Overcoming Waste Removal Challenges at Savannah River Site: A Case Study of Tank 15 – 16198

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ABSTRACT

Tank 15 is a High Level Waste Tank at the Savannah River Site containing sludge waste that had been allowed to dry due to several flaws in the primary tank wall. In order to remove the tank waste, the sludge had to first be rehydrated. Due to the age of Tank 15 and the thirty years of "dry sludge tank" status, there were numerous technical challenges and risks that had to be addressed to demonstrate operational readiness to add liquid to a tank with known flaws. Liquid management was a key to readiness since Tank 15 did not have the infrastructure to mitigate waste accumulating in the annulus or to transfer waste out of the primary tank as a means to control a large leak.

The project team's fundamental expectation was that some amount of liquid would migrate to the annulus through identified flaws as the sludge waste was rehydrated. Communication was crucial to ensuring this expectation was propagated to management, the customer, and the regulators. Equipment upgrades, provisions for annulus liquid management (monitoring and removal), and readiness for outgoing transfers mitigated waste migration. Liquid addition methodology and facility modifications were developed to safely rehydrate the sludge while monitoring the integrity of the primary tank. These efforts culminated in successfully adding 697 m^3 (184,000 gal) of liquid to Tank 15, rehydrating the sludge waste.

INTRODUCTION

Tank 15 is one of four Type II High Level Waste Tanks at the Savannah River Site (SRS). Type II waste tanks were assembled in the late 1950s without stress relieving the welds, which resulted in heat affected zones around the welds that are prone to stress corrosion cracking. Type II tanks also include a 1.5 m (5 ft) tall annulus pan around the tank exterior for containing waste should it leak from the primary tank and prevent it from reaching the environment.[1] Because of the lack of full secondary containment, these tanks are classified as non-compliant waste tanks, as defined by South Carolina Department of Health and Environmental Control (SCDHEC), and are given a high priority for tank closure.

Each of the Type II tanks has documented flaws and three have leaked into the annulus at some time during their operational life. Tank 15 had twenty known leak sites ranging from 0.76 m (30 in) above the tank floor to 5.1 m (200 in) above the tank floor.[2] In the late 1980s, the decision was made to allow Tank 15 to dry, preventing further waste migration to the annulus. The dried sludge volume is estimated to be 708 m^3 (187,000 gal).[3]

When the Tank Farm Documented Safety Analysis (DSA) was developed, a dry tank containing sludge required additional controls due to the higher potential for aerosolization of the dried sludge and the potential for release of radiological contamination.[4] In order to prepare Tank 15 for closure, the sludge must be rehydrated and removed from the tank via mechanical mixing and simultaneous transfer to another location. Due to the age of Tank 15 and the thirty years of "dry sludge tank" status, there were numerous technical challenges and risks that had to be addressed to demonstrate operational readiness to add liquid to a tank with known flaws. Recent events in the Department of Energy Environmental Management Complex heightened the sensitivity of leaking waste tanks.

Prior to allowing the tank to dry, waste removal campaigns were performed in Tank 15. Only two standard slurry pumps were used, resulting in a sludge layer that is sloped from 1.8 m (70 in) in the north half of the tank down to 0.66 m (26 in) in the south half. A fixed length transfer pump was installed on the south side of the tank for this campaign, which transferred sludge slurry from Tank 15, through an above grade transfer line to the tank farm waste transfer system.[5] Some years after the installation of the mixing and transfer equipment and the ensuing waste removal campaign, the dry tank controls were implemented via the DSA implementation, which rendered the mixing and transfer equipment unusable because of the lack of required controls for operation. This included the above grade transfer line because it could not be leak tested or qualified to survive a seismic event. This paper discusses the various challenges that had to be overcome to ensure the rehydration of the dry sludge was performed in a safe and efficient manner.

DISCUSSION

Dry Sludge Tank Controls

Accident analysis for tanks containing dry sludge predicted scenarios that could suspend/aerosolize powder-like solids. The excessive addition of liquid has the potential to create aerodynamic forces that could result in resuspension and potential release of the dry sludge material. As a first level of control, a program for limiting large liquid additions was established. The program was developed to allow flexibility in controlling liquid additions to prevent the excessive liquid addition scenario, but avoided quantifiable acceptance criteria.[4]

In lieu of quantitative criteria for a maximum pressure to prevent impingement of a pressurized liquid on the sludge surface, a multi-discipline team devised a way to bound the liquid addition energy by another dry sludge aerosolization accident discussed in the DSA. That accident scenario postulated dropping of an object that impacts the surface of the dry sludge resulting in the suspension and release of sludge particles. This accident scenario was limited by the size of an object that could fall through open risers. The source term analysis showed that because the object size is limited to the diameter of the largest riser opening and the energy is limited by gravity and the height of the object when dropped, the potential release did not exceed the dose limitations for onsite workers.[4]

The primary liquid source for rewetting the tank was the inhibited water system. Inhibited Water (IW) is well water with small concentrations of sodium hydroxide and sodium nitrite to prevent corrosion in carbon steel equipment and piping systems. The IW system is a pressurized system, so a downcomer was designed to convert the pressurized flow to gravity flow prior to impacting the solids. This was accomplished by attaching an open-topped container to the end of a downcomer (pipe inserted into the tank through a tank top riser), causing the liquid to fill the container and overflow. The overflowing liquid would then fall to the liquid surface only influenced by the force of gravity (see Figure 1). The height of the open container above the sludge was kept less than 0.46 m (18 in) for two reasons: 1) to limit the fall height to much less that assumed for the dropped object accident and 2) to maintain the impacted sludge surface area less than or equal to the area of the object assumed in the accident scenario.[5]

The volume of liquid addition also required control based on the program description. The expected volume of liquid required to rewet the sludge was estimated to be 568 m^3 (150,000 gal). The addition was divided into batches limited to 95 m^3 (25,000 gal). The limited batch size further demonstrated that an excessive liquid addition would not occur.[5] In addition, the small batch size aided the demonstration of the tank integrity and limited the risk to the environment (see “Tank Integrity”).

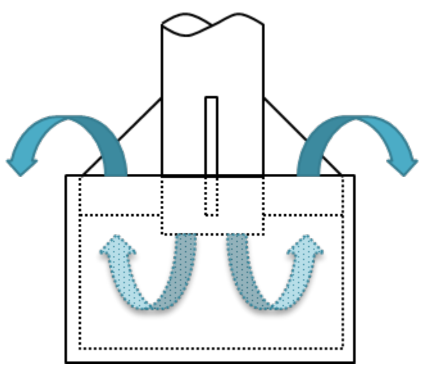

Figure 1. End of Liquid Addition Downcomer

Tank Integrity

As discussed above, Tank 15 had a history of leakage into the annulus. During the approximately 30 years the tank had been dry, regular structural monitoring was conducted. Yearly visual monitoring covered 96% of the tank wall, and selective non-destructive examination was performed every seven years. Some flaws were monitored via ultrasonic testing (UT) since 2002, while the tank was dry. UT inspection results identified that some of the flaws increased in size between the inspections; however, all growth was within expected margins (i.e. within the stress fields established in heat affected zone around the welds). Since known flaws showed some signs of growth, it was expected that new flaws could have developed, and since the tank was dry, those new flaws may not be identifiable by visual inspection. Analysis of the structural integrity monitoring data and evaluation of critical flaw lengths demonstrated that while leakage was likely to occur upon adding liquid, the tank's structure was sound based on National Codes.[1]

Liquid addition batches were limited to 95 m^3 (25,000 gal), which is less than the volume of the annulus pan. A minimum 36 hour monitoring period between batches was also implemented to allow for identification and evaluation of potential leak sites. The small batch additions allowed the tank's integrity to be verified in increments, while minimizing the risk to the environment. Small leaks could be identified and evaluated during the monitoring period (see "Liquid Management"). If a flaw leaked excessively, causing the tank's integrity to be questioned, liquid additions would be halted; however, the volume at risk would be contained in the annulus pan.[6]

Liquid Management

Since known leak sites would be submerged in order to rewet the sludge and new leak sites were expected, the project team began early during process development to communicate the expectation of primary tank leakage during and after liquid additions. With no recent history on the leak rate from the Tank 15 primary tank, liquid management was a high priority for the tank farm, the Department of Energy-Savannah River (DOE-SR), and SCDHEC. A multi-faceted approach was adopted to demonstrate that leakage from the primary into the annulus was expected to be small, yet contingency plans were established in the event leakage could not be managed by the installed equipment.

Having the expectation of liquid in the annulus, equipment and procedures were established as mitigation. A combination of installed equipment, staged equipment (ready for installation), and process limitations were used to demonstrate the eventuality of a leak could be efficiently managed. Table I provides an overview of the identification methods and mitigation techniques established for management of leaks. The DOE-SR and SCDHEC were kept engaged during the solidification of the planned leak responses and layers of mitigation included in the project scope. [6,7]

Process Limitations:

Limiting the volume of liquid addition batches (as described in "Tank Integrity") was the primary protection from excessive leakage. The small batches were added with hold times after each liquid addition for monitoring so that leaks could be identified and evaluated while ensuring the annulus could contain the potential leak volume. Operable annulus ventilation was ensured prior to each liquid addition. Leaks into the annulus are typically self-sealing. As the liquid migrates through a flaw in the primary tank, it contacts the heated air circulating in the annulus causing the liquid to evaporate. The high salt content of the waste results in the salt crystals forming as the liquid evaporates, plugging the leak site; however, humidity and the annulus air flow rate contribute significantly to the rate at which annulus evaporation is able to occur.

TABLE I. Leak Response Summary

Issue	Identification Method	Mitigation Technique
Small Leak with possible accumulation in annulus	• Visual Monitoring • Annulus Bubbler	• Use annulus ventilation to evaporate liquid and seal leak • Increase visual monitoring at leak sites, but continue liquid additions
Leak (≤DSA leak rate) with increasing level in annulus	• Visual Monitoring • Annulus Bubbler/Alarm	• Use annulus ventilation to evaporate liquid and slow & seal leak • Monitor for continued accumulation • Evaluate need for CTS deployment • Increase visual monitoring at leak sites, but continue liquid additions
Large Leak (>DSA leak rate) with increasing level in annulus	• Visual Monitoring • Annulus Bubbler/Alarm • Annulus Conductivity Probes	• Use annulus ventilation to evaporate liquid and slow leak • Monitor for continued accumulation. • Deploy CTS • Pause liquid additions • Evaluate continuation of liquid additions vs immediate transfer system installation
Excessive Leak with rapid annulus level increase	• Visual Monitoring • Annulus Bubbler/Alarm • Annulus Conductivity Probes • Radar (primary tank)	• Use annulus ventilation to evaporate liquid and slow leak • Monitor level accumulation • Deploy CTS • Stop liquid additions • Install transfer system

Equipment:

In the event of a large leak[a], a Contingency Transfer System (CTS), dedicated for use in Tank 15, was procured and staged for rapid deployment. The CTS consists of a well pump attached to a jacketed transfer hose and cable tray with adjustable

[a] The DSA assumes a worst-case leak rate based on historical data from another Type II tank, which had hundreds of documented leak sites. For the purpose of this discussion, a “large leak” is one with a leak rate exceeding the rate assumed in the DSA.

supports to maintain the slope of the hose. For Tank 15, shielding, in the form of lead blankets, is also deployed to maintain worker dose as low as practical. When deployed, the pump is lowered to the annulus floor via a tripod and winch while the transfer hose discharge is routed along the tank top back to the primary tank. The pump is powered by a portable generator.[4] This system is capable of transferring approximately 5.7 m^3/hr (25 gal/min), which is almost two orders of magnitude greater than the worst-case leak rate assumed in the DSA.[8]

Since the CTS would return waste from the annulus to the primary, the waste level in the primary tank would never decrease to a point the leak would stop. A large leak would be cause for evaluation and potentially for removing liquid from the primary tank to stop the leak. As described in “Legacy Equipment” the new transfer pump was not able to be installed prior to rewet due to contamination control and worker radiological dose concerns with removing equipment while the tank waste was dry. Readiness for liquid additions was demonstrated by completing the new transfer system design, having all materials on-hand, completing shop fabrications, and having all work packages and operating procedures approved (some procedures were awaiting final approval after field validation once equipment was installed). Discussions with the DOE-SR and SCDHEC facilitated understanding of the balance sought between personnel protection and demonstration of readiness. The ability of the CTS to continue returning waste to the primary tank at a significantly higher rate (almost 2 orders of magnitude) than the worst case historical leak prevents significant accumulation of waste in secondary containment. This aided in justification of the time required for removal of legacy equipment and installation of the new transfer system.

Monitoring:

Visual Monitoring was accomplished by installing cameras in up to three primary tank risers and a minimum of three annulus inspection ports. The primary tank and the annulus were viewed during all liquid additions and the annulus was inspected at least once each day during the monitoring period after an addition, more frequently if active leaks were observed.[9] The monitoring period of 36 hours was selected based on the time required for a puddle to accumulate and be seen by one of the three cameras if a small leak was in an inaccessible area of the annulus.

Instrumentation was also utilized for monitoring liquid levels in the primary tank and the annulus. Prior to liquid additions, a radar level detector was installed to monitor the primary tank liquid level. Monitoring the primary tank liquid level facilitated tracking the progress of liquid additions, quantification of the solids remaining in the tank, and providing yet another means of detecting an excessive leak. The tank farm DSA requires a credited alarm to protect the annulus vapor space from reaching a flammable concentration of hydrogen, which is triggered by one of two credited conductivity probes. While only one probe is required to be operational by the safety analysis, both were operational as a prerequisite to liquid additions. A bubbler and differential pressure indicator provided level indication in the annulus. An alarm was established on the bubbler to activate prior to credited conductivity probe alarm. The conductivity probes were set at 0.30 m (12 in) above the annulus floor, and the bubbler alarm was established at half that value.[6]

Ventilation:

The generation of hydrogen gas as a result of the radiolysis of water is the primary source of flammable gas in the waste tanks. Engineered and programmatic controls are in place to prevent the waste tank vapor space from reaching a flammable or explosive composition. Tank 15, while dry, had been shown to lack the potential for reaching a flammable vapor space composition when only considering atmospheric "breathing" (no forced ventilation). In preparation for liquid additions, the potential for generating hydrogen was reevaluated. Forced ventilation was shown to be required once liquid was added to the waste tank, but the ventilation system was not operable. Even if the ventilation system was repaired, additional modifications would be required to prevent a flammability hazard during waste removal activities. Since the repairs required were fairly extensive, the project team elected to perform all the necessary modifications prior to liquid additions. The modifications included repair of the steam reheater, replacement of the exhaust HEPA filter housing, replacement of the fan motor, and installation of a safety class flow indicator. The exhaust stack was also extended to mitigate anticipated high concentrations of mercury during waste removal activities, and facility experience with waste removal operations led to the installation of a demister. By implementing all modifications for waste removal prior to liquid additions, any risk associated with uncertainty in waste tank chemistry (affecting hydrogen generation rate) was mitigated because all engineered controls were available if needed.[5]

LEGACY EQUIPMENT

Preparations for the waste removal campaign described in the "INTRODUCTION" involved the installation of four slurry pump spray chambers, two slurry pumps, transfer pump, shielded valve box, and shielded above-grade transfer line. Since only two slurry pumps were used, two of the spray chambers had plugs installed and were never used. As a result, there were almost no empty risers for installing new equipment.

Thoron (radon-220) is a gaseous decay product of thorium-232. The half-life of thoron is short (56 seconds); thus, in tanks with several centimeters of liquid above the sludge, the thoron decays prior to reaching the vapor space. The decay products of thoron are particulates. When the particulates are formed in liquids, they are captured by the liquid and settle without reaching the vapor space. In tanks without adequate liquid coverage, such as Tank 15 prior to liquid additions, the thoron can reach the vapor space prior to decay, resulting in HEPA loading or contamination in huts or glove bags installed over open risers. The Tank 15H Riser 8 Dismantle and Removal (D&R) process was initiated in 2010 but stopped due to program priorities. At the point work was stopped, a riser plug that extended through a spray chamber had been removed, and the primary ventilation system was out of service. Several delays were encountered due to contamination levels in the huts as a result of thoron decay.

With the lack of primary ventilation and no liquid in Tank 15H to slow its release, thoron was able to migrate to the hut and decay, leaving its daughter products as contamination. As a result of the personnel contamination concerns, tank intrusive work (removing equipment or plugs isolating the tank vapor space) was evaluated for risk to personnel and for necessity prior to liquid additions. Only critical scope was undertaken prior to liquid additions (ventilation modifications and installations of the liquid addition downcomer and the radar level indicator). Scope that would be needed if the tank leaked (e.g. the transfer system) was completed as far as practical without opening the tank vapor space. As an example, the transfer system design was completed, and all materials were ordered and received. Work packages for all D&R and installation field work were developed and approved. Even the operating procedures for transferring out of Tank 15 were developed so that the implementation duration was as short as possible.[6]

LIQUID ADDITIONS

Upon completion of a readiness assessment, liquid additions commenced for rehydrating the sludge in Tank 15. The expected volume of liquid required to rewet the sludge was estimated to be between 326 m^3 (86,000 gal) and 757 m^3 (200,000 gal) with a best estimate of 568 m^3 (150,000 gal). The wide estimate range was due to the sloped topography of the sludge and the unknown interstitial void space volume. The sludge was covered with liquid and the sludge was declared to be rewet after 697 m^3 (184,000 gal) of liquid had been added to Tank 15.[10] Known leak sites reactivated near the end of the liquid additions; however, the leak rate was extremely small. Visual monitoring of the tank wall also identified four new leak sites as condensation wept through the flaws located above the liquid level.[11] Only one of the newly discovered leak sites is currently below the liquid level. As expected, however, continued use of annulus ventilation resulted in sealing a majority of the leak sites. Figure 2 shows a known leak site (a) before liquid additions, then (b) after a leak formed and plugged with salt. The leak rate has slowed to the point that the seepage evaporates before reaching the annulus pan for those sites that have not been completely sealed. The CTS was never deployed.

With the sludge covered by liquid, the thoron gas generation is minimal, so legacy equipment removal has begun in earnest. A total of 4 mixing pumps and a telescoping submersible transfer pump will be installed to support waste removal efforts in Tank 15.

Figure 2. Known Leak Site Before and After Liquid Additions

CONCLUSIONS

Development of an operating strategy that incorporated safety controls, reasonable process limitations and equipment modifications were necessary to successfully complete sludge rewetting in Tank 15. Assessing the benefits and risks of field work promoted a defendable strategy for holding the implementation of some modifications until after liquid additions when risks to personnel were lower. Concurrently, provisions for rapid installation and operation of those modifications, should they be needed, were brought to an advanced stage of readiness as a contingency. Communicating expectations for tank leaks within the company, with the DOE-SR, and with SCDHEC prior to declaring readiness for liquid additions facilitated understanding and agreement of the multiple layers of leak mitigation available and the state of readiness of each layer. Although several leak sites were reactivated and four new leak sites were discovered, the expectations established in advance allowed additions to be completed with no delays. In the end, 697 m^3 (184,000 gal) of liquid were successfully added to Tank 15. With the sludge covered by liquid, legacy equipment removal has begun in preparation for waste removal efforts.

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