106 deployed this type of technology between August and December 2003. The technology by itself, however, was unsuccessful at meeting retrieval targets and an oxalic acid process was added to supplement retrieval efficiency. Waste retrieval operations have begun on the next tank using this technology, C-103, and design, fabrication, and construction activities have begun on C-108. Both these tanks are being retrieved with a sluicing system similar to the C-106 retrieval design with some modifications.

The first significant modification is the use of DST supernatant as a sluicing medium rather than raw water. This modification reduces the amount of DST storage space required for the tank retrieval. The second significant modification to the system is a reduction in the complexity of the control system and the placement of as much of the hardware as possible outside the farm boundary to improve access for maintenance. Delays and expenses associated with electronic equipment failures and maintenance have been significant. These lessons learned have been applied to follow-on systems of all types.

The Modified Sluicing system with supernatant recirculation from the DST provides a relatively high waste retrieval rate. The system infrastructure includes a portable valve pit to direct the supernatant flow to one of two sluice nozzles (located on opposite sides of the tank) to more efficiently mobilize the tank waste.

Tank C-103 Retrieval

Tank C-103 was constructed during 1943 and 1944 with a nominal capacity of 530,000 gals. Approximately 72,000 gals of sludge and 5,000 gals of water were present in the tank at the beginning of sluicing operations. Due to the tank status (non-leaker designation) and waste form (sludge), C-103 retrieval utilizes the modified sluicing technology, and is designed to allow DST supernatant to be recycled and employed as the sluicing medium.

The retrieval system for Tank C-103 is installed in three existing reinforced concrete process pits that provide secondary containment for the primary transfer piping. The sluicing system consists of two sluice nozzles and a slurry pump in the tank. The sluicing system is controlled from an operator station in a trailer located outside the farm fence. The waste retrieved from Tank C-103 is then transferred to DST AN-106 where the solids are allowed to settle out and the supernatant is pumped back to the sluice nozzles. The AN-106 supernatant recirculation pump is also controlled from the same operating station.

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% (~9,900 gal.) of the waste has been successfully removed from C-103 and transferred to the DST system. The slurry pump located in the tank failed in mid-December and is currently being replaced so that retrieval operations can continue.

Tank C-108 Retrieval

The configuration of Tank C-108 is different in that there are no concrete pits and only a single central corrugated metal saltwell pump pit. The slurry pump will be located in the central saltwell pump pit. The C-108 sluice nozzles will be installed in new riser extensions and above ground metal pits that house the equipment and provide secondary containment in case of a leak from a pipe or connection. Tank C-108 waste retrieval equipment design and construction is underway, with retrieval operations planned for fiscal year 2007.

MODIFIED SLUICING RETRIEVALS OF SALTCAKE TANKS (S-102/S-112)

Saltcake waste forms represent some different challenges from sludge waste forms in both physical and chemical characteristics. Salt based retrieval systems focus on mobilizing the soluble salts by dissolving them rather than relying on the physical force from sluice water to move waste towards the retrieval pump intake. However, it should be noted that there are no pure saltcake (i.e., soluble waste) or sludge (i.e., insoluble waste) tanks at Hanford. All tanks have a mixture of waste forms at varying degrees. There are also variations in the solubility of different forms of saltcake. Tank S-112 had a higher percentage of saltcake and was the selected tank for the performance of a Saltcake Dissolution Technology Demonstration. Tank S-102 has a mixture of soluble salts (white saltcake), moderately soluble salts (black saltcake), and insoluble sludge. The saltcake dissolution and sluicing technology is referred to as a modified sluicing method. Modified sluicing in a saltcake tank versus a sludge tank differs only in the manner in which the waste responds to the sluicing. Generally in a saltcake tank, soaking for a period of a few days to a few weeks can improve retrieval efficiencies. This soaking may have little impact in a sludge tank. Retrieval of waste from a saltcake tank involves various water introduction and management devices, along with a progressive cavity pump for waste removal. Water is introduced to the tank through various sources and allowed to soak in the tank for a period of time. Limiting liquid levels in the tank to below past practice levels is one requirement agreed to with regulatory agencies to minimize the potential for a leak. Control of the specific gravity of the waste is used to optimize the waste retrieval efficiency and minimize the volume of liquid that must be sent to and stored in the DSTs.

Tank S-112 Saltcake Dissolution Operational Performance

The retrieval system was operated in Tank S-112 between September 2003 and May 2005 and removed over 96% of the waste. The overall volumetric system efficiency has been better than planned, as shown in Figure 1. The chart does show, however, as the technology reached the limits of capability that the overall waste efficiency dropped significantly and is slightly behind planned removal rates. At that time, discussions with the Washington State Department of Ecology led to declaration that the technology had truly met the limits of technology and the saltcake dissolution demonstration was completed.

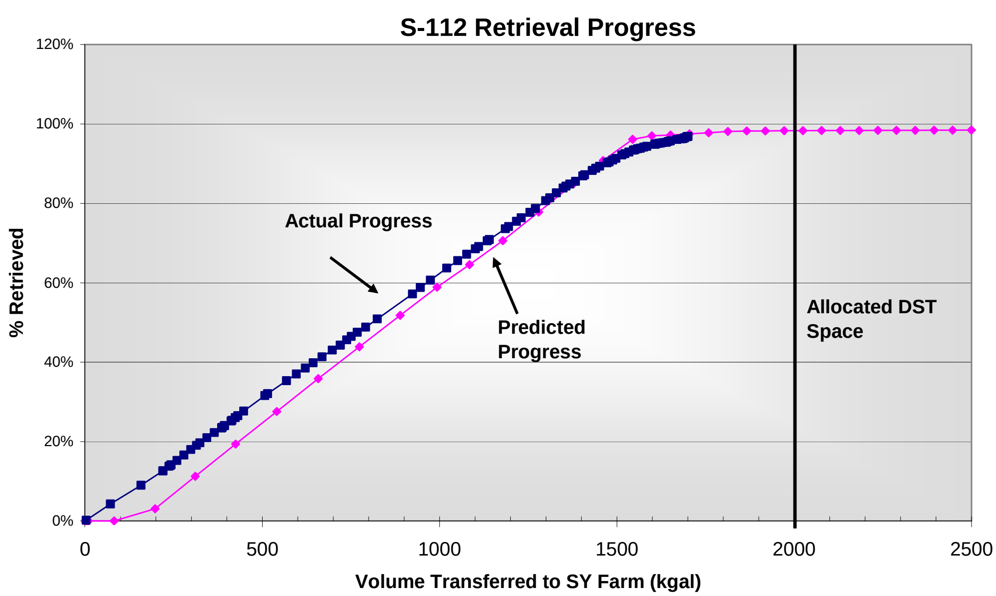

Fig. 1. Chart of Tank S-112 volumetric efficiency using saltcake dissolution.

Several factors play into this volumetric efficiency:

- The rate of retrieval of waste from S-112 was somewhat slower than predicted. The original assumption was that the process would be limited by the ability to add and remove water from the tank. In practice, after the first 30% 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.

Overall progress from an operational perspective has been farther from plan than the volumetric efficiency of the system. Figure 2 shows operational progress and the extended duration of retrieval operations.

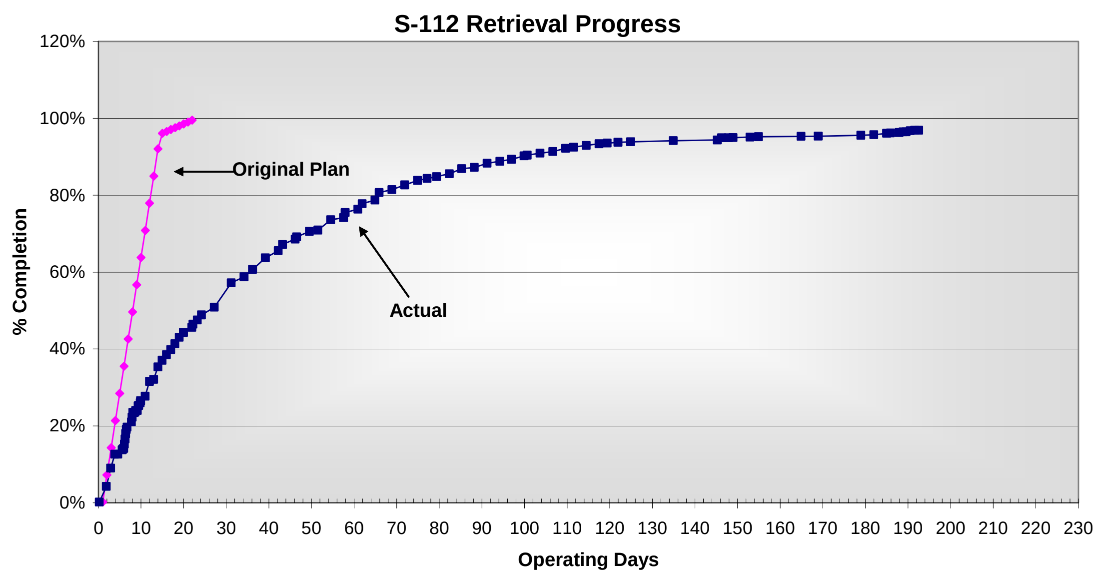

Fig. 2. Chart of Tank S-112 operational efficiency using saltcake dissolution.

The following are the overall operational implications that contributed to this performance:

- 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 that removed layers of waste across the tank. This allows greater waste contact time and yielded a higher specific gravity, thereby reducing the waste volume generated.
- Multiple and moveable discharge points for re-circulated waste within the SST would have improved the dissolution of waste. The S-112 system had a single re-circulation 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 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.
- 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.

Tank S-112 Saltcake Dissolution Lessons Learned

The significant drop in efficiency of the S-112 retrieval led to a review this fall to determine if the technology had reached its limits of application. A prolonged soak of the tank (over a month) with 50,000 gal of water including recirculation activities, led to a minimal rise in specific gravity. The salt in Tank S-112 has sat largely undisturbed for over 20 years. During this time, the temperature difference between the center of the tank and the walls drove a slow re-crystallization of the salt at the cold interface. This has resulted in a very dense monolithic layer at the bottom of the tank, which does not respond readily to the sluicing retrieval method. Engineering calculations were performed based on this retrieval experience and it was determined that up to a year of additional operations would be required with these limited dissolution rates to achieve retrieval targets for the tank. In addition, the amount of waste generated to be sent to DSTs would be significantly above the allotted volume in the already taxed DST system. The decision was made to discontinue the use of the modified sluicing system on its own with a residual of 29,000 gal of hard heel, which will have to be retrieved by alternative methods.

Tank S-112 Remote Water Lance Rapid Demonstration Project

The S-112 Remote Water Lance Rapid Demonstration was initiated to determine if high pressure water lancing applied in proximity to the waste surface would be effective in breaking up or dissolving the remaining hardened waste in S-112. A remote water lance device has been developed that is known as the "Salt Mantis" and is designed to water lance submerged under water at approximately 35,000 psi. The purpose of the demonstration is to deploy the system in real tank environments to determine: operability, lifespan of the critical Salt Mantis components, effectiveness in breaking up/dissolving saltcake heel, and overall technology performance.

The ongoing Salt Mantis demonstration began in the summer of 2005 when training was performed at the Hanford Cold Test Facility prior to being installed in SST S-112. The Salt Mantis was installed in S-112 on November 17, 2005 and demonstration operations were commenced on November 18 and continue through the present. Table IV shows the performance data collected to date.

Table IV. Remote Water Lance Performance Data

Date	Volume Transferred	Waste retrieved	Average density	Efficiency
11/18/2005	5,833	1425	1.21	24.4%
11/21/2005	5,868	806	1.12	13.7%
11/22/2005	0	0		
11/23/2005	0	0		
11/29/2005	18083	2213	1.11	12.2%
11/30/2005	11360	758	1.06	6.7%
12/12/2005	0	0		
12/13/2005	5930	437	1.07	7.4%
12/14/2005	4058	1193	1.25	29.4%
12/15/2005	0	0		
12/16/2005	6275	1586	1.21	25.3%
12/19/2005	3931	935	1.20	23.8%
12/20/2005	0	0		
12/22/2005	9761	2447	1.21	25.1%
1/3/2006	1238	68	1.05	5.5%
1/4/2006	9874	2123	1.18	21.5%
1/5/2006	6633	1275	1.17	19.2%
1/6/2006	7641	587	1.07	7.7%
1/9/2006	3632	301	1.07	8.3%
1/10/2006	7208	977	1.12	13.6%
1/11/2006	5391	571	1.09	10.6%

As of January 11, 2006, 100% of the hard heel waste has been broken up and 61% of the residual waste has been retrieved to the DST system.

Remote Water Lance Lessons Learned

Several lessons learned have been identified during the demonstration at the Cold Test Facility and in S-112. These include:

- Testing in a clean area such as the Hanford Cold Test Facility proved invaluable. Engineering and Quality Assurance were able to perform their evaluations in a hands-on environment. The construction crew was able to practice installing and removing the system in a credible tank environment. The operations crew was able to learn operations issues and practice conduct of ops in a safe environment.
- Material compatibility and load paths need to be evaluated and resolved early in the project.
- The Salt Mantis was more efficient at breaking up hard-heel saltcake simulant and S-112 waste while submerged underwater.
- The functional life of the Salt Mantis is a major issue due to minimal ability to perform maintenance on the system without significant ALARA (As Low As Reasonably

Achievable) considerations. Nozzle materials and construction are currently under review to determine how to maximize the life span of the equipment without any maintenance.

- Camera placement and lighting in the tank affects the ability to navigate around obstructions.
- The Salt Mantis has been very effective at breaking up hard-heel waste, and moderately effective at mobilizing insoluble wastes to the pump intake.

Tank S-102 Retrieval

Tank S-102 is a 100 series SST located in S-Farm in the 200 West Area of the Central Plateau. Nearly 440,000 gal of Sludge and saltcake were contained in the tank at the start of retrieval. Tank S-102 represented a different challenge than Tank S-112 on two fronts: 1) this tank has a large inventory (~35,000 gal) of sludge below the saltcake and 2) the saltcake is in two layers, the top layer is largely sodium nitrate salt, which dissolves readily in water, and the lower layer is a sodium fluoride phosphate salt, which has a low solubility in water. These layers were called the white and black salt layers respectively. The black salt and sludge have very different physical properties than the white salt. Black salt and sludge appears to have a much smaller particle size and to behave in many ways like pond mud. As such, they do not dissolve or suspend readily and flow as a thick mud under pressure. The small particle size results in the water not being able to flow easily through the waste to the transfer pump. However, the potential impacts of these differences were not well understood when the system was designed and installed.

In December 2004, operations began using the original progressive cavity pump. The retrieval team was unable to sustain pumping from this pump due to screen plugging. Many attempts were made to jump-start the pumping, including back-flushes, nitrogen and air sparging, and adjusting the pump height. The attempts failed to work. A second variable height pump was installed in S-102 to allow the retrieval of waste from the top down. The production from this pump was markedly improved and retrieval operations could be sustained over time.

Operations began in December 2004 and volumetric efficiency is shown in Figure 3.

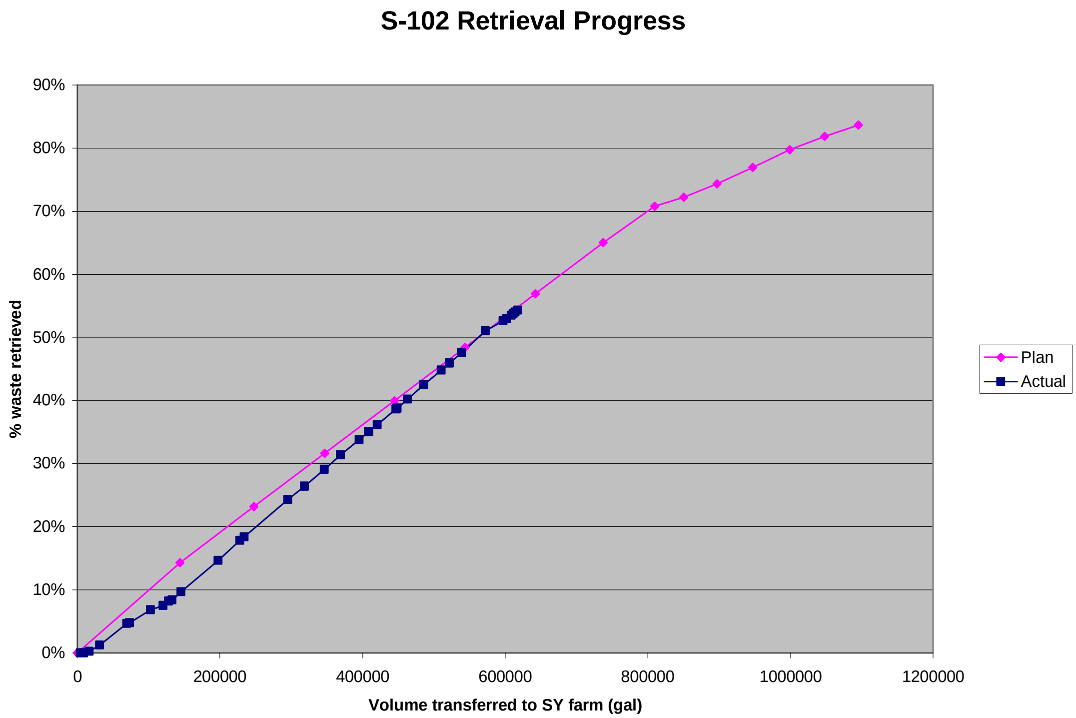

Fig. 3. Chart of Tank S-102 volumetric efficiency.

Figure 3 shows that the adjustable height pump using a “layered” top-down pumping strategy performed within anticipated efficiencies.

The operational efficiency, however, was not as productive as shown in Figure 4.

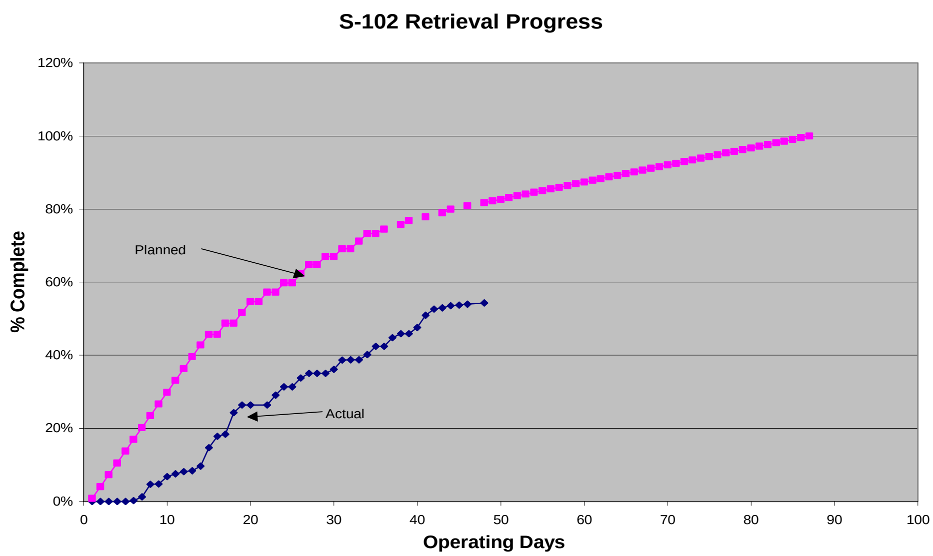

Fig. 4. Chart of Tank S-102 operational efficiency.

Several operational considerations led to delayed retrieval operations in S-102:

- The importance of tank chemistry data in determining the equipment design and the process strategy. The waste properties in 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 and flushing 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 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.

Tank S-102 Lessons Learned

Several lessons learned from S-102 have potential application on future tanks; particularly pump intake screen plugging and use of variable height pumps. The waste in this tank near the bottom (as described earlier) led to continual plugging of the intake screen on the installed pumping system. Water flushes, nitrogen sparges and air sparges were all used to allow the system to begin operation, but the production efficiency was sufficiently low that a new pumping system was installed. The screen size compared to the actual particle size seen in operation appears to have been a mismatch and it is anticipated that the original system will not be put into use until a "hole" has been mined around the pump to allow an open liquid flow pathway to the pump screen.

The new variable height pumping system was suspended from a cable mounted to a winch on the riser. This allows for operational flexibility to start at the top of the tank and work down into the main waste area. This also allows movement back up when areas exist that temporarily plug the pump and/or will maximize the ability to get near the bottom of the tank once a majority of the waste is removed. Retrieval has progressed well using this pumping system and is limited by space availability in the 200 West DSTs and operations crew availability.

VACUUM RETRIEVAL OF SLUDGE TANKS (C-201/C-202/C-203/C-204)

C-200 Series Sludge Retrieval

The two major considerations for the retrieval of the C-200 series tanks were the size of the tanks with a smaller 55,000-gal capacity and their status as assumed leaking tanks. This required a retrieval approach that minimized the amount of liquids introduced into the tank at any one time while removing a small amount of residual material. Sluicing operations are precluded due to the significant quantities of water used and their inefficiency at removing small heels. The planned leaking tank technology in general for SSTs involves a combination of an in-tank vehicle (used in 100-series tanks) with an articulating mast/vacuum retrieval system. The reach of the mast (~18 feet) combined with the smaller circumference of the 55,000-gal tank allowed the use of the vacuum retrieval system without the in-tank-vehicle to mobilize the insoluble sludge materials with minimal water addition.

One challenge for implementing this system was approval to operate within the safety basis established in the Documented Safety Analysis (DSA). Both dissolution and sluicing techniques have previously been used before in the tank farms and required only minor review/analysis. The introduction of an air moving device required some modifications to the DSA including some controls on the process.

Operational Performance of System

The system was operated from June 2004 to March 2005 to retrieve Tank C-203. Some components were then connected to Tank C-202 with retrieval operations from June to August 2005. Components were again moved and connected to Tank C-201 with retrieval operations beginning in October 2005 and are still currently under way. Operation of the system in Tank C-204 is planned for mid-2005 to complete this group of four smaller size tanks.

Tank C-203 - The pre retrieval estimate of waste contained in the tank was 2,600 gal. When retrieval completed in March 2005, approximately 3,050 gal of waste had been retrieved from Tank C-203. The total post-retrieval waste volume in SST C-203 is estimated to be 18.55 cubic feet (139 gal). Retrieval limits to meet regulatory requirements require a total residual waste volume of less than 30 cubic feet. This includes the residual waste volume on the tank bottom (both liquid and solid) at the 95% upper control limit (14.8 cu ft) plus the residual waste volume on the stiffener rings, equipment void space, and tank walls (5.11 cu ft). Using this definition, the total post-retrieval waste volume in C-203 is estimated to be 19.9 cu ft (149 gal) thus meeting the criteria of less than 30 cu ft. Overall system performance against desired end point criteria is shown in Table V.

Table V. C-203 System Performance

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

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

- Use shorter hose lengths were used between the Articulated Mast and the vacuum vessel.
- Removed sharp bends between the vacuum line and the top of the Articulated Mast.
- Performed transfer line flushes at the end of each operating day instead of after each batch.
- Reduced water usage and air injection at the vacuum head, which resulted in higher vacuum and increased retrieval rates.

These improvements led to an overall retrieval efficiency improvement from 0.05 gal waste retrieved per gal of DST waste created for Tank C-203 to 0.07 for Tank C-202. This resulted in a 34 % reduction in the DST space required for retrieval.

Tank C-201 – Tank C-201 operations used the improvements identified in both Tanks C-203 and C-202. To date, approximately 70% of the waste has been removed from C-201. A mechanical failure has led to a lack of ability to perform remote rotation of the mast. The mast is currently being moved manually to accommodate this equipment issue at the minimum overall exposure, waste generation, and operation impacts.

Overall operational efficiency for the three tanks is shown in Table VI.

Table VI. C-201 System Performance

Tank	Operating Days	Waste Removed	Waste Transferred to DSTs	Efficiency
C-203	34	3,036 gal	65,368 gal	5%
C-202	17	1,032 gal	14,575 gal	7%
C-201	4	263 gal	4,867 gal	5%

Waste retrieval operations in Tanks C-203 and C-202 were concluded when the residual waste volumes were estimated to be below 30 ft^3 (224 gal) and when falling efficiencies, as measured by drops in slurry specific gravities and gal of waste retrieved per batch, indicated that the limits of the technology had been reached. The residual waste volume in Tank C-203 is 139 gal, consisting of 100 gal on the bottom of the tank and 38 gal on the tank walls. The residual waste volume in Tank C-202 is 147 gal, consisting of 64 gal on the bottom of the tank, 38 gal on the tank walls, and 45 gal contained in equipment that remains in the tank. Wastes on the tank walls and in equipment are not accessible by the vacuum retrieval system.

C-200 Series Lessons Learned

A significant issue with this retrieval system has been the reduced efficiency of the operation from the articulating mast to the vacuum retrieval system batch tank. A combination of higher than anticipated specific gravity of the waste materials combined with long vacuum line lengths were believed to have caused these inefficiencies. A mock-up of the existing vacuum system configuration was performed at the Cold Test Facility using clear acrylic piping to observe retrieval dynamics, as well as simulating field conditions in length and elevation changes to determine if the field condition was affecting the vacuum performance. This mock-up was run first with existing system configuration to replicate conditions in the field and then with a shorter and supported (closer to level) configuration. The results were conclusive and have led to reductions in the length of the vacuum line and removal of low spots in the line.

Numerous operational and construction lessons learned have been implemented between the C-203 to C-202 to C-201 progression that have provided significant improvement in efficiency. Table VII briefly describes the significant improvements to the overall operation:

Table VII. C-200 Retrieval Duration Comparisons

	C-203	C-202	C-201
Construction	9 Months	3 Months	3 Months
Retrieval	9 Months	6 Weeks	TBD

TANK WASTE TREATMENT SYSTEM OPTIMIZATION

Optimization of the overall mission for the Office of River Protection lies in combining the capabilities of the Tank Farms facilities with those of the Waste Treatment Plant to minimize both life-cycle cost and schedule. The Tank Farms facilities are performing a number of projects and strategic initiatives to evaluate how best to support that mission. In particular, supplemental treatment of low-activity waste, potential pre-treatment options for waste outside of WTP, and in-tank activities are all being considered for their impacts on advancing the mission.

Supplemental Treatment

The Demonstration Bulk Vitrification System (DBVS) is being demonstrated to determine if it is capable of being a long-term Supplemental Treatment System for the Tank Farms, which could potentially process up to 60% of the Low-Activity Wastes (LAW). The project has progressed in the past two years from a concept to a majority of the detailed design completed, performance of an engineering scale test with real tank waste, performance of several full scale tests using simulated waste, receipt of a Research, Demonstration and Development Permit under RCRA from the State of Washington, and commencement of construction at the site. The DBVS system will be discussed in significant detail in other papers at WM’06, but the following lessons learned are intended to provide an overview of the implications of the project on the Tank Farms system.

DBVS Lessons Learned

The project shifted to a “bottoms-up” melt in the past year from the traditional “top down” that has been used in the bulk vitrification technology. In this application, a starter amount of waste is placed in the bottom of the container and the melt begins. Waste is then added in batches until the entire cavity of the container is filled. The traditional top down melt fills the cavity with waste, begins the melt at the top and progresses down to the bottom until all of the waste has been vitrified. The significant difference is that a top down container has 50% of the volume in the container unused at the end due to shrinkage of the waste volume during vitrification, while the bottoms-up uses a majority of the container space. The life-cycle cost of the containers, disposal costs, and technetium deposition led the project to pursue a bottoms-up type of approach. Potential issues that are being evaluated are increased temperature, increased duration of melt, and technetium deposition.

The DBVS progress has also confirmed another known project management concept of the use of risk management and contingency in the development of any project, particularly at technology development with relatively high risk. Implementation of this commercially used technology to a highly contaminated, higher risk environment has led to significant increase in cost than originally planned. An increased safety system, ventilation system, seismic regulatory requirements, and other factors were not originally planned into the estimated cost of the project and have shown a significant cost of the overall system.

Supplemental Pretreatment

Additional pretreatment capabilities could potentially have both positive life-cycle cost and schedule implications for the Tank Farms and WTP missions. The current Pretreatment Facility capability at the WTP represents a limiting factor for certain waste types and timeframes in the operations of the facility. Most Hanford tank wastes require solid liquid separation and cesium removal to meet regulatory requirements for immobilized low-activity waste (ILAW) waste treatment. A down-select process was performed on potential cesium removal technologies in 2004/2005 to determine the best candidate to proceed with on a laboratory and pilot scale.

Workshops held in 2002 with industry, university and national laboratory representatives identified six supplemental LAW treatment and three supplemental pretreatment technologies for pretreatment of LAW. The results of this technology review are outlined in Table VIII:

Table VIII. LAW Pretreatment Technology Evaluation

LAW Pretreatment Technologies	Evaluation
Ferrocyanide (FeCN) precipitation of Cs137 and sulfide precipitation of Tc99	• FeCN process introduces energetic reactions in the pretreated LAW • Sulfide precipitation process lacks maturity; only demonstrated with neutral leachate from mud
Avian keratin fibers to remove soluble radionuclides	• Process demonstrated at lab-sale to remove Cs from liquid simulant, however regeneration of fibers not demonstrated • Introduces excess carbon and sulfur which is detrimental to vitrification process • Process lacks technical maturity
Caustic Side Solvent Extraction	• Only separates Cs137 • Not demonstrated with Hanford LAW which contains components (e.g. K and organics) known to effect process
Fractional Crystallization	• Previously demonstrated at lab-scale with actual LAW samples • Industrial process • Will separate all soluble radionuclides from LAW

Cesium ion exchange and selective dissolution technologies are being developed separately and were not considered as part of this evaluation. Based on the results of this evaluation, a decision was made to further investigate Fractional Crystallization for potential application at the Hanford Tank Farms.

The basic Fractional Crystallization process revolves around the fact that crystals of non-radioactive salt species (particularly Sodium Nitrate) will tend to exclude foreign atoms such as cesium. The process involves a combination of evaporation under vacuum, formation of salt crystals, filtering and washing with saturated sodium nitrate solution, and repetition of the process to achieve a desired decontamination factor (DF). This process, similar in nature to industry processes used to produce pure salt and sugar, has been demonstrated in the laboratory on real Hanford Tank waste and shown to have a DF that could meet pretreatment requirements.

The target waste to be treated is either DST supernatant or retrieval liquors from SST saltcake tanks. The process would then either feed a supplemental treatment technology such as bulk vitrification or the LAW facility at WTP.

The demonstration project has been broken down into three phases with the first phase being non-radioactive stimulant work at laboratory scale, second phase of radioactive waste processing at laboratory scale, and pilot/full-scale deployment similar to the DBVS if the technology proves viable. Phase 1 is currently funded and underway. Non-radioactive stimulant laboratory work has been completed and analysis is currently underway to provide the results. In parallel, computer modeling of the process has been performed, a preliminary process flow sheet has been developed, and a Pretreatment Process Plan is in draft. Phase 2 is currently planned for fiscal year 2006 and will provide for radioactive waste laboratory work, computer modeling of the radioactive processing, and an update to the Pretreatment Process Plan.

In-Tank Activities

A system plan has been developed by the Office of River Protection to understand the overall systems engineering of the combined Tank Farms and WTP operations. This plan models the combined operation and is used as a planning tool for changes in capabilities, timing, and operational performance. Beginning in the fall of 2004, the Tank Farms performed a series of optimization studies to evaluate changes in operations and facilities that could be used to supplement the mission and reduce either life-cycle cost and/or schedule as well as reduce technical performance risk of the baseline systems. A total of 13 options were screened down to five for performance of full optimization studies. The following describes the outcome of these studies which were focused on solids: washing/leaching, strontium/transuranic pretreatment, leachate processing in supplemental treatment, waste staging alternatives, and blending of solids.

The first optimization study revolved around potential use of solids washing and leaching as a method to reduce overall high-level waste (HLW) volume. Certain constituents, particularly aluminum, chrome, and vanadium, are present in the sludge waste form that cause waste loading in the HLW glass to be less than optimal. Washing of the solids and leaching of the solids is planned in the Pretreatment Facility of WTP, but could be supplemented to optimize overall facility throughput. The study considered washing and leaching in both the DSTs or in a small new tank/processing facility at the Tank Farms, called a Waste Retrieval Facility (WRF). Modeling indicated that both options were viable with a Rough Order of Magnitude (ROM) cost of $47 million incremental for the DST option and $134 million incremental for the WRF option.

The second optimization study evaluated potential solutions to strontium and transuranic constituents that represent a challenge to the WTP in Envelope C waste types, which exist in only two DSTs. Overall, Envelope C waste pretreatment dominates the WTP ultrafilter module and limits HLW feed preparation when it is being processed. Elimination of this pinch point in HLW feed prep could shorten HLW downtime by six months with no adverse impact on HLW canister count. Precipitation of these materials from tank supernatants was reviewed and determined to be feasible at an incremental cost of $2.6 million.

The third optimization study evaluated methods to handle leachate from tank washing/leaching operations and WTP internal recycle streams, rather than using the Pretreatment Facility for these wastes. Specifically, the use of the Supplemental Treatment Plant (STP), which is baselined as bulk vitrification, was reviewed for viability in directly treating this waste stream. This was deemed not viable due to cesium loading being too high for the design shielding and treatment processing plans for the STP, with the current design and flow sheet planned for the WTP.

The fourth optimization study evaluated alternatives for waste staging to supplement both Tank Farm operations and WTP operations. The current situation is that DST space is at a premium with competing missions, including SST retrievals, efficient WTP feed batches, and potential DST in-tank pretreatment operations. The study evaluated temporary storage in sound SSTs and/or use of the grout vaults to allow optimal support to all missions. The ROM costs were estimated at $52.1 million for upgrading five SSTs (excluding tank integrity assessment work) or $59.2 million to upgrade the four existing grout vaults. Both options estimate at approximately $10 per gal of usable space.

The fifth optimization study evaluated blending alternatives both for high-hydrogen generating wastes (i.e. Tank AZ-101) and general blending of sludge wastes. The high-hydrogen generating wastes represent an anomaly from the general waste population but drive up to $100 million in HVAC improvements to the WTP to support safe processing. Blending these wastes to provide a better waste mixture also has the side benefit of lowering the design basis for the WTP and eliminate this potential $100 million upgrade over the baseline. General blending could reduce overall waste envelope variations, allow higher waste loadings per canister, and have the potential to significantly reduce overall HLW operations and associated canister count. The AZ-101 blending with SST C-102 was determined to be viable and have an incremental cost of $8.6 million. General blending was also evaluated, determined to be viable, and needs to be considered for optimizing overall operation of the WTP.

The results of these five optimization studies are currently being incorporated into the overall mission plan for the combined operations and being considered for appropriate incorporation into the baseline.

CONCLUSION

Significant progress is being made in both the retrieval and treatment of Hanford Tank Farm waste. At least three tank retrievals have been completed by the writing of this paper when the baseline in 2002 was to have only one completed. Significant progress has been made in deploying and demonstrating over seven different technologies and/or combinations in the retrieval of tank waste. Difficulties in achieving 99% of waste removed with the use of only one technology has been seen, with no 75-foot-diameter SST successfully retrieved with only one technology. Finally, design, construction and operational efficiencies are evolving from a demonstration level towards a production scale over the three years since accelerated retrieval was envisioned.