Significant Progress In The Deployment Of New Technologies For The Retrieval Of Hanford Radioactive Waste Storage Tanks - 8102

R. E. Raymond, R. A. Dodd, K. E. Carpenter, M. H. Sturges
CH2M HILL Hanford Group, Inc.
P.O. Box 1500, Richland, WA 99352

ABSTRACT

Significant enhancements in the development and deployment of new technologies for removing waste from storage tanks at the Hanford Site have resulted in accelerated progress and reduced costs for tank cleanup.

CH2M HILL Hanford Group, Inc. is the U.S. Department of Energy, Office of River Protection's prime contractor responsible for safely storing and retrieving approximately 53 million gallons of highly-radioactive and hazardous waste stored in 177 underground tanks. The waste is stored in 149 older single-shell tanks (SST) and 28 newer double-shell tanks (DST) that are grouped in 18 so-called farms near the center of the Hanford Site, located in southeastern Washington State. Tank contents include materials from years of World-War II and post –war weapons production, which account for 60 percent by volume of the nation's high-level radioactive waste.

A key strategy for improved cleanup is the development and deployment of innovative technologies, which enhance worker safety, resolve technical challenges, streamline retrieval processes, and cut project costs and durations. During the past seven years of tank cleanout projects we have encountered conditions and waste chemistry that defy conventional approaches, requiring a variety of new tools and techniques. Through the deployment of advanced technology and the creative application of resources, we are finding ways to accomplish the retrieval process safely, swiftly, and economically.

To date, retrieval operations have been completed in seven tanks, including a record six tanks in a two-year period. Retrieval operations are in progress for another three tanks.

This paper describes the following tank cleanup technologies deployed at Hanford in the past few years and being developed for future use:

- Modified sluicing, using recycled supernatant
- Vacuum retrieval
- High-pressure mixer (Rotary Viper)
- Chemical Addition
    - Oxalic acid dissolution
    - Caustic solution
- Saltcake Dissolution
- Modified sluicing using raw water

- Remote water lance
- Pulse jet mixer pumps
- Mobile retrieval tools
    - Sand Mantis
    - FoldTrack
    - Squeegee
- Mobile Retrieval System

This paper will also discuss the beneficial effect these technology deployments have had on improving safety, reducing costs, and improving the quality of waste cleanup.

INTRODUCTION

The environmental cleanup agreement at Hanford (specifically, Milestones M-45-00, M-45-03C, and M-45-13 of the *Hanford Federal Facility Agreement and Consent Order, aka Tri-Party Agreement)* sets a goal for tank waste retrieval such that retrieval must continue until the limits of technology or 360 ft^3 whichever is less. To date, seven tanks have been retrieved to meet the criteria in the *Tri-Party Agreement*. Significant progress has been made in the development of new and innovative technologies to support the mission of waste retrieval from Hanford's SSTs. The following sections contain a discussion of the existing and new technologies for waste retrieval being used or under development at Hanford.

EXISTING RETRIEVAL TECHNOLOGIES

This section provides an overview of the currently available waste retrieval technologies that have been developed for use in waste retrieval from Hanford's waste storage tanks. Available retrieval technologies are those that have been proven in the operational environment and can be readily deployed. A retrieval technology is considered feasible/viable if it could possibly remove a significant amount of additional waste from the tank.

Hanford tank waste characteristics vary by tank. The waste ranges from predominantly soluble saltcake to insoluble sludges. Several tanks are also known to contain concrete-like solid layers. Many tanks have all these present at various depths in the tanks.

Modified Sluicing Using Recycled Supernatant

The current retrievals in C Farm are using modified sluicing with recycled supernatant as the carrier fluid for insoluble waste forms. This retrieval approach does not require as much DST storage space since the carrier fluid is reused. The infrastructure requirements for a re-circulated supernatant modified sluicing system are significantly greater and more complex than systems using raw water.

Near the end of retrieval, the majority of the remaining waste in an SST is a fine granular material (sand/mud) with some larger "gravel" or "cobble" material. Hanford experience shows that, near the end of retrieval, it requires approximately one million gallons of recycled supernatant to retrieve the first 1000 gallons of waste, then one million gallons of supernatant is required to retrieve the next 500 gallons of waste.

Applying this technology to an SST requires the design, procurement, and construction of the following:

a. Replacement retrieval pump.
b. DST supernatant recirculation pump and instrumentation.
c. New demister and exhauster upgrades.
d. New Hose-in-Hose Transfer Line (HIHTL) system from the SST to the DST and from the DST to the SST. This HIHTL would require instrumentation and shielding.
e. New portable valve pit and pit manifolds.
f. New shielding.
g. New sluicers (three) with HIHTL hoses and shielding.
h. New control system.
i. New water supply system.

This retrieval technology has proven to be cost effective in that DST space requirements have been minimized due to the reuse of supernatant as a carrier fluid.

Vacuum Retrieval System (VRS)

The VRS consists of an Articulating Mast System (AMS) with a vacuum head, a vacuum pump, a slurry vessel, and a number of slurry transfer pumps. The AMS is remotely manipulated to retrieve waste from a 20-ft-diameter area on the tank floor. Vacuum pumps are used to create a vacuum to draw the waste up through the AMS and deposit the waste in the slurry vessel. From the slurry vessel, waste is pumped though an aboveground HIHTL to a DST. The AMS is composed of a hydraulically powered articulating arm with a vacuum head that can be rotated, extended, and retracted as necessary to reach within a 20-ft diameter along the tank floor.
A series of five scarifying, high-pressure, low-volume water jets, located on the outside of the vacuum head, are used to dislodge waste as needed.

A VRS system developed by Non Entry Systems Limited (NESL)[1] was deployed into the 200-Series tanks in C Farm and successfully removed waste. The VRS might have the capacity to retrieve significant SST waste volume. However, the depth of the tank (i.e., distance waste has to travel vertically up the mast) is significantly higher (required lift of almost 50 ft) and not yet tested. In addition, there are significant obstructions in SSTs that would be in the way of the arm.

High-Pressure Mixer (Rotary Viper)

The Rotary Viper is a rotating spray system mounted on a long shaft that can be inserted directly into tank waste. The Rotary Viper sprays water from nozzles at approximately 32,000 psi at a

---

[1] Non Entry Systems Ltd., Swansea, United Kingdom.

flow rate of approximately 4 to 9 gpm. The water dissolves the waste and mobilizes the waste so it can flow to a central pump for removal. The Rotary Viper can also be positioned to clean pump screens, which can become clogged with waste as retrieval progresses. Because the Rotary Viper uses low volumes of water, it helps minimize the amount of waste to be transferred to the DSTs. The Rotary Viper was tested in the Hanford Cold Test Facility (CTF) using a mixture of potter's clay, sand, and gravel, and has been deployed at SST 241-S-102.

Chemical Addition

Chemical addition would consist of adding chemicals to the tank residuals to dissolve and loosen waste. Chemical addition technology was used in SST 241-C-106 (RPP-20577, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*) and more recently in SST 241-S-112 (RPP-RPT-27406, *Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112*). The process relies on the reaction of a chemical with the residual waste to either decrease the particle size or to convert insoluble material to soluble or vapor form to decrease the residual waste material. Decreasing the particle size enables the smaller waste pieces to be more easily suspended in the liquid and pumped out of the tank.

Oxalic Acid

For SST 241-C-106 retrieval, oxalic acid was added to the tank to dissolve residual wastes and reduce particle size. Laboratory tests at the Savannah River Site and Hanford Site showed the oxalic acid was generally as effective as any other acid for dissolving the sludges in the storage tanks (RPP-17158, *Laboratory Testing of Oxalic Acid Dissolution of Tank 241-C-106 Sludge*). Oxalic acid can be used effectively on iron oxides but is not as effective on other materials. Similarly, caustic addition can be effective on alumina or silica waste forms. During the retrieval process after chemical addition, pH or density is monitored to determine when the chemical reaction has achieved diminishing returns. One disadvantage to oxalic acid chemical addition is that, following use of this technology, the waste must be neutralized which generates significant volumes of oxalate solids in the tank.

Caustic Solution

In SST 241-S-112, a 25 wt% caustic solution (NaOH) was added to dissolve waste and assist in reducing particle size. The 25 wt% caustic solution addition to SST 241-S-112 appears to have aided the retrieval efforts. Sample analysis results show that aluminum is the single largest constituent of the remaining solid waste in SST 241-S-112. Some mineral forms of aluminum are very soluble in strong caustic solutions. Other mineral forms of aluminum are very difficult to dissolve. In all cases, the dissolution is a slow process. At typical tank temperatures it might take up to six months for the reaction to complete. If a strong caustic solution (~50 wt%) were placed in the tank and allowed to digest for six months to a year, it may be possible to either dissolve or break up a significant fraction of the remaining waste. However, laboratory testing would be required to establish how effective this treatment would be.

It should be noted that this process dissolves a non-hazardous component from the remaining waste matrix. It is not clear that it would result in significant retrieval of either additional radionuclides or hazardous waste components and, therefore, may have little to no effect on the risk associated with the residual waste in the tank. It should also be noted that the process would involve the addition of a hazardous chemical to the tanks and consume additional DST space that would otherwise be available for retrieval of other SSTs and increase the final vitrified waste volume since Na is a volume limiting element for vitrification of Hanford tank waste.

Saltcake Dissolution

In saltcake dissolution, water is added to the tank through sluicers. This water dissolves nitrate and nitrite salts, which flow to a central pump for removal from the tank.

Modified sluicing using raw water

Modified sluicing uses waster through sluicers as a means to mobilize insoluble waste and push it to a central pump for removal from the tank. This retrieval approach requires a significant volume of DST storage space, most of which can be recovered using evaporation.

Remote Water Lance (RWL)

The RWL, also known as the Salt Mantis, uses a 32,000-psi water jet (ultra-high pressure water jet) on a mobile “Mantis” chassis. The Salt Mantis can be deployed through a 12–in. riser and can move or transit within the tank.   The Salt Mantis was demonstrated to be able to breakup and mobilize waste at the Hanford CTF while operating in submerged and in emerged conditions. The unit is heavy and may perform particle size reduction by running its wheels over the waste. This technology was deployed successfully in Tank 241-S-112.

DEVELOPING NEW TECHNOLOGIES

New technologies are under development that could possibly enhance retrieval performance for future tanks. A brief description of these technologies follows. The technologies discussed are at varying stages of development. Some require substantial investment in research and development while others are already used elsewhere but would need to be adapted for use at the Hanford Site.

AEA Technology Power Fluidics™[2] and Russian Pulsatile Mixer Pumps

Two innovative pumps have been developed and demonstrated. They have similar characteristics and purposes. More detailed information regarding these technologies can be found in RPP-20577.

The AEA power fluidic pump is designed for mixing and pumping tank waste up and out of tanks using vacuum and pressurization cycles to draw waste into a vessel and transfer waste up

[2] AEA Technology Power Fluidics™ is a registered trademark of AEA Technology, Glengarnock, United Kingdom.

and out through an eductor. This technology was evaluated for several years. The power fluidics pumping system was tested by the Hanford Site SST Retrieval Program to demonstrate potential for dissolution of saltcake waste and mobilization and retrieval of insoluble solids (e.g., sludge waste). Testing results indicate that the fluidic mixing and pumping system was capable of transferring waste but some of the key features needed further demonstration and refinement.

The Russian Integrated Mining and Chemical Combine fluidic concept for mixing and pumping tank waste is similar to the power fluidics system but has design details different for the pump mechanism and nozzles. While the power fluidics system has no moving parts in the pump, the Russian unit uses a simple check valve mechanism. Both systems use two distinct cycles, fill and discharge, to perform a mixing action.

Mobile Retrieval Tool (MRT)

One of the lessons learned from the past and ongoing retrievals is that it may be useful to have a technology that takes the retrieval pumping function to the waste. The MRT is such a tool. The MRT comprises three sub elements:

(1) Remote controlled platform that can navigate around the tank,
(2) Pump and transfer system that is the mechanism to move waste up and out of the tank, and
(3) If necessary, booster pumps and conditioning systems that transfer an optimized waste form to the DST system.

Mobile retrieval tools have the potential to significantly improve the quality and effectiveness of waste retrieval efforts. Reduced costs are also anticipated from better use of water and shorter retrieval efforts. Two MRT prototypes were demonstrated at the Hanford CTF in 2006. These vendor-specific MRTs are described in the following sections:

Sand Mantis – TMR Associates

The Sand Mantis[3] combines a jet-pump technology with the existing "Mantis" chassis (i.e., same body as RWL "Salt Mantis" used in SST 241-S-112). The Sand Mantis jet pump sucks up waste in the front end of the unit and passes the waste stream through a high-energy venturi powered by a 32,000-psi water jet. The waste is then sent through an umbilical cord up and out of the tank. As the waste passes through the venturi, the size of the particles is reduced. In certain conditions, an inline booster pump may be required to support transfer to a DST tank. The Sand Mantis was demonstrated to be able to pump waste up and out of an S Farm mock tank at the Hanford CTF while operating in submerged and emerged conditions. The unit is heavy and may perform particle-size reduction by running its wheels over the waste. This technology shows promise for future applications.

[3] TMR Sand Mantis is a Mantis technology of TMR Associates, Lakewood, Colorado.

FoldTrack – Non Entry Systems, Ltd.

The FoldTrack[4] has an innovative design allowing a very powerful tracked platform to be lowered through a 12-in. riser. In addition, the FoldTrack is equipped with a squeegee that can aid in pushing waste to a central location, and a spray-bar equipped with high pressure nozzles. The unit is heavy and may perform particle size reduction by running over waste. This technology is currently under advanced testing before planned deployment in Tank 241-C-109.

Squeegee

The MRTs and RWLs can be fitted with a squeegee that enables the device to push waste to a central location or to an existing retrieval pump. A prototype unit was built for use with the RWL in SST 241-S-112 but was not deployed. The performance of squeegees is unknown at this time and, therefore, development and testing is planned prior to deployment in an SST.

Mobile Retrieval System (MRS)

The MRS consists of a VRS in combination with an in-tank vehicle (ITV). A prototype was built by NESL and demonstrated at the Hanford CTF. The VRS would be installed through a riser in the tank but, due to its limited reach, it would be supplemented by an ITV that could be moved throughout the tank, breaking up and transporting waste within the range of the VRS mast. The ITV crushes and breakups waste using its tracks or wheels. After breaking up the waste, the ITV pushes the waste into the 10-ft effective radius of the VRS mast. The technology has not yet been developed or tested under these conditions (i.e., 100-Series tank with significant debris), so it is not currently available for deployment in an SST.

CONCLUSION

The development and deployment of new technologies for removal of waste from Hanford waste storage tanks has resulted in improvements in the quality and efficiency of waste retrieval. Safety has also been enhanced by extensive pre-development testing and use of remotely-operated technologies. Continued development of technology has the potential to make further improvements in quality and efficiency.

---

[4] NESL FoldTrack is a product of Non Entry Systems Ltd., Swansea, United Kingdom.

REFERENCES

89-10, Revision 7, *Hanford Federal Facility Agreement and Consent Order*, dated July 23, 2007.

D. B. BECHTOLD, G. A. COOKE, D. L. HERTING, J. C. PERSON, R. S. VISWANATH, and R. W. WARRANT, *Laboratory Testing of Oxalic Acid Dissolution of Tank 241-C-106 Sludge*, RPP-17158, Revision 0, Fluor Hanford, Richland, Washington (2003).

D. L. PARKER, *Stage II Retrieval Data Report for Single-Shell Tank 241-C-106*, Revision 1, RPP-20577, CH2M HILL Hanford Group, Inc., Richland, Washington (2007).

J. A. VOOGD, *Demonstration Retrieval Data Report for Single-Shell Tank 241-S-112*, Revision 1, RPP-RPT-27406, CH2M HILL Hanford Group, Inc., Richland, Washington (2005).