Hanford's Double-Shell Tank AY-102 Recovery Project – 17416

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ABSTRACT

Since at least August 2012, Hanford Tank 241-AY-102 (AY-102) has been leaking from its primary tank into its secondary containment. A pumping plan was developed in 2013 to provide a path forward for recommended remediation actions to be implemented as part of the AY-102 Recovery Project. On March 21, 2014, the Washington State Department of Ecology issued Administrative Order No. 10618 requiring Washington River Protection Solutions and the United States Department of Energy to conduct actions related to and including the removal of waste from AY-102. The three parties agreed to resolve the appeal of the Administrative Order through a Settlement Agreement which addresses the remaining requirements and implements enforceable milestone dates, including initiation of waste retrieval by March 4, 2016 and completion of waste retrieval operations by March 4, 2017 [1].

The AY-102 Recovery Project was developed to address the Settlement Agreement requirements. While retrieval of waste from Single-Shell Tanks has been performed at Hanford for decades, retrieval from Double-Shell Tank AY-102 required adaptation of the existing technologies to a new environment on a larger scale than previously encountered. A significant number of obstructions and in-tank equipment limit accessibility to the high source term AY-102 waste and the location of the selected receiver tank required installation of an extensive, heavily-shielded above-ground transfer line. Despite countless challenges and obstacles encountered throughout, the project successfully completed system design, fabrication, installation, testing, and the first phase of operations within a highly compressed, aggressive schedule. Waste retrieval operations in AY-102 commenced on March 3, 2016 and the initial operating phase concluded on April 30. Additional sluicing capability was required to complete the mission and four Extended Reach Sluicers were installed to support the second operating phase, which began on December 8, 2016. As of December 31, 2016, approximately 97% of the original waste volume had been removed, resulting in an estimated remaining waste volume of about 75,000 liters.

INTRODUCTION

Tank 241-AY-102 (AY-102) was the first of what would ultimately be 28 high level waste storage Double-Shell Tanks (DSTs) constructed at the Hanford Site. Construction completed in 1970 and the tank was put into service in 1971 with a designed service life of 40 years. The tank consists of a 22.9-meter diameter carbon steel primary liner with a nominal storage capacity of 3,800,000 liters inside a 24.4-meter diameter carbon steel secondary liner, which is encased by a reinforced concrete shell. The primary tank is supported by refractory concrete on the floor of the secondary liner. An annular space of 0.8 meters is formed between the primary tank and secondary liner. Figure 1 shows AY-102 at various stages during construction.

Figure 1. AY-102 Tank Construction

Tank AY-102 has a flat primary tank bottom, which differs from the dished bottom single-shell tanks that have been retrieved previously. The tank bottom is composed of primarily 9.5-millimeter thick steel plate, with the exception of a 1.2-meter diameter, 25.4-millimeter thick plate located at the center and 22.2-millimeter thick plate located along the perimeter of the tank bottom joined to the tank bottom knuckle. A small, vertical section of 22.2-millimeter thick steel plate, referred to as the bottom transition plate, is also joined to the bottom knuckle (Figure 2).

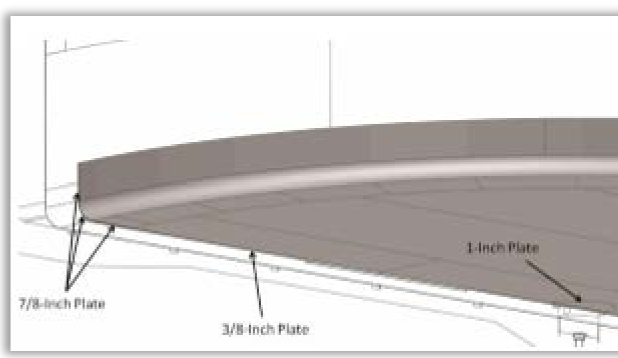

Figure 2. Primary Tank Bottom and Knuckle

The AY-102 primary tank contains a significant number of obstructions and in-tank equipment. The tank was originally designed as an aging waste tank and as a result, is equipped with 22 air lift circulators designed to reduce the potential for steam bumping by minimizing the vertical temperature gradient in the waste. The air lift circulators vary in height, but each consists of a 0.8-meter diameter casing extending to 0.8 meters above the tank bottom, as shown in Figure 3. The tank also has dry wells, drain lines, thermocouples, a steam coil, a corrosion probe, and other obstacles presenting a challenge for waste retrieval operations.

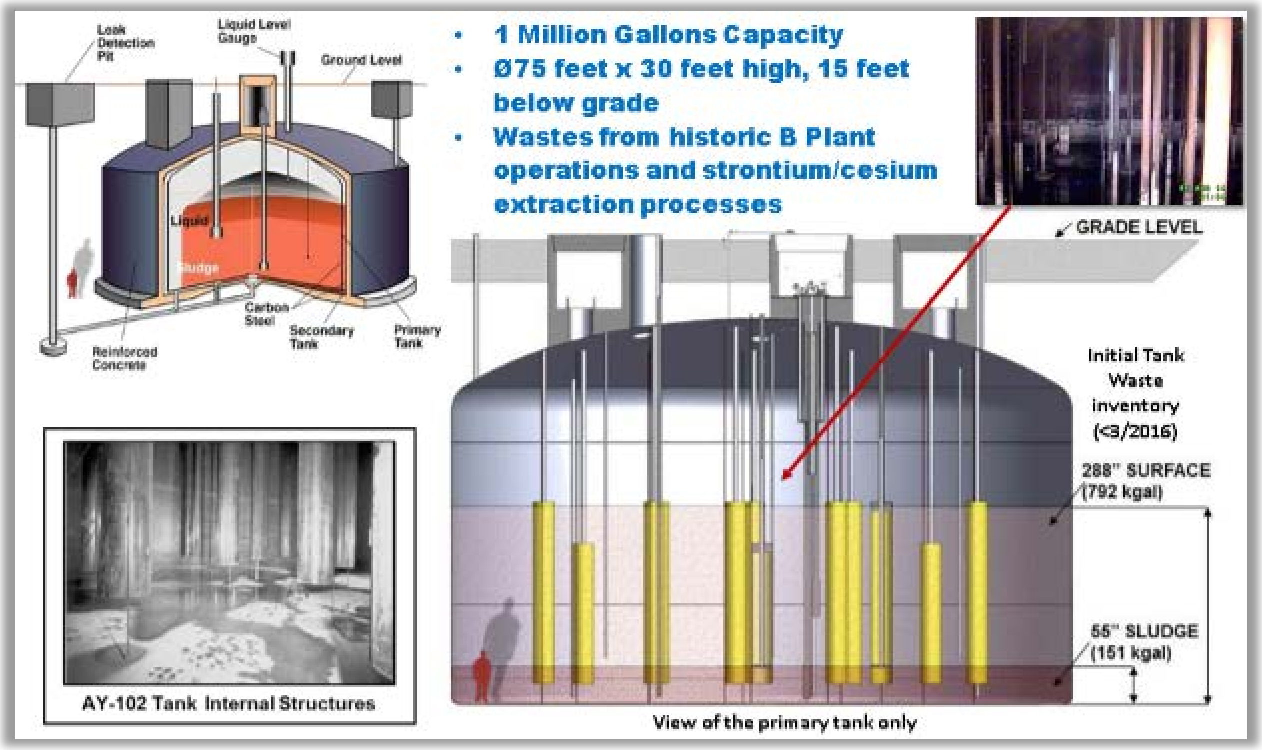

Figure 3. Tank AY-102 Overview

Tank AY-102 received waste from a variety of sources since entering service in 1971. Most notably, AY-102 served as the receiver tank for high-heat sludge waste retrieved from single-shell tank 241-C-106 in 1998-99. The AY-102 sludge was anticipated to consist of two relatively distinct layers, with the first located in the bottom 20-30 centimeters and originating from a number of transfers through the 1980s and 1990s, and the second in the remaining 109-120 centimeters consisting of sludge material that was sluiced from 241-C-106. The upper solids layer, anticipated to primarily consist of iron, aluminum, sodium, and carbonate species, was expected to be readily mobile through sluicing because it was retrieved previously. The operational history and a previous core sample suggested the lower sludge layer would contain a higher fraction of iron, uranium, and aluminum, potentially resulting in a less mobile waste form [2].

At the beginning of the project in 2012, the tank contained 2,654,000 liters of supernate waste and 572,000 liters of sludge/interstitial liquid with a radionuclide inventory consisting of 610,000 Curies Cs-137 and 4,211,000 Curies of Sr-90 contributing to a total heat load of approximately 30,000 W [3]. The heat was primarily being removed through operation of the annulus ventilation system, which directed ambient air to a distribution chamber beneath the primary tank liner, and through evaporation from the primary tank, which resulted a loss of over 9,500 liters of condensate each month.

In August 2012, an accumulation of material was discovered at two locations on the floor of the annulus that separates the primary tank from the secondary liner, and at a third location on the primary tank dome above the waterline. A formal leak assessment team was established to review the construction and operating histories, and determine whether the material found on the annulus floor resulted from a primary tank leak. There was consensus agreement among the leak assessment team members that the radioactive material on the annulus floor of Tank AY-102 was the result of waste leaking from a breach in the bottom of the primary tank. The probable leak cause was identified as corrosion at high temperatures in a tank whose waste containment margins had been reduced by construction difficulties. The comprehensive review of construction history highlighted a number of issues that were encountered and may have played a role in the tank failure, including trial-and-error repairs that left the primary tank bottom with residual stresses [2]. Of particular note, the primary tank floor plate weld rejection rate was 36 percent and weld maps showed some area being reworked as many as four times before finally passing radiography examination. As a result, the AY-102 leak integrity classification was changed from “sound” to “assumed leaker.” Figure 4 shows images inside the annulus of AY-102 from in-tank inspections performed in 2016 prior to the start of retrieval operations.

Figure 4. AY-102 Annulus Waste Accumulation[1]

On March 21, 2014, the Washington State Department of Ecology issued Administrative Order No. 10618 requiring Washington River Protection Solutions and the United States Department of Energy to conduct actions related to and including the removal of waste from AY-102 [1]. The three parties agreed to resolve the appeal of the Administrative Order through a Settlement Agreement which addresses the remaining requirements and implements enforceable milestone dates. The major commitments set forth in the Settlement Agreement include:

- Completion of design, procurement, installation, and commissioning of the retrieval system, as well as initiation of waste removal operations no later than March 4, 2016.

[1] GE (logos in Figures 4 and 16) is a registered trademark of General Electric Company Corporation, Fairfield, CT.

- Completion of waste retrieval operations no later than March 4, 2017.

DISCUSSION

Project Approach

When material was discovered in the annulus of AY-102 in August of 2012, an effort was set in motion to assess the extent of the degraded condition of the tank, and to provide for retrieving the material from the tank. The AY-102 Pumping Plan was released in June 2013 to provide a road map for all the recommended remediation actions to be implemented as part of the AY-102 Recovery Project [4]. The deadlines imposed by the Settlement Agreement constrained the project to be executed on a very aggressive schedule.

The AY-102 Retrieval Project Team was really mobilized twice. The first time was beginning in June 2013 with assembling team members, and preparing project scoping documents. This effort was suspended in late November, 2013 due to funding limitations, and as such no real progress was made towards solving this issue from November, 2013 through January, 2014. In February, 2014, funding was re-established and the project was re-started.

Within the next 24 months, all of the design, equipment fabrication, testing, field construction/installation, and readiness activities needed to be completed. To complicate the process, this retrieval effort would encounter a number of risks and challenges. The major challenges elaborated in subsequent sections include:

1. Receiver Tank Selection
2. Transfer Structure Shielding
3. Infrastructure and Equipment Upgrades
4. Availability Retrieval Equipment
5. Pump Design Updates
6. Ventilation System Capability
7. Tank Vapor Issue Evolution
8. Overall Project Execution

Execution - Overcoming Challenges

An alternatives analysis was performed to determine the most appropriate technologies to apply for mobilization and transfer of the liquid and solid waste from AY-102. The analysis selected modified sluicing and high-pressure water as the two retrieval technologies [5]. Sluicing mobilizes the solids in the tank using recycled supernate waste sprayed onto the waste through a nozzle attached to a hydraulically driven, remote-operated arm. The resulting slurry is pumped from AY-102 to the DST receiver tank and introduced through sub-surface distributor nozzles. The solid particles settle and separate from the supernate waste, which is recycled from the receiver tank to the sluicer arm in AY-102. Toward the end of retrieval operations, the remaining waste that cannot be effectively sluiced with supernate alone is typically in the form of hard, agglomerated particles. High-pressure water supplied through additional nozzles on the sluicer arm provides a motive force to reduce the size of the particles to aid continued sluicing efforts.

The AY-102 retrieval work plan specified the use of four Extended Reach Sluicers, which are capable of articulating around the various in-tank obstacles and to reach the tank bottom. Due to schedule constraints regarding procurement, fabrication, and installation of four Extended Reach Sluicers, waste retrieval commenced using two Sluice Cannons located in pits 180 degrees from one another. The Sluice Cannons were spare parts from previous C-Farm retrievals, which were refurbished for use in AY-102. While the sluicers were only capable of spraying supernate at a fixed height well-above the solid waste surface, operations were expected to be effective in mobilizing the bulk of the sludge waste based on the anticipated sludge properties.

An overview of the retrieval and transfer system is shown in Figure 5. The major elements of the retrieval and transfer system include:

- Remote-operated, hydraulically driven sluicing arms
- Variable-height, hydraulically-driven slurry and supernate pumps
- Above-ground, shielded hose-in-hose transfer lines
- In-tank cameras and lights supporting remote operation of the sluicers
- A shielded valve box housing process instrumentation and allowing the recycled supernate to be directed to each of the sluicers

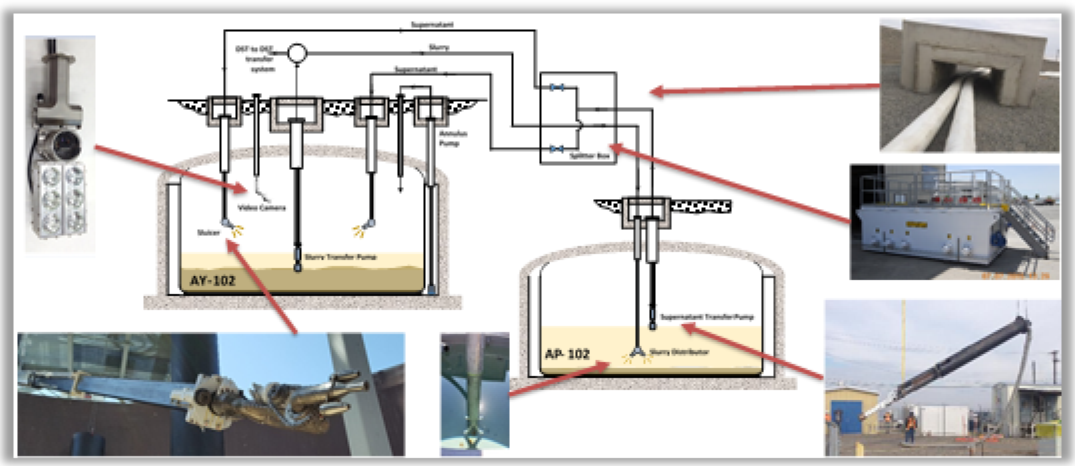

Figure 5. Retrieval Transfer System Overview

1. Receiver Tank Selection

During the early planning stages of the AY-102 Recovery Project, several potential receiver tanks were identified and evaluated [6]. While the initial preferred options included tanks in close proximity to AY-102, which would be preferable in order to limit the transfer line length and overall project cost, issues were identified regarding waste compatibility causing two nearby tanks to receive a lower rating. The initially preferred tank in the analysis was Tank 241-AY-101, residing next to AY-102. However, further analysis suggested Tank 241-AY-101 may have suffered from tank construction issues similar to AY-102, which could result in conditions susceptible to future failure. As a result, Tank 241-AP-102 (AP-102) was selected as the best option to receive waste from AY-102.

The selection of AP-102, located in the 241-AP tank farm, required installation of over 1,200 linear meters of above-ground transfer line piping. To traverse the distance between the two tanks, installation work was required near the 241-AX tank farm where heavy construction work was underway to prepare for the future retrieval of the 241-AX tanks, which required a significant integration effort to properly prioritize and safety conduct field work. Figure 6 shows a work crew digging a trench through the 241-AX tank farm for transfer line installation.

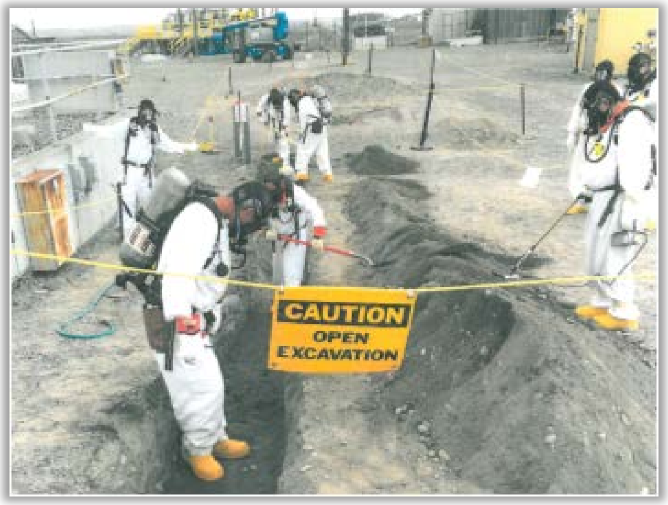

Figure 6. Trench Digging through 241-AX Tank Farm

The transfer line also required excavation through contamination areas, where the work was performed by personnel on supplied air respirators, through sandy, desert terrain, and under two Hanford Site roads, as shown in Figure 7.

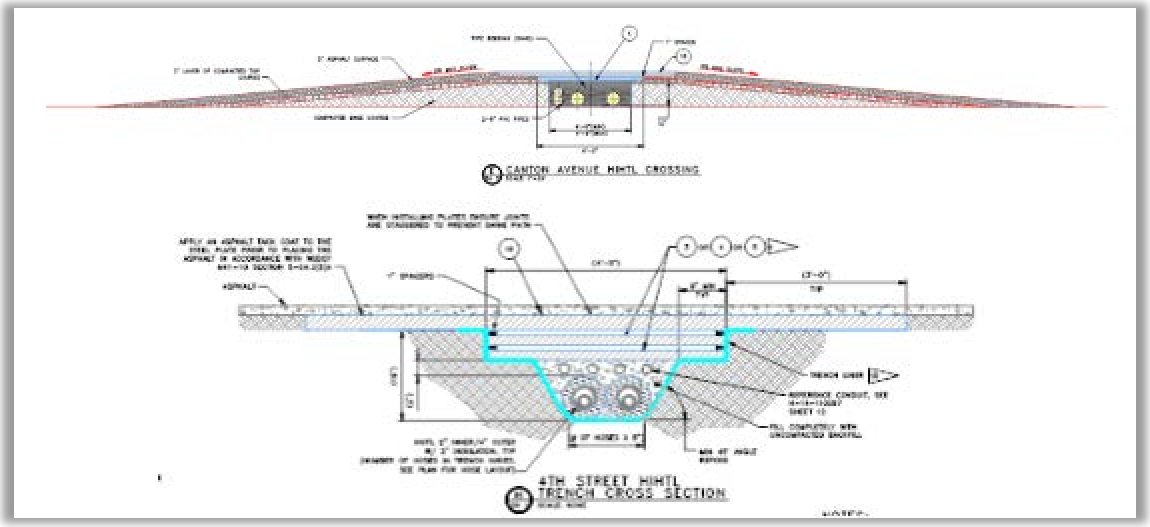

Figure 7. Canton Avenue and 4th Street Transfer Line Road Crossings

Figure 8 shows the original conceptual view the design team developed for transfer line routing, overlaid on an actual aerial photo of the completed installation.

Figure 8. Conceptual Sketch and Aerial Photo of the Waste Transfer Route

2. Transfer Structure Shielding

The high source term waste in AY-102 required extensive shielding beyond the scope of what had been done to support previous single-shell tank retrievals. When the high-heat waste was previously retrieved from tank 241-C-106, it was transferred to AY-102 through below-grade transfer line piping which utilized the soil overburden to aid in shielding. The existing infrastructure did not support using existing buried transfer line piping for continuous retrieval operation, resulting in a variety of shielding materials being necessary along the transfer route.

Where normal vehicle access would be required and digging was tolerable, the transfer line was buried to a depth of approximately 30 centimeters and covered with multiple 5-8-centimeter think steel plates, resulting in a total steel thickness of 10-15 centimeters. Where crane access was required, the transfer lines were buried, but the steel plates were required to span the trench at a greater distance to allow for the higher loads imparted by cranes. In total, over 354,000 kilograms of steel plate were procured and installed along the transfer route.

Where excavation was not feasible, hose barns were used to shield the transfer line. Lead-Antimony hose barns have been used at the Hanford Site for many years, but the higher dose rate required 5-centimeter thick units in favor of the previous 2.5-centimeter units. To accommodate the new units, the specification required modification and the vendor had to make changes in their fabrication, packing, and shipping processes. Approximately 600 5-centimeter Lead-Antimony hose barns were used to shield the transfer line. The inter-farm area between 241-AY and 241-AP farms utilized concrete hose barns as a less expensive alternative to excavation or Lead-Antimony shielding. Approximately 53 concrete hose barns measuring 0.6-meters thick and 3-meters long and weighing roughly 20,000 kilograms each were procured and installed. The logistics of contract placement, fabrication, shipping, receipt/inspection, and off-loading of these components proved challenging, but in the end, were an effective alternative. Figure 9 shows installation of the hose barns along the slurry and supernate transfer lines.

Figure 9. Lead-Antimony (left) and Concrete (right) Transfer Line Shielding Installation

3. Infrastructure and Equipment Upgrades

A large amount of tank preparation and infrastructure upgrade work was required on both tanks AY-102 and AP-102. The construction team had to perform numerous high-risk work evolutions, including 7 pit entries and refurbishment of 5 of those pits and removal of long-length equipment, which included 5 obsolete pumps in contact with tank waste. This work was necessary prior to installing new retrieval and transfer equipment. Some of the work performed is shown in Figure 10.

Figure 10. Tanks AY-102 and AP-102 Equipment Removal and Pit Refurbishment

After the preparation work was completed, installation of the long-length equipment in the refurbished pits also proved challenging. In total, two pump assemblies were installed in the AY-102 and AP-102 primary tank pits, one pump assembly was installed in the annulus of AY-102, and six sluicers were installed, including the original two Sluice Cannons for the first phase of operations and the four Extended Reach Sluicer replacements, which required subsequent removal of the Sluice Cannons. In addition, the pump pits required installation of transfer line piping and valves to direct the flow of waste. Figure 11 highlights some of the installation work performed.

Figure 11. Equipment Installation

4. Availability of Retrieval Equipment

At the outset of the project, a decision was made to utilize four Extended Reach Sluicers to support waste retrieval operations. As the design was unfolding, issues were encountered with the Extended Reach Sluicers supporting retrieval of waste from single-shell tank 241-C-111. While the issues in 241-C-111 were successfully resolved to support retrieval of waste from that tank, the resulting impact to the vendor's delivery schedule, in addition to lingering uncertainty regarding the required modifications, resulted in a direction change for the project. In an attempt to remain within the confines of the scheduled start date dictated in the Settlement Agreement, the AY-102 Recovery Project was forced to evaluated alternatives to Extended Reach Sluicers for meeting the start-date milestone.

The project identified older model spare sluicing equipment that had supported previous C-Farm retrievals available in storage. Based on the anticipated sludge waste characteristics, these Sluice Cannons (also often referred to as Standard Sluicers) were selected as the best alternative to achieve initiation of operations. The equipment was not anticipated to be capable of reaching the desired end-state for retrieval operations in AY-102, which is why it was not selected in the alternatives evaluation, but it was expected that the sluicers could remove the bulk of the high-heat sludge within the compressed schedule. Three of the units were sent to the vendor for refurbishment and ultimately two of the units were installed at AY-102 to support initiation of retrieval operations.

The impact was a course change for the design subcontractor and required re-work of the already-completed design media as well as additional high-risk field work to later remove the sluicers for replacement with Extended Reach Sluicers, as outlined previously. The impact area for the Sluice Cannons was limited due to in-tank obstacles and equipment, as well as the proximity to the waste surface. The Sluice Cannons were originally designed to be operated in C-Farm tanks, which have a tank bottom elevation difference of nearly 6 meters compared to AY-102. As a result, the

Extended Reach Sluicers were still necessary to successfully complete waste retrieval. The difference in projected coverage is shown in Figure 12.

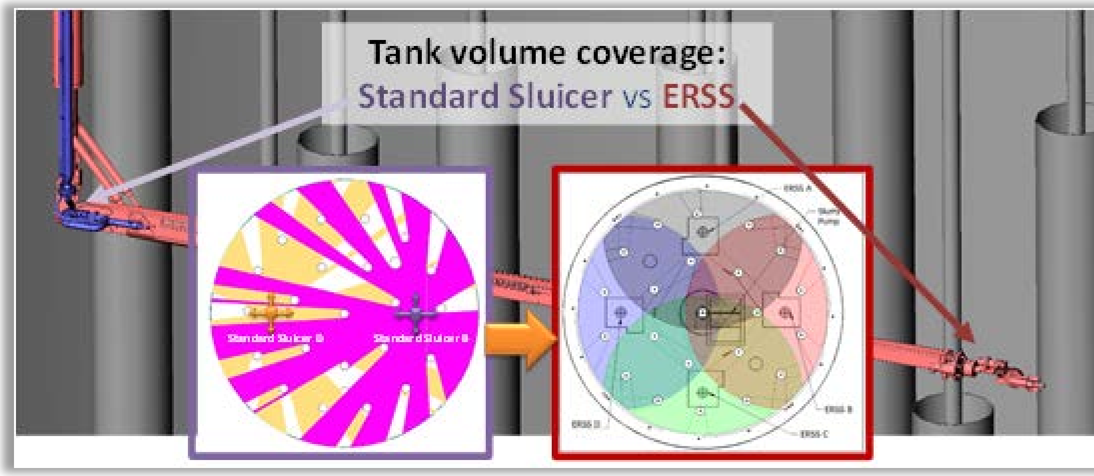

Figure 12. Sluicing Equipment Comparison

5. Pump Design Updates

Figure 13. Transfer Pump Fabrication

Equipment issues with the pre-retrieval transfer pump in AP-102 as well as technical concerns with early removal of supernate from AY-102 resulted in identification that both the slurry and supernate pumps would need to be operational with the pump assembly submerged in liquid waste. The initial AY-102 retrieval system design assumed both AY-102 and AP-102 would be in a pumped down configuration with minimal supernate waste present. The pumps utilized previously in single-shell tank retrieval operations are termed “immersible”. That is, the bottom end of the pump could be immersed in waste, but only up to the upper bearing housing, which could not be submerged due to the risk of waste permeating to the housing. The pumps procured to support AY-102 retrieval operations required redesign by the vendor to incorporate a double-mechanical seal capable of being submerged and continuously operated in a liquid depth up to 6 meters of water head. Development, testing, and implementation of the new barrier fluid reservoir system required a significant time dedication, but was successfully completed to support the project schedule. Figure 13 shows fabrication of one of the transfer pumps used for AY-102 retrieval.

6. Ventilation System Capability

Inadequate ventilation of tank AY-102 to support retrieval operations was identified as a major project risk early on. The ventilation system servicing the AY-102 primary tank also services three other nearby DSTs. Due to air in-leakage, the tanks are routinely operated near the minimum required negative pressure. With the pending installation of retrieval equipment in numerous tank risers, concerns were raised regarding the ability of the existing ventilation system to continue pulling adequate negative pressure at the start of operations. Additionally, based on high-pressure water operation experience in previous retrievals, in addition to the high temperature of the sludge waste, there were concerns that adequate tank headspace visibility may not be achieved. The risk was determined to be great enough to warrant mitigative actions to pursue an alternative ventilation system.

The AX Farm Retrieval Project included a ventilation design for two portable exhauster units to ventilate the four tanks in the 241-AX Farm. The portable exhausters were designed to operate at a flow rate considerably higher than the existing unit servicing AY-102. A decision was made to pursue installation of additional ductwork that could tie one of the exhausters into AY-102, if necessary. However, the project schedule for the portable unit required significant acceleration in order to support the Settlement Agreement milestone dates. The design and equipment procurements were fast tracked in an attempt to have the system ready for retrieval operations. In the end, the advanced schedule could not be met and retrieval operations commenced with the existing system providing ventilation to AY-102. Retrieval operations were successfully conducted without requiring alternate ventilation. As such, the tie-in work to the portable unit was shut down following initiation of operations, however the added activities necessary for carrying the design and fabrication to that point added unplanned scope to the project resources.

7. Tank Vapor Issue Evolution

Vapor protection controls were of particular concern for AY-102 retrieval operations. Odor issues were encountered during retrieval of waste from 241-C-106 to AY-102 in 1998-99. As a result, tank vapor issues were anticipated and conservative controls were implemented to support operations. In part, those controls included expanded vapor control boundaries and resulted in the majority of the retrieval operating hours being performed on weekends in order to restrict access around the tank farms without impacting other critical tank farm work. Limiting operation to weekends caused a delay in sluicing initiation as minor equipment issues encountered upon start-up often required support that could not be provided until the following weekday.

8. Overall Project Execution

The aggressive schedule imposed by the Settlement Agreement deadlines, in addition to the high degree of scrutiny and visibility, were the biggest execution challenges set upon the project. The Settlement Agreement deadlines were based upon a preliminary project roadmap with limited details regarding the technical solution to be implemented and allowed very little room for necessary contingencies to upset conditions. Expectations from the project stakeholders were high and largely based on a history of experience with single-shell tank retrievals that, while being similar in general scope, were not directly applicable to the first-time retrieval of a DST.

The project team secured the safe and timely completion of all deliverables ahead of the deadlines and under budget, thanks largely to the contribution of key subcontractors in all areas of the project (ARES Corp. for the design, AGI Manufacturing Inc., HiLine Engineering and Fabrication Inc., Riverbend Transfer Systems, Columbia Energy and Environmental Services, Mid-Columbia Engineering, Monarch Machine, for equipment fabrication, and American Electric Inc. for construction and testing). Project success was built through the implementation of the following key project management tools:

- Early and in-depth risk analysis and mitigation: Lessons learned from years of tank farm operations and input from relevant subject matter experts helped identify the biggest threats within the first two months of project execution and mitigating actions were defined and included in the project scope. In total, 67 risks were managed within the project risk register, many of which were realized, and mitigating actions significantly reduced the negative impacts.
- Detailed initial planning and schedule acceleration: The risk analysis set an ambitious target for schedule acceleration to ensure enough contingency and float would be available to absorb the impacts from potential upset conditions. Weekly meetings focused on schedule development, integration, and optimization. Within six months, the project team managed to build 71 days of float into the schedule and accomplished the critical milestone of retrieval operations start-up with only 33 hours and 45 minutes of residual float.
- Frequent and open communication with all stakeholders: Regular (monthly, weekly, and even daily) communication with the project team, internal management, external customers (United States Department of Energy – Office of River Protection), and the key stakeholder (Washington State Department of Ecology) was a critical routine for the project. Frequent, transparent communication was utilized to ensure all participants were aligned, coordinated, and focused on the right priorities, to promote the project accomplishments, to solicit feedback, and to ensure expectations were met. This strategy built trust and the collaborative support of stakeholders to the project mission was vital, as evidenced by an unprecedentedly rapid turnaround of a permit revision that would have prevented the start of retrieval.

Retrieval Operations

Through all of the challenges encountered, the project persevered and retrieval operations were initiated on March 3, 2016. Retrieval operations began removal of the AY-102 supernate waste. Approximately 2,086,000 liters of supernate waste were transferred from AY-102 to Tank 241-AW-105. The transfer was completed on March 7 through the Double-Shell Tank piping system using the newly installed retrieval slurry pump in AY-102.

Figure 14. AY-102 Sluicing Operations

Following removal of the majority of the supernate waste, sluicing operations using the Sluice Cannons commenced on March 30. As anticipated, the sludge was readily mobilized by the Sluice Cannons and despite the limited impact area of the sluice stream, a high solids loading in the slurry was maintained through the first 150 operating hours. Figure 14 shows an in-tank image of active sluicing operations. Operations were performed intermittently, primary on weekends due to expanded vapor protection controls in place. In total, approximately 304 hours of sluicing operations were performed until shutdown on

April 30, 2016 to support installation of the Extended Reach Sluicers due to a decrease in retrieval effectiveness.

The Sluice Cannons removed an estimated 428,000 liters of sludge and interstitial liquid waste, which represents removal of 75% of the original sludge and interstitial liquid volume. In total, approximately 2,661,000 liters of waste were removed from AY-102 during the initial retrieval phase, representing removal of 95% of the original waste volume, as shown graphically in Figure 15. At the completion of operations with the Sluice Cannons the total remaining waste in AY-102 was estimated at approximately 155,000 liters, which included waste accumulation in the annulus [7].

The field work to install and test the Extended Reach Sluicers completed in October 2016 and retrieval operations resumed December 8, 2016. As of December 31, 2016 the Extended Reach Sluicers had operated for over 100 hours and updated residual waste volume measurements indicated an estimated 75,000 liters of waste remained in the primary tank and annulus. Based on the flat-bottom design of the tank and the suction-break elevation for the slurry pump, it is anticipated that at least 30,000 liters of total waste will remain in the tank at the conclusion of operations.

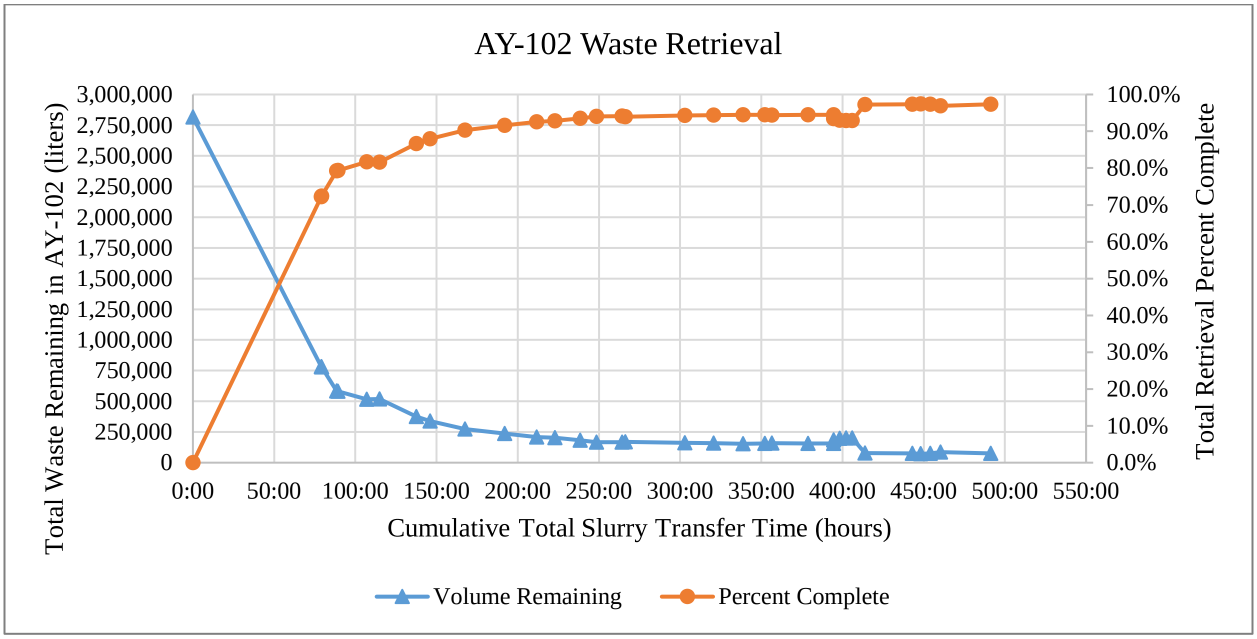

Figure 15. AY-102 Waste Retrieval Progress

While the initial retrieval phase was very successful, it was not uneventful. In the early morning hours of April 17, 2016, during normal active sluicing operations, the annulus liquid level began to increase rapidly. Exacerbation of the leak site during retrieval was recognized as a possibility and as a result, contingent actions were identified prior to operations. Those contingent actions required temporary suspension of retrieval operation to complete the final tie-in of the already-installed annulus pumping system.

Following suspension of operations, the annulus waste reached a maximum level above the refractory air slots to approximately 21.6 centimeters before gradually decreasing. The gradual decrease was attributed to absorption of liquid waste into the refractory and evaporation [8]. The annulus pumping system became operational on April 21, 2016 and was used periodically to remove liquid accumulation in the annulus during retrieval operations. In total, the annulus liquid level was pumped down 15 times during the first sluicing campaign.

During the operational shutdown to support installation of the Extended Reach Sluicer equipment, the remaining visible liquid waste heel in the annulus evaporated, exposing a layer of solid material. The solid material was sampled and is believed to consist of a mixture of sludge waste and refractory, but the sample analysis has not been completed. Figure 16 shows the progression of the annulus waste condition as observed during annulus video inspections through Riser 87. The left image shows the pre-retrieval condition on February 3, 2016, the middle image shows the condition following the initial liquid leak to the annulus as of April 20, 2016, and the right image shows the recent condition with solid material exposed as of August 9, 2016.

Figure 16. Annulus Waste Condition

Through initial operations with the Extended Reach Sluicers, the annulus level has been managed to inhibit additional solids deposition. Retrieval operations are anticipated to continue through February 2017 with a targeted milestone completion date of March 4, 2017. Following completion of retrieval operations, the final tank condition will be assessed to determine whether the leak site(s) can be inspected. The results of the inspection are expected to provide basis for determining the tank can be repaired and returned to service or should be permanently closed.

CONCLUSIONS

The AY-102 Recovery Project was developed to address requirements dictated in a Settlement Agreement, including removal of waste from the primary tank. A significant number of obstructions and in-tank equipment limited accessibility to the high source term AY-102 waste and the location of the selected receiver tank required installation of an extensive, heavily-shielded above-ground transfer line. Despite countless challenges and obstacles encountered throughout, the project successfully completed system design, fabrication, installation, testing, and the first phase of operations within a highly compressed, aggressive schedule. The project team secured the safe and timely completion of all deliverables ahead of the deadlines and under budget through early and in-depth risk analysis and mitigation, detailed initial planning and schedule acceleration, and frequent and open communication with all stakeholders. Waste retrieval operations in AY-102 commenced on March 3, 2016 and the initial operating phase concluded on April 30. Additional sluicing capability was required to complete the mission and four Extended Reach Sluicers were installed to support the second operating phase, which began on December 8, 2016. As of December 31, 2016, approximately 97% of the original waste volume had been removed, resulting in an estimated remaining waste volume of about 75,000 liters.

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