Discovery of the First Leaking Double-Shell Tank- Hanford Tank 241-AY-102 – 14222

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ABSTRACT

A routine video inspection of the annulus space between the primary tank and secondary liner of double-shell tank 241-AY-102 was performed in August 2012. During the inspection, unexpected material was discovered. A subsequent video inspection revealed additional unexpected material on the opposite side of the tank, none of which had been observed during inspections performed in December 2006 and January 2007. A formal leak assessment team was established to review the tank's construction and operating histories, and preparations for sampling and analysis began to determine the material's origin. A new sampling device was required to collect material from locations that were inaccessible to the available sampler. Following its design and fabrication, a mock-up test was performed for the new sampling tool to ensure its functionality and capability of performing the required tasks. Within three months of the discovery of the unexpected material, sampling tools were deployed, material was collected, and analyses were performed. Results indicated that some of the unknown material was indicative of soil, whereas the remainder was consistent with tank waste. This, along with the analyses performed by the leak assessment team on the tank's construction history, lead to the conclusion that the primary tank was leaking into the annulus. Several issues were encountered during the deployment of the samplers into the annulus. As this was the first time samples had been required from the annulus of a double-shell tank, a formal lessons learned was created concerning designing equipment for unique purposes under time constraints.

INTRODUCTION

Tank 241-AY-102 was the first double-shell tank built, and one of two buried in the 241-AY tank farm at the Hanford site. It has a 22.9 m diameter and a 3,785 m^3 capacity. The tank was designed to hold waste at a maximum temperature of 450 K. This tank was constructed in 1970 and placed into service in 1971. This tank received and transferred a variety of wastes from various plant and laboratory processes and evaporator campaigns from 1971 to 1998. Ninety-seven percent of the high-heat sludge from tank 241-C-106 was sluiced into tank 241-AY-102 between November 1998 and October 1999, accounting for a majority of the solids currently in the tank. A majority of the supernatant liquid in the tank was transferred to tanks 241-AN-106 and 241-AW-102 in December of 2006 and replaced with supernatant from tank 241-AP-101 in January 2007. The total volume of waste in this tank as of July 1, 2012 is 3,223 m^3, of which 2,652 m^3 is supernatant liquid and the remaining 571 m^3 is sludge solids and interstitial liquid [1].

During a routine video inspection through Riser 90 into the annulus area between the primary tank and secondary liner in August of 2012, material was discovered in a location that had not been observed in inspections performed in December 2006 and January 2007 [2]. The origin of these solids was unknown. Subsequent video inspections were performed through additional annulus risers around to determine if any additional unidentified solids were present around the remainder of the annulus region. A second location was identified, with solids observed on the floor of the annulus near Riser 83. Images of the unidentified solids are shown, along with their relative locations, in Fig. 1.

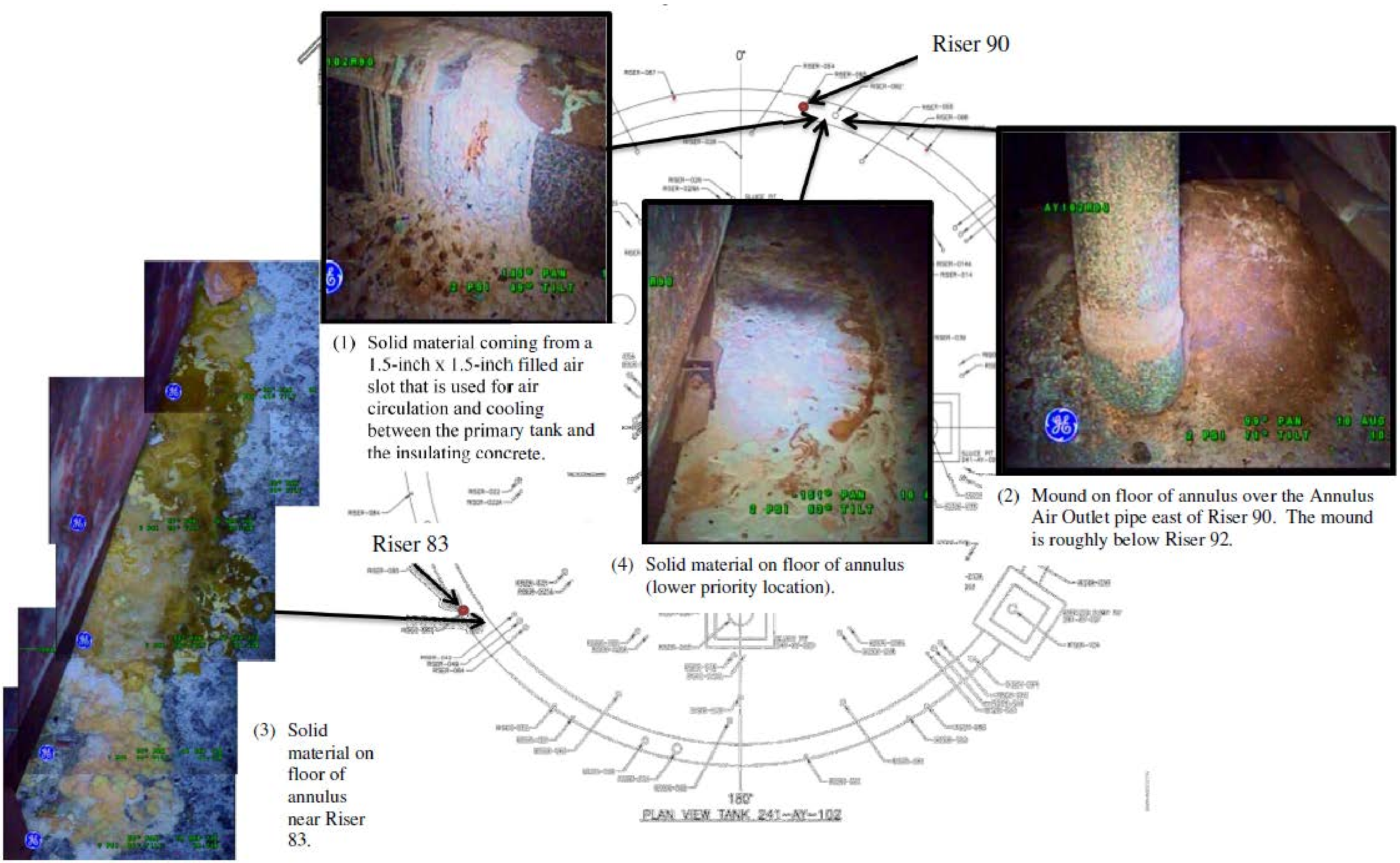


Fig. 1. Images taken of the unknown solids with arrows pointing to their general locations in the annulus on a plan view diagram of tank 241-AY-102.

The annulus Continuous Air Monitor was still operational and was not indicating elevated radiation levels within the annulus. When the camera from the inspections was recovered, it also did not indicate increased radiation above minimum contamination levels [2]. With the discovery of the unknown material at these locations, a formal leak assessment team was established consisting of individuals from Engineering, Base Operations, and Environmental Protection. The team was tasked to review the construction and operating history of tank 241-AY-102 and determine if the material could have originated from a leak from the primary tank into the annulus. Additionally, samples were requested in order to determine the unknown materials' origin [3].

As this was a first-of-its-kind task, a method for obtaining samples of the material in the annulus was needed. The Off-Riser Sampling System, shown in Fig. 2, was the only available remote sampler at the Hanford tank farms that was fit for this task. This sampler was equipped with a scoop that could obtain material off the floor, but it would not be able to obtain material from the air-slot or mound locations near Riser 90 as designed. The consistency of these materials was unknown, and the location of a majority of the material near Riser 90 was not conducive to using the Off-Riser Sampling System (Fig. 2). Therefore, a second remote sampler was required.

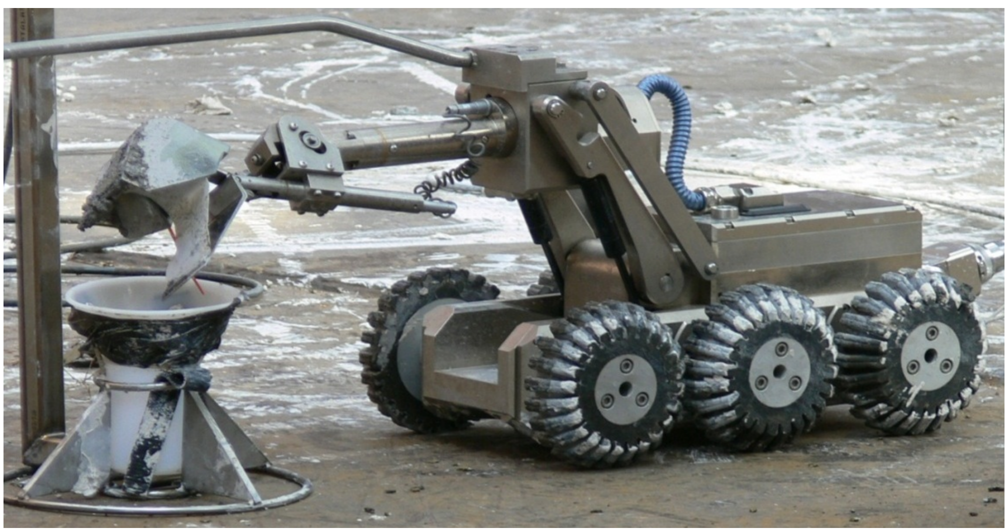


Fig. 2. The Hanford tank farms Off-Riser Sampling System.

NEW SAMPLING TOOL DEVELOPMENT

A new sampling device needed to be developed, fabricated, tested, and deployed in a short period of time to obtain samples from the unknown materials near Riser 90. This task was subcontracted out to AREVA Federal Services LLC. The new device would need to be able to fit through the available riser, maneuver within the annulus, and obtain multiple samples from the material mounded over the air inlet pipe, as well as the material originating from a refractory air-slot. This sampler would need to be able to collect and dispense the material into a sample jar retrieval device for transportation of the material to the 222-S laboratory on the Hanford site for analysis. One of the key concerns was that the consistency of the materials was unknown.

Within 10 weeks, the Remote Underground Sampler (Fig. 3) was designed, fabricated, tested, certified, and deployed into the 241-AY-102 annulus through Riser 90 to collect samples. This tool was designed by modifying off-the-shelf robotics and parts to collect potentially hard material, as the annulus materials' consistency and texture was unknown. The sampler's primary collection mechanism was an auger bit within a sleeve. A scoop was positioned underneath the end of the auger to collect any material that was not collected in the sleeve. This scoop was designed to dump material into a sample container as well as compress back toward the sampler through compression springs as the auger bit and sleeve were pushed further into the sample media. This was incorporated into the design so the bit could take a full depth sample and the scoop would not hinder its progress. Additional capabilities included an air actuated tilt and rise function for the sampler platform and a camera and light attached in order to aid the operator during its remote maneuverability.

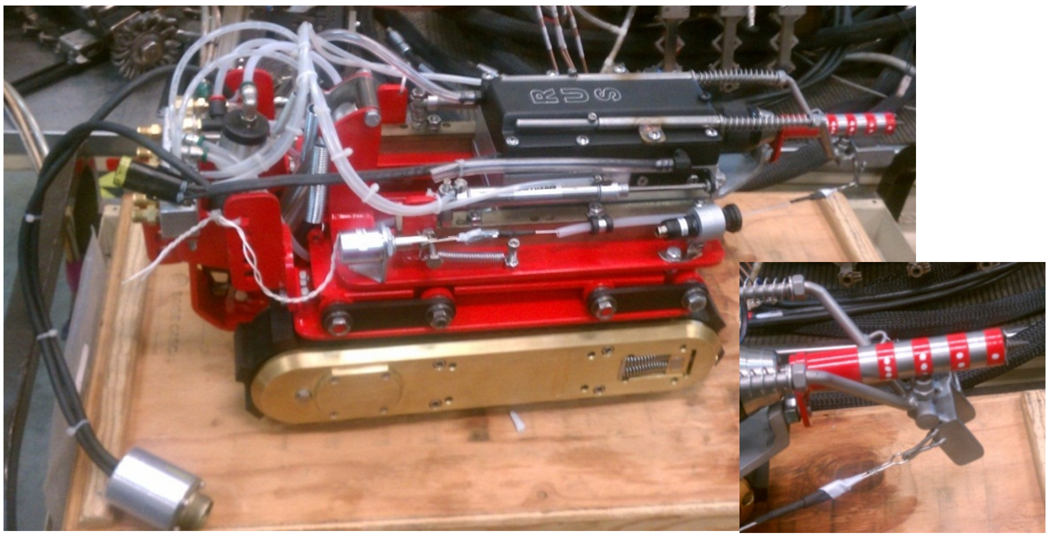


Fig. 3. The Remote Underground Sampler designed to collect material from the annulus sample locations near Riser 90.

Prior to the Remote Underground Sampler's deployment into the annulus (Fig. 3), a mock-up test was performed to ensure it was capable of performing all of the required functions. The mock-up test, performed at AREVA Federal Services LLC, included deploying the sampler through a glove bag and 0.30 m riser, maneuvering the sampler in a 0.76 m wide space using the attached and remote cameras deployed in the mocked-up riser, maneuverability in a space typical of where the "mound" was located, collecting a sample of material from a salt block at a mocked-up version of the "air-slot" location, and then depositing the material into the sample bottle for collection through the glove bag. The results of this limited mock-up testing indicated that the sampler would be capable of maneuvering within the tight annulus space and function as required.

SAMPLE COLLECTION AND RESULTS

A total of three locations were identified in the 241-AY-102 annulus for material collection in order to determine its origin [4]. The main concern was whether the primary tank was leaking waste into the annulus. The first sampling location was the material on the floor of the annulus near Riser 83. The Off-Riser Sampling System (Fig. 2) was deployed through Riser 91 since it was the closest riser that was large enough to deploy the sampler and access that sample location. In order for the sampler to get to the sample location, it would have to maneuver over three 0.10 m diameter thermocouple conduit pipes (see Fig. 4). The second sampling location was the material in the "air-slot" and "mound" near Riser 90. The Remote Underground Sampler (Fig. 3) was deployed through Riser 90 to collect samples from these two locations.

Fig. 4. Thermocouple conduit pipe located on the annulus floor between Riser 91 and Riser 83.

Samples Near Riser 83

Once deployed through Riser 91, the Off-Riser Sampling System (Fig. 2) was maneuvered over the three thermocouple conduit pipes and a sample was collected. The thermocouple conduit pipes were very difficult to maneuver over and resulted in many tumbles of the sampler and, ultimately, terminal damage to the sample scoop. One scoop of sample material was collected from this location and taken to the laboratory for analysis. Additionally, it was observed that the material at this location was wet under the dry solid surface. The sampler left wet tracks on the annulus floor after it drove through the material in an attempt to collect samples.

The 12.8-gram sample (see Fig. 5) was weighed when it was received at the laboratory [6]. Of the total mass, 6.2-grams was the yellowish-white material and the remainder was the darker material. The dark material was magnetic and was separated from the yellowish-white material to analyze separately. For the lighter colored material, analyses for anions, cations, radioisotopes, carbon analysis, pH, and solid phase characterization were performed. For the dark material, only a solid phase characterization was performed.

Fig. 5. Sample material collected from the annulus floor near Riser 83.

Results of the solid phase characterization, using Scanning Electron Microscopy (SEM), Polarized Light Microscopy (PLM), and X-ray Diffraction (XRD), indicated that the darker material was consistent with mill scale. The lighter material's solid phase characterization [7] identified sodium and potassium salts. The remaining analytical results [6] were compared to 241-AY-102 interstitial liquid and supernatants from both 2006 and 2012 to determine if the concentrations were similar to those of tank waste liquids (see Table I). Other information used to assist with the analysis of this material's origin included the visual observation of liquid at the annulus sample location that dried and re-wetted over time, the pH of the sample material (approximately pH 11 using litmus paper), and the radioactive dose rate of 45 mR/hr obtained in the field upon collection of the sample in the glove bag.

TABLE I. Comparison of analyte concentrations on a dry weight basis – Riser 83 annulus floor sample results vs. 241-AY-102 tank waste Best-Basis Inventory liquid analyte concentrations

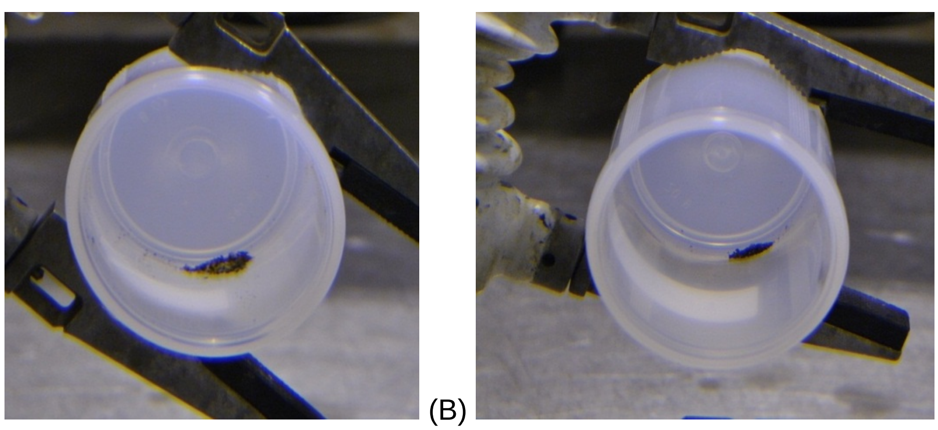
Analyte	Sample	2006 AY102 Sludge Interstitial Liquid	2006 AY102 Supernatant	2012 AY102 Sludge Interstitial Liquid	2012 AY102 Supernatant	Units
Total inorganic carbon	4.31E+04	3.97E+05	2.30E+05	3.99E+05	7.52E+04	ug/g
Cobalt-60	< 1.07E-02	2.04E-02	1.35E-02	1.19E-02	2.72E-03	uCi/g
Cesium-137	9.09E+01	1.52E+02	9.94E+01	1.36E+02	2.62E+02	uCi/g
Magnesium	< 1.43E+02	< 4.83E+00	1.94E+01	—	—	ug/g
Strontium-89/90	1.20E-01	8.39E+00	5.63E+00	7.49E+00	3.57E-01	uCi/g
Aluminum	9.28E+03	1.64E+03	5.74E+03	1.65E+03	1.51E+04	ug/g
Calcium	< 3.56E+02	< 1.66E+01	1.57E+01	< 1.66E+01	1.63E+01	ug/g
Potassium	3.90E+04	2.42E+03	1.32E+03	2.43E+03	6.92E+04	ug/g
Sodium	2.91E+05	3.39E+05	2.98E+05	3.40E+05	2.74E+05	ug/g
Fluoride	8.60E+02	3.16E+02	2.27E+02	3.17E+02	3.85E+03	ug/g
Nitrite	5.87E+04	3.49E+04	1.51E+05	3.50E+04	4.84E+03	ug/g
Nitrate	1.81E+05	1.87E+03	1.72E+03	1.87E+03	2.42E+05	ug/g
Phosphate	2.14E+03	1.89E+04	1.22E+04	1.90E+04	3.00E+03	ug/g

Samples Near Riser 90

The sampling event using the Remote Underground Sampler (Fig. 3) started off with more difficulties than expected [8]. When initially deploying the new sampling device through Riser 90 into the annulus, the sampler got stuck. The internal diameter of the riser used for deployment of the sampler was slightly smaller than expected. Although the sampler was ultimately maneuvered and fit through the annulus riser, the light and camera sustained terminal damage in the process. During the sampling of the two locations (e.g. the filled air-slot and the mound shown as locations (1) and (2) in Fig. 1) on October 15 and 17, 2012, additional functionalities were lost on the sampler leading to its terminal failure. These included the following:

- Loss of functionality of sample scoop
    - Pre-cleaning potentially removed essential lubrication for its functionality.
- Loss of raise and tilt functionality
    - The actuators that allowed these functions were only rated to 140 °F, but the environment in the annulus was potentially near or above this temperature leading to its failure.
- Loss of auger functionality
    - After taking the last sample on October 17, 2012, the auger had seized and was unable to rotate. This may have been due to a particle being lodged between the sample sleeve and the auger bit in the sleeve.

Prior to its terminal failure, two samples were obtained from both sample locations on October 15, and two additional samples were obtained on October 17. The two samples from October 15 (see Fig. 6) were very small in size (0.1-gram each) and appeared to be mostly composed of black magnetic solids. Solid phase characterization of these two samples using SEM, PLM, and XRD resulted in the identification of mostly iron oxide/hydroxide in both samples [7]. The material from the mound also identified some sodium salts (sodium nitrate, sodium nitrite, sodium carbonate) as well as soil mineral types, such as Albite and Quartz.



(A) (B)

Fig. 6. Samples collected October 15, 2012 from the mound (A) and air-slot (B) locations in the annulus near Riser 90.

The two samples collected from the mound and air-slot locations on October 17 were slightly larger in mass; 0.12-grams from the mound location and 0.2-grams from the air-slot location. Both samples (Fig. 7) appeared to contain material more consistent with that observed at their locations than the previous samples. Solid phase characterization (SEM, PLM, and XRD) was performed on both samples, with additional analyses performed on the air-slot sample due to sufficient mass. The additional analyses performed on the second air-slot sample included gamma energy analysis (GEA), inductively coupled plasma (ICP), and strontium-89/90.

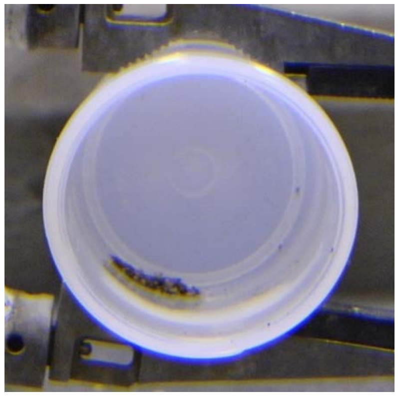
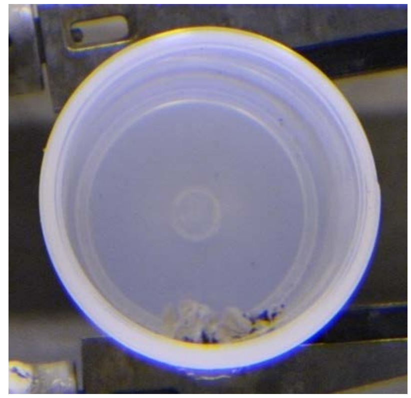
(A)  (B) 

Fig. 7. Samples collected October 17, 2012 from the mound (A) and air-slot (B) locations in the annulus near Riser 90.

Solid phase characterization of the second mound sample indicated the presence of sodium sulfate and typical Hanford soil phases, including quartz, potassium feldspar, plagioclase feldspar, and amphibole or pyroxene [7]. No other mineral or solid phases were identified on this sample and it did not have a measurable dose rate.

Analyses of the second air-slot solids identified various sodium salts (sodium nitrate, sodium nitrite, sodium carbonate, sodium phosphate, sodium fluoride phosphate, and sodium oxalate) and gibbsite [7]. Analytical results from GEA, ICP, and Strontium-89/90 [6] provided analyte concentrations (Cesium-137, Strontium-89/90, Aluminum, Potassium, and Sodium) that could be compared to those of 241-AY-102 tank waste liquids (see Table II).

TABLE II. Riser 90 annulus air-slot sample results compared to 2006 and 2012 241-AY-102 tank waste Best-Basis Inventory liquid analyte concentrations

Analyte	Sample	2006 AY102 Sludge Interstitial Liquid	2006 AY102 Supernatant	2012 AY102 Sludge Interstitial Liquid	2012 AY102 Supernatant	Units
Cesium-137	4.21E+01	1.52E+02	9.94E+01	1.36E+02	2.62E+02	uCi/g
Magnesium	< 9.26E+00	< 4.83E+00	1.94E+01	—	—	ug/g
Strontium-89/90	6.88E+00	8.39E+00	5.63E+00	7.49E+00	3.57E-01	uCi/g
Aluminum	9.06E+02	1.64E+03	5.74E+03	1.65E+03	1.51E+04	ug/g
Calcium	< 3.70E+02	< 1.66E+01	1.57E+01	< 1.66E+01	1.63E+01	ug/g
Potassium	6.04E+03	2.42E+03	1.32E+03	2.43E+03	6.92E+04	ug/g
Sodium	3.46E+05	3.39E+05	2.98E+05	3.40E+05	2.74E+05	ug/g

CONCLUSIONS

The floor sample taken under Riser 83 was found to have solid phases typical of tank waste, including the sodium and potassium salts [7]. Analytical data for this sample [6] was characteristic of 241-AY-102 interstitial liquid and supernatant (Table I). Visual inspection of this location during and after sampling indicated the area was moist, with the sampler creating tracks during sampling activities that dried over time [5]. The quick pH test of this material using pH test paper with 1 mg solid sample and a couple drops of water estimated the pH at approximately 11, which was consistent with caustic tank waste. Finally, the sample had a measurable dose rate of 45 mR/hr window open upon collection of the material out of the tank riser in the field [6]. The assessment team was led to the conclusion that this material's origin was tank waste.

Of the material collected under Riser 90, the air-slot sample had both solid phases and analytical data [6] characteristic of 241-AY-102 interstitial liquid and supernatant [5]. The solid phases included sodium and potassium salts as well as gibbsite, which is a common aluminum solid phase in tank waste [7]. The analytical data [6] indicated similar concentrations when compared to 241-AY-102 supernatant and interstitial liquid concentrations (Table II). This indicated that this material's origin was most likely tank waste.

Finally, the material collected under Riser 90 from the mound indicated many solid phases characteristic of Hanford sediment in both samples, including quartz and various feldspars [7]. Since none of the other indicators were there for this to be considered tank waste, the leak assessment team identified it as probably not tank waste due to the following:

- The physical nature and apparent chemical composition of the material was clearly different from the Riser 83 floor material or the Riser 90 air-slot material.
- The outer crust was easily broken. The material beneath the crust was granular and easily broken up.
- The location of the mound was somewhat away from the annulus walls, suggesting that it was not formed by a flow of material from beneath the primary tank.
- The SEM results indicated a mixture of rust and soil with a small amount of a sodium-rich phase for the first sample. Sampling activity from both locations using the same auger and bit more than likely resulted in cross-contamination that may account for the sodium.
- The sample specimen contained no detectible beta/gamma radiation using the 222-S Laboratory room monitors.
- The material was directly under an active annulus ventilation exhaust outlet. In 1989, when the annulus ventilation system underground ductwork was replaced, both the annulus supply and exhaust duct penetrations were open to the annulus near Riser 90 for the ductwork tie-ins. Soil could have inadvertently entered the penetrations and fallen directly into the annulus

Following completion of the sample analyses and the assessment of its construction history and use, there was a consensus among the leak assessment team members that two of the three materials sampled from the annulus floor region were the result of waste leaking from a breach in the primary tank. The probable leak cause was identified as corrosion at high temperatures in a tank whose containment margins had been reduced due to construction difficulties [5].

Lessons Learned

Following the conclusion of the sampling and analysis activities, a formal Lessons Learned was created based upon designing equipment for unique purposes under time constraints [8]. This document was published in OPEXShare on May 20, 2013. It highlighted some of the issues that arose with the new sampler (Fig. 3) development and provided recommendations to prevent a recurrence should this task need to be performed again in the future. These recommendations included:

- Complete a functions and requirements document and a failure mode analysis during the initial planning stages. Re-evaluate the primary functions and failure modes as the scope and design evolves to ensure a high confidence level in the planned design and operations. Document decisions and design changes throughout the process.
- Based on the lessons learned, revise the design drawings, incorporate lessons learned, and develop a functions and requirements document in anticipation of future needs.
- Identify specific approval criteria required for testing prior to deployment.
- Integrate organizations, including identification of roles, responsibilities, authorities, and accountabilities in the initial planning stages to limit design evolution and miscommunication during the design and implementation process.
- When integrating teams from different organizations; the expectations, conduct of operations, and communications need to be well-defined to ensure efficient operations during deployment.
- Ideally, a sampler would be designed, fabricated, tested, and readily available for any type of annulus sampling that may be necessary now and in the future.

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