241-AY-102 Leak Detection Pit Drain Line Visual Inspection – 15678

Theodore Venetz *, Kayle Boomer *, Jason Engeman *, Jason Gunter *, John Garfield **, Brandon Vazquez *, Cameron Joslyn*
* Washington River Protection Solutions
** AEM Consulting, LLC

ABSTRACT

In October 2012, Washington River Protection Solutions LLC (WRPS) determined that waste had leaked into the annulus of Tank 241-AY-102. WRPS conducted an extensive review of Tank AY-102 and increased both inspection and monitoring of the tank; however, the precise cause and location of the leak could not be determined. In parallel with the leak in the primary tank, the Tank AY-102 leak detection pit (LDP) was accumulating water through the drain system external to the secondary tank liner. Liquid collecting in the LDP is suspected to be from water intrusion and collects at a rate such that the LDP must be pumped routinely. Following a routine pumping event on June 20, 2013, elevated radiation dose rates were noted on the transfer hose and surface contamination readings were found on the transfer pump when it was removed from the Tank AY-102 LDP. These two field readings suggested that tank waste from a secondary liner breach could be leaking into the LDP. As a result, WRPS initiated a plan to ascertain the integrity of the secondary tank liner including a robotic inspection of the LDP.

To perform the robotic visual inspection, a custom robotic crawler with a deployment device was designed, built, and operated by IHI Southwest for WRPS to inspect the 6 in (152 mm) leak detection pit drain line. To ensure success when deployed in the field, the inspection equipment was demonstrated at both the IHI facility in Denver, Colorado, and the Hanford Site using full scale piping mockups.

On November 20, 2013 WRPS inspected the 6 in (152 mm) diameter drain line. The deployment device successfully attached to the drain line, and the crawler entered the drain line and traversed to within approximately 7 ft (2.1 m) of the central sump located under the center of the tank before losing traction. Crawler performance was satisfactory, and the quality of the camera image and lighting provided sufficient detail to document the current condition of the visible regions of the pipe. The inspection showed that the majority of the drain line was dry. Two wet areas were observed, a portion of the line nearest the LDP and a portion near the center of the tank. The portion nearest the LDP was under water prior to pumping on November 14, 2013.

Although sediment and debris were seen during the inspection, it is believed to be construction debris and corrosion products. No material was found in the inspection that looked like tank waste or the material seen in the Tank AY-102 annulus (i.e., no greenish or yellowish deposits or dark fluids, dried salt deposits, or crystalline material). The contamination levels seen on the crawler were consistent with past values seen on LDP pumping equipment. Sampling and analysis of the recovered residues from the crawlers did not find material consistent with tank waste.

INTRODUCTION

The U. S. Department of Energy’s Hanford Site, near Richland, WA contains twenty-eight 1 million gal (3785 m^3) capacity double-shell underground waste storage tanks. The tanks are grouped in tank farms, containing from two to eight tanks. The earliest tank farm, 241-AY Tank Farm, located in the southeast portion of the 200 East Area, was completed in 1970. Tank AY-102 is one of two tanks in the 241-AY Tank Farm, and the first double-shell waste tank constructed at the Hanford Site.

The double-shell tank structure consists of a carbon steel primary tank enclosed by a carbon steel secondary liner, inside a concrete shell. The primary tank rests inside the secondary steel liner on an insulating refractory pad on top of the secondary liner and structural foundation. An annular space 30 in (0.76 m) wide is formed between the primary tank and the wall of the secondary liner. The primary tank and annulus have separate ventilation systems, designed to maintain the internal pressures negative with respect to ambient pressure.[1]

During a routine visual inspection of the annular space in August 2012, an accumulation of material was discovered at two locations on the annulus floor of Tank AY-102 (Riser 83 and 90).

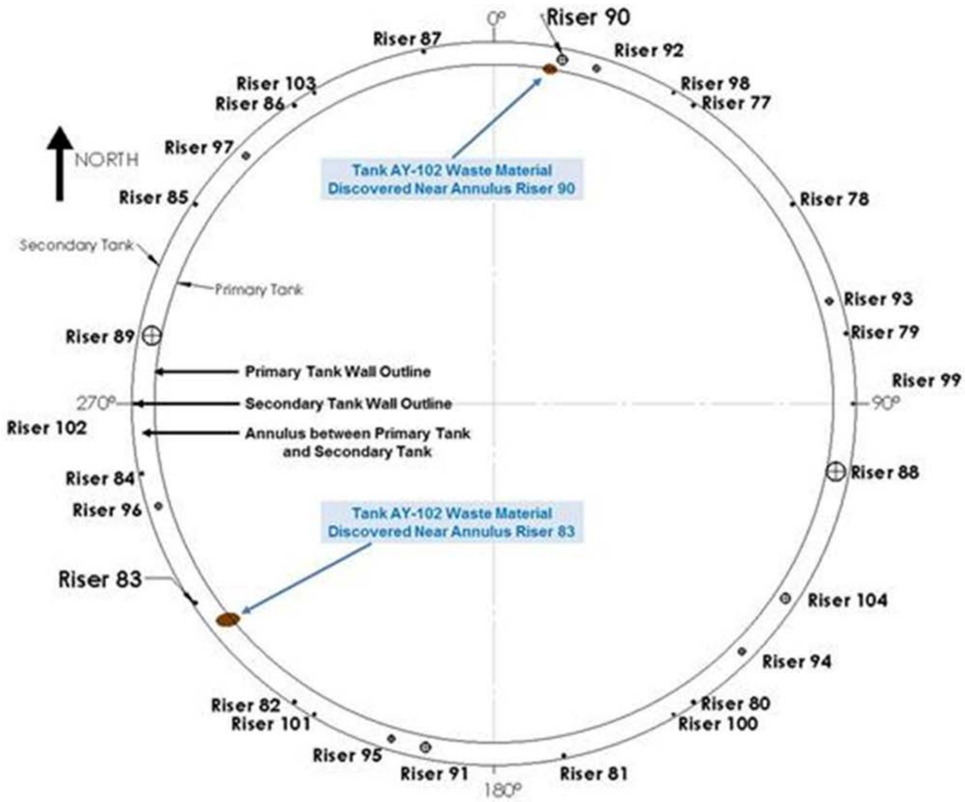

FIGURE I: Leak Accumulation Sites First Discovered in August 2012

In October 2012, Washington River Protection Solutions LLC (WRPS) determined that waste had leaked into the annulus of AY-102.[2] WRPS conducted an extensive review of Tank AY-102 and increased both inspection and monitoring of the tank; however, the precise cause and location of the leak could not be determined. In March 2014, additional material was detected on the annulus floor underneath Riser 77 which is adjacent to Riser 90. Ongoing periodic inspections are being performed at the waste accumulation sites (Risers 77, 83, and 87) and via six other risers to view >95% of the annulus floor to track for changes (see Figure II).

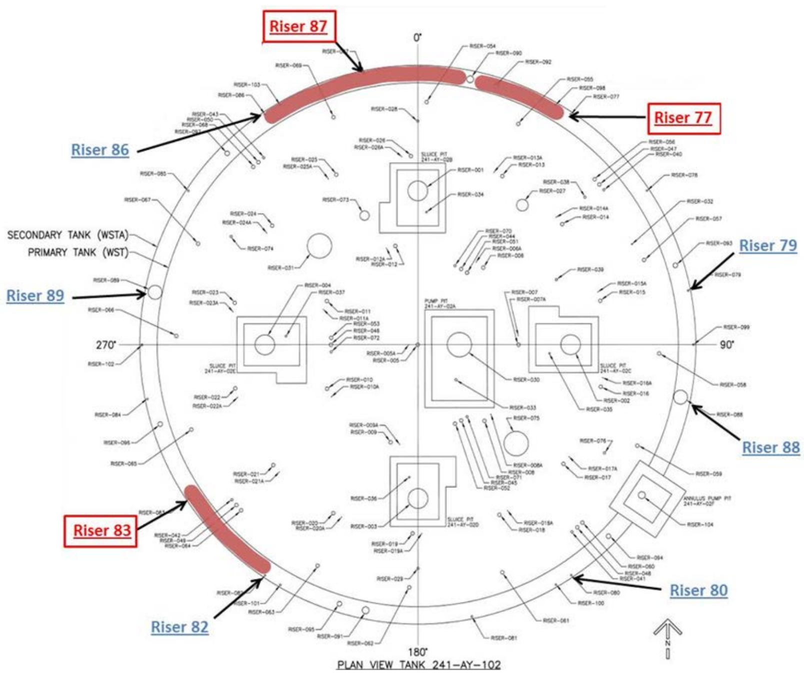

FIGURE II: View of Waste Accumulation Sites on Annulus Floor as of September 10, 2014 in Tank 241-AY-102

Since August 2012, these leak accumulation sites have continued to grow in volume with a total leak accumulation volume estimated at 30.6 gal (0.116 m^3) as of 9/10/2014 (see Figure III).

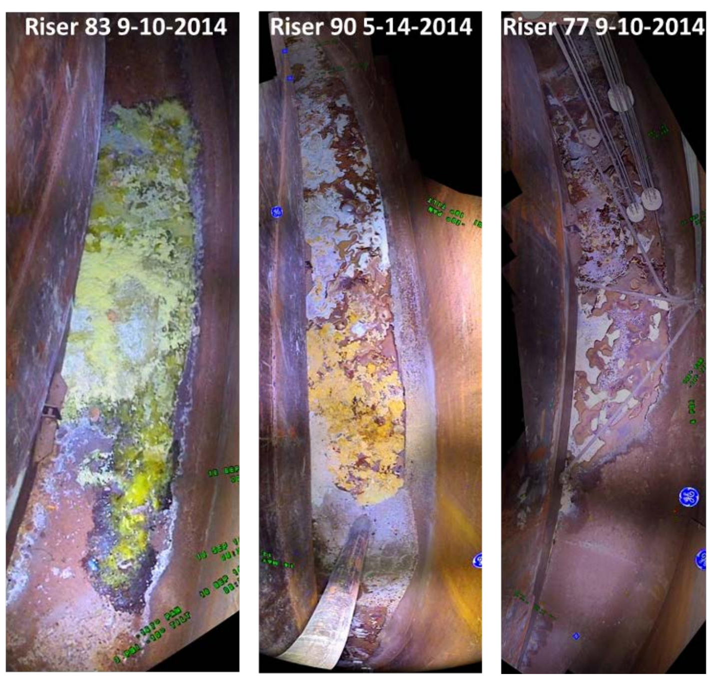

Figure III: Leak Accumulation Sites to Date in Tank 241-AY-102.

At the same time the Tank AY-102 leak detection pit (LDP) was accumulating water through the drain system external to the secondary tank liner. Liquid collecting in the LDP is suspected to be from water intrusion and collects at a rate such that the LDP must be pumped routinely. Following a routine pumping event, elevated radiation dose rates were noted on the transfer hose and surface contamination readings were found on the transfer pump when it was removed from the Tank AY-102 LDP.[3] These two field readings suggested that tank waste from a secondary liner breach could be leaking into the LDP. As a result, WRPS initiated a plan to ascertain the integrity of the secondary tank liner by performing a robotic inspection of the LDP drain line piping.

LEAK DETECTION PIT CONFIGURATION

The double-shell tank (DST) leak detection pits (LDPs) are tertiary systems designed to detect leakage from the secondary tank liner. The concrete foundation beneath the secondary liner is slotted and fitted with drain connections at the center of the tank, at the edge of the concrete foundation, and at a midpoint between these two drains (see Figure IV). The system was designed so that any tank waste released from the secondary liner would accumulate in the foundation slots and drain into the LDP.

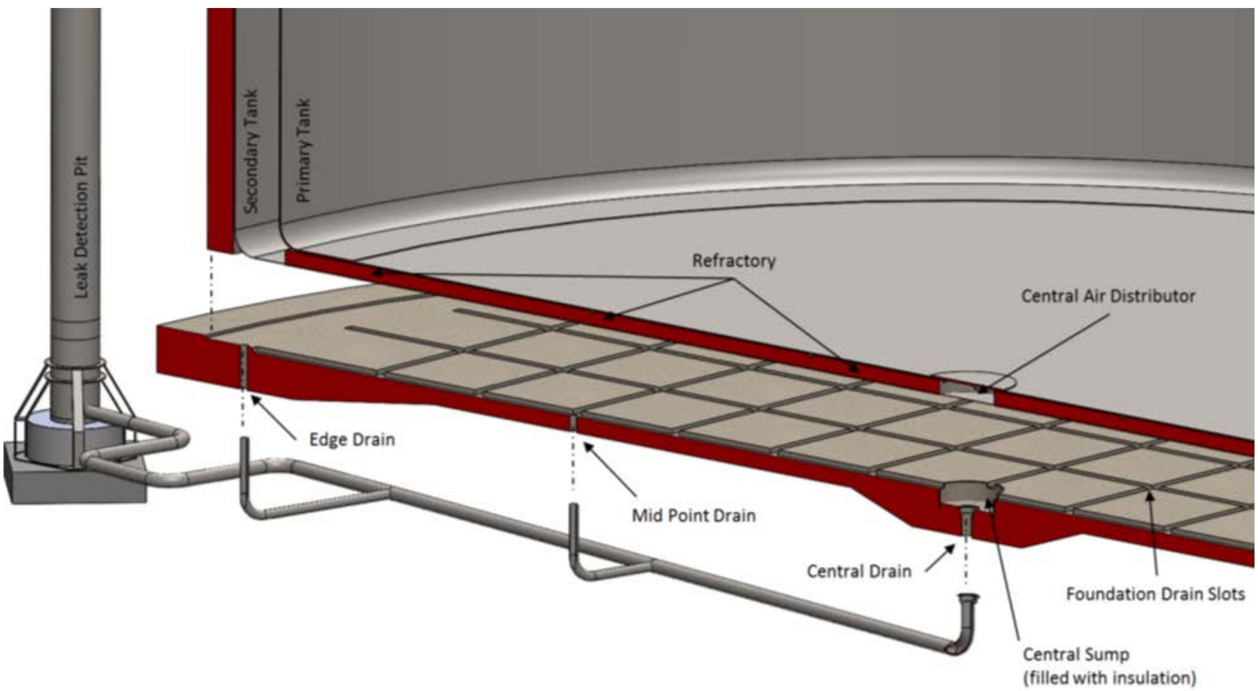

FIGURE IV: Foundation Drain Locations

For the 241-AY Tank Farm, the 6 in (152 mm) diameter drain line manifold runs to a 48 in (1.2 m) diameter by 18 in (0.46 m) high carbon steel sump tank that is located approximately 62 ft (19 m) below-grade and below the level of the tank foundation (see Figure V and Figure VI). The drain line connects to the sump tank in a single 24 in (0.61 m) riser, which extends to a leak detection pump pit. The pump pit is located flush with the ground surface.

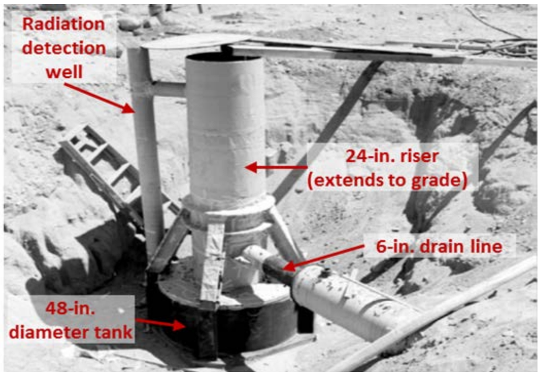

FIGURE V: Leak Detection Pit Construction

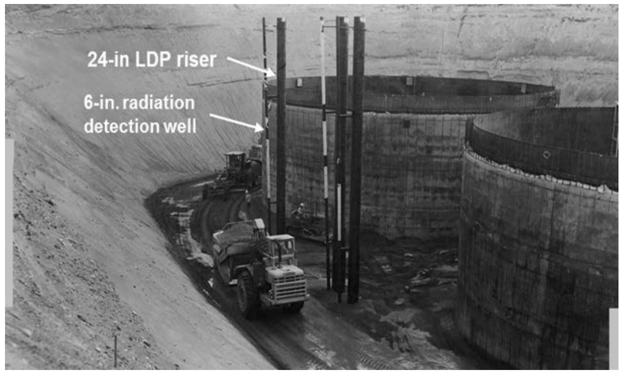

FIGURE VI: Leak Detection Pit Construction

For a breach from the secondary liner to be detected, the foundation drains and LDP drain system need to direct the flow of waste into the LDP sump tank, where a leak would be indicated by an increase in the LDP liquid level and an increase in radioactivity in the samples taken from the LDP.

INSPECTION TOOLING DEVELOPMENT

WRPS conducted a down-selection among four vendors by applying a structured decision-making process based on the Kepner-Tregoe multivariate decision analysis technique.[4] IHI Southwest Technologies, Inc. (IHI) was selected and awarded the contract to perform the visual inspection of the LDP. To accomplish the robotic inspection, IHI designed and fabricated a robotic pipe crawler to traverse through 6 in (152 mm) Schedule 40 pipe. Figure VIII shows the IHI robotic pipe crawler in its final configuration. The crawler featured a pan/tilt/zoom color camera head assembly with a dimmable array of LED lights for illumination.

Figure VII: IHI Robotic Pipe Crawler Fabrication

To deploy the crawler into the 6 in (152 mm) drain line, IHI designed and fabricated a deployment mechanism (see Figure VIII). The deployment mechanism would serve to house the crawler as it was lowered the 62 ft (18.9 m) below grade as well as orient the crawler chassis for direct maneuvering into the 6 in (152 mm) drain line.

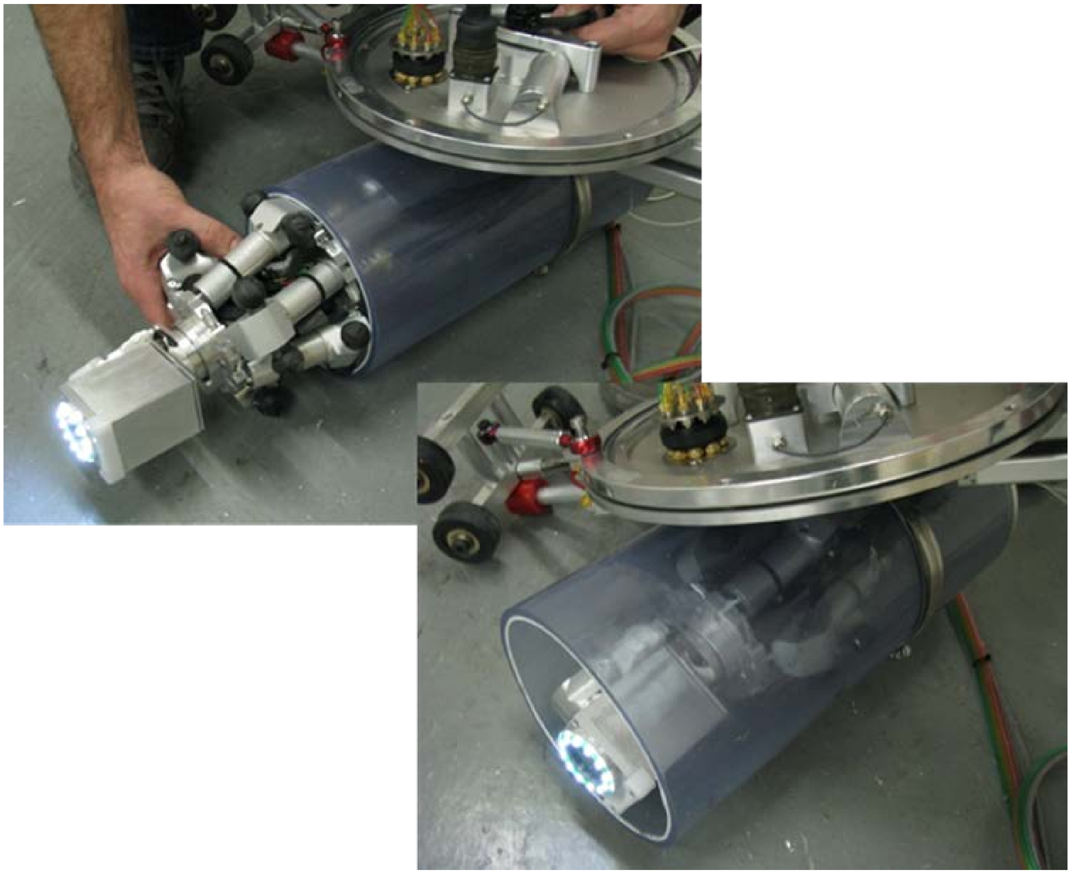

FIGURE VIII: IHI Pipe Crawler Deployment Mechanism

The IHI robotic inspection system was demonstrated using a full-scale mockup at one of the IHI fabrication facilities. The equipment was demonstrated a second time using a full-scale mockup in the Hanford 200 East Area before deployment at Tank AY-102.

RESULTS

On November 20, 2013, the crawler deployment device was lowered into the LDP riser and successfully aligned with the drain line.[5] The crawler entered the drain and traversed to within several feet of the central sump before losing traction. The following section provides top level descriptions and inspection photographs of each section of the pipe, indexed to Figure IX.

- **Section #1:** The entrance was partially wetted and had sediment and corrosion consistent with past inspections.

- **Sections #2, #3, and #4:** The pipe was wet with considerable sediment and rust in the bottom of the pipe into section 4, which is between the third and fourth elbows in the expansion loop. This wetness is consistent with the level of water in the LDP prior to pump down six days before the inspection.

- **Sections #5 and #6:** Very dry and showed no evidence of dripping or drainage from the slots in the 101 mm (4 in) drain lines. These sections showed less debris and corrosion product in the bottom of the pipe.

- **Sections #7 and #8:** Past the second tee, were wet and had a similar volume of debris and corrosion products as found in the first four sections.

- The central sump was not observed, since the crawler could not traverse through the last few feet of the drain line due to the amount of debris present (see "G" of Figure X).

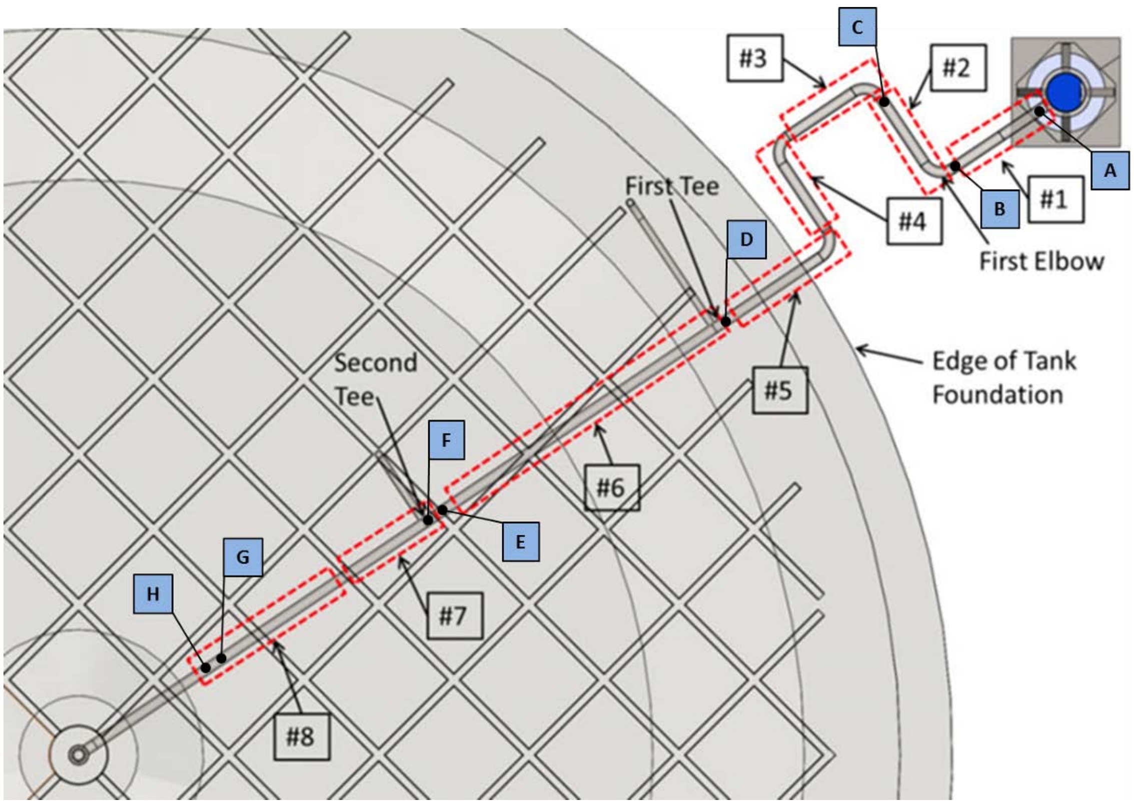

FIGURE IX: Inspection Overview

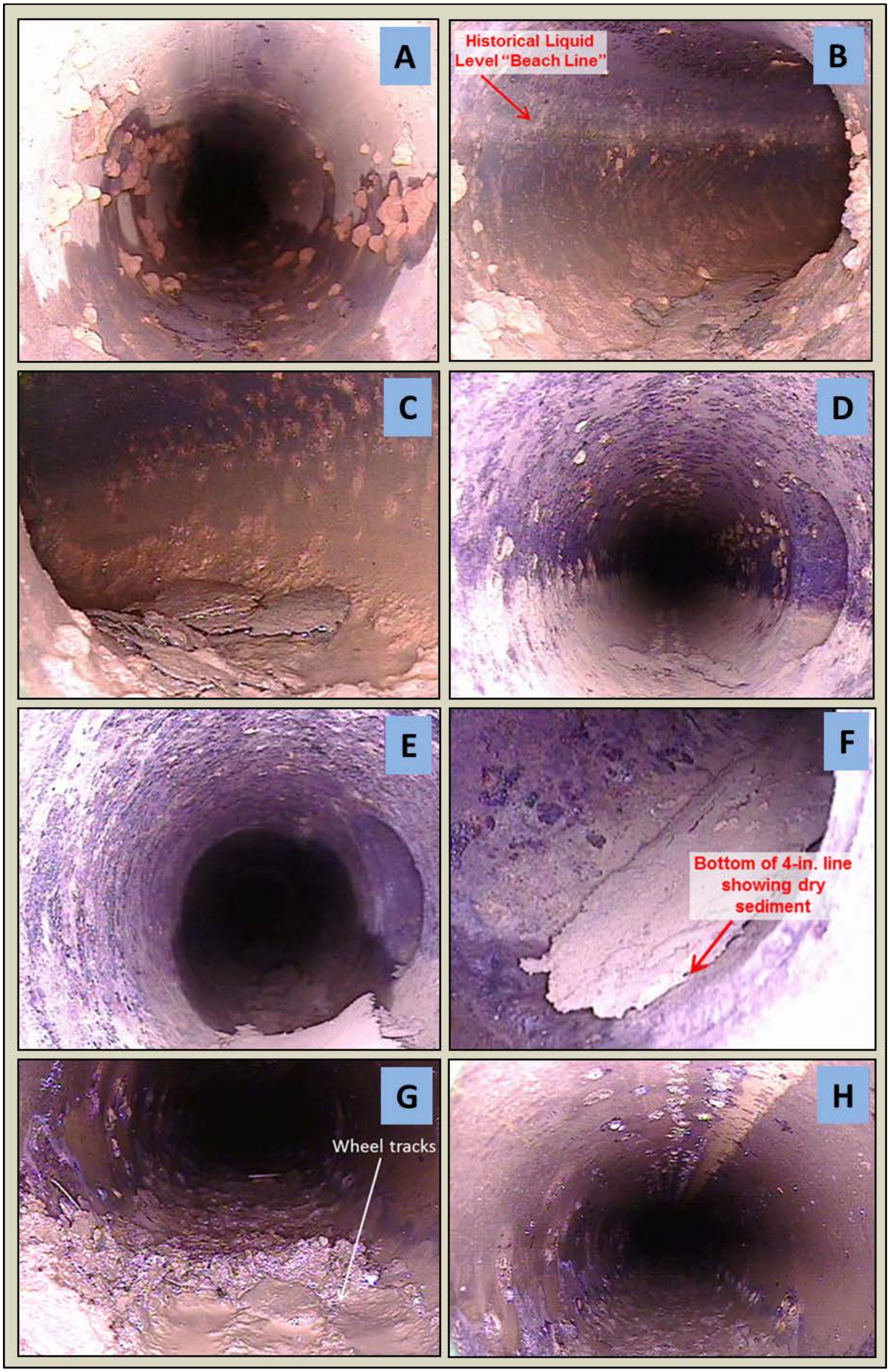

FIGURE X: Drain Line Visual Inspection Photographs

Prior to the inspection, it was assumed that the intrusion was liquid migrating through the expansion joint between the vertical concrete sidewall and the foundation pad (see Figure IX). The expectation was that the first tee (see "D" in Figure X) might show the presence of liquid because it drains from a point nearest this joint. Both the first and second tees were dry (see "D" and "F" in Figure X) and did not show the presence of any liquid. During the inspection, no other sources of water intrusion were observed.

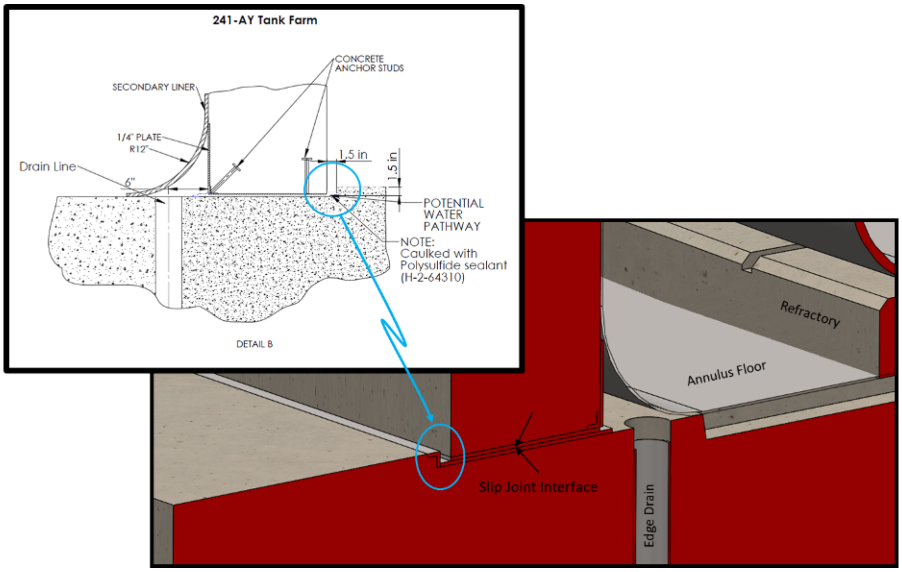

FIGURE XI: Concrete Wall/Foundation Expansion Joint Interface

The 6 in (152 mm) drain line was wet from the center of the tank to the second tee connection (sections #8 and #7 in Figure IX) and from between the second and third elbows down to the LDP sump tank (sections #4, #3, #2, and #1 in Figure IX). The wet environment seen in sections #1 - #4 (see Figure IX and Figure X) is remnant to the liquid level prior to pumping down the LDP (six days before the inspection).

Although the debris proved to be an impediment to the crawler and may cause a delay in the flow of waste to the LDP, it is insufficient to restrict the flow of a substantial amount of liquid to the LDP. If small leaks occur in the secondary liner, it is unlikely that the waste would reach the LDP sump in a timely fashion with or without the presence of the debris. This conclusion is based on the rate of flow of waste from the Tank AY-102 primary tank, in which waste has moved slowly over a year or more to cover a relatively small fraction of the liner floor.

Radiation and Chemical Analysis of the Debris on the Crawler

The dose readings taken off the crawler in the field and the laboratory were 12-27 mRad/hr window open, and <0.5 mRad/hr window closed, respectively. A lower dose rate was reported in the 222-S Laboratory. The primarily beta particle dose is consistent with past surveys of the equipment removed from the sump.
Radionuclides, cesium (Cs-137) and Strontium (Sr-90), were present in low concentrations and in a ratio similar the LDP samples. There was no evidence of particles with chemical signatures consistent with tank waste. Specifically, no sodium-rich, potassium-rich, nitrate, sulfate, or phosphorus bearing salts were found. These results indicate the material analyzed from the crawler was not tank waste.

The solids consisted, in a large part, of a very fine particulate and appeared dark orange to brown in color. Of these solids, the majority were composed of rust and scale. Minor amounts of silicate soil minerals and a calcium-rich phase were also found. The calcium-rich phase is probably derived from cement or groundwater precipitation. Traces of a phase consistent with graphite were also observed. This compound may have come from the dry lubricant that was scattered about the sliding joint of the tank concrete wall during construction. Additional details on the results of specific analysis that were performed are provided below.

The chemical characterization of the solids was primarily iron from rust in the debris with trace quantities of Cs-137 and Sr-90 (Table I).[6] The Cs-137 to Sr-90 ratio is similar to past LDP liquid samples and not similar to waste samples from the tank or the annulus (Figure XII). The overall concentration of Sr-90 is similar to annulus materials, but the more mobile component, Cs-137, is much lower than any of the tank or annulus materials.

TABLE I: Crawler Solids Laboratory Results

Radionuclides	
Cs-137	0.126 uCi/gm
Sr-90	1.67 uCi/gm
Cs-137/Sr-90	0.075
Element	
Iron	487000 ug/g
Calcium	10800 ug/g
Manganese	3490 ug/g
Aluminum	1680 ug/g
Lead	1380 ug/g
Anions	Trace NO_3^-, NO_2^-, Sulfate (20-40 ppm) (Analysis not performed for Oxide, Hydroxide, Carbonate)

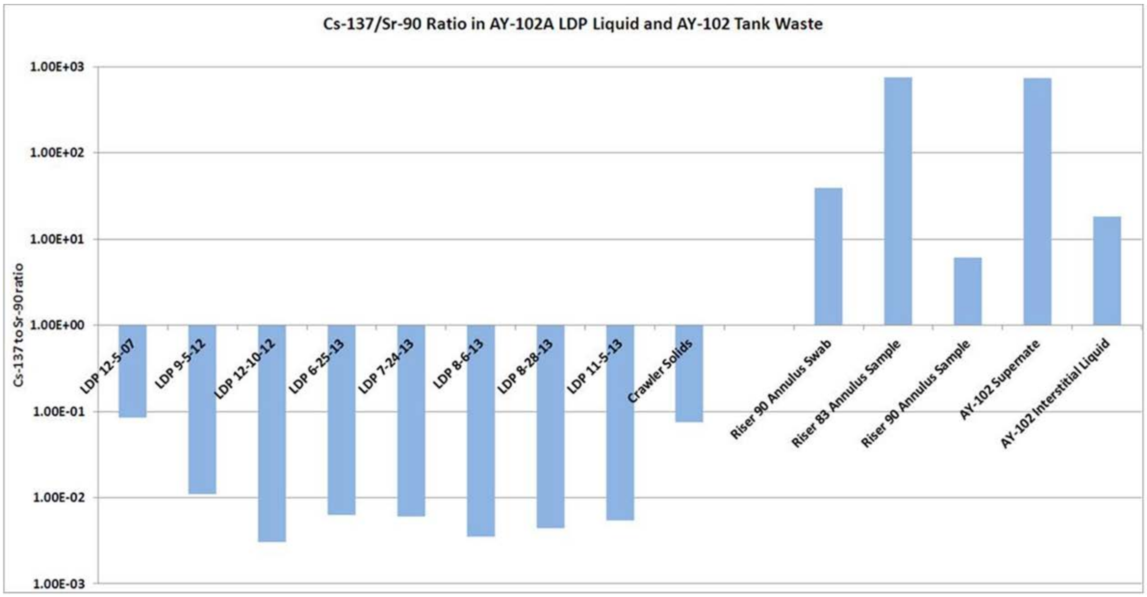

Figure XII: Cs-137/Sr-90 ratio from Crawler Solids Compared to other AY-102 Samples

Debris in the Leak Detection Pit Drain Line

The drain line contained sufficient debris to hinder crawler movement. It was determined the debris is not Tank AY-102 waste. This quantity of material was unexpected. From a review of tank construction photographs, one potential debris source could be from construction activities (see Figure XIII). During much of the secondary tank liner bottom construction, the foundation slots and drain line piping facilitated collection of dust, concrete, wood, and welding material remnants which could have easily blown or fallen into the drain line.

FIGURE XIII: Debris Observed in Drain Line Piping Likely Attributed to Tank Construction Activities

Also, in some sections of the drain line, the debris appears to be corrosion products, but the drain line does not show signs of excessive degradation. None of the material seen had the appearance of tank waste (i.e., no greenish or yellowish deposits or dark fluids, dried salt deposits, or crystalline material).

DISCUSSIONS

Visual data from the robotic inspection has resulted in maturation of the water in-leakage theories. Re-entry into the LDP for confirmation of these theories has not been performed. Adding temperature, pressure, and humidity sensory devises to the robotic tooling would enable confirmation of these theories. However, without performing a second inspection, the following factors have been identified as plausible explanations for the water intrusion phenomena currently experienced in the LDP. It is highly likely these factors work together additively.

Temperature Gradients in the Foundation

The annulus air is distributed radially through a central air distributor in the refractory layer, which leaves the refractory and concrete foundation cooler in the middle and warmer toward the outer radius (see Figure XIV), as indicated by embedded thermocouples. Thermal gradients as depicted in Figure XIV give a means for air flow to transport dissolved moisture (100% relative humidity air) which will condense in some portions of the system and subsequently evaporate in others depending on the local temperature driven by thermal gradients. Figure XV is gives a theoretical thermal profile (cross section view) of the Tank AY-102 and surrounding soil which shows the air moisture transport mechanism is present within the system. Confirmation of these thermal gradients would require a second entry with the IHI robotic pipe crawler equipped with onboard temperature/pressure/humidity sensory devices.

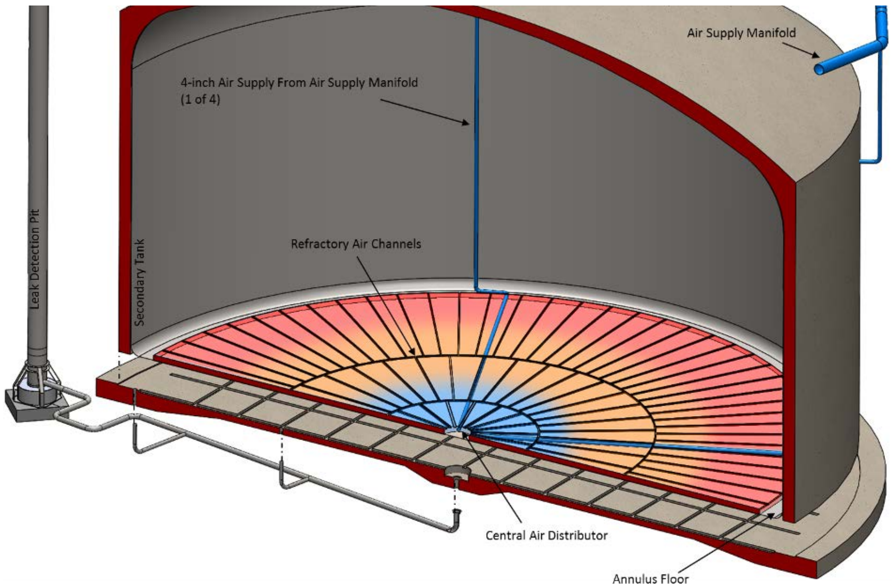

FIGURE XIV: Tank Bottom Thermal Profile

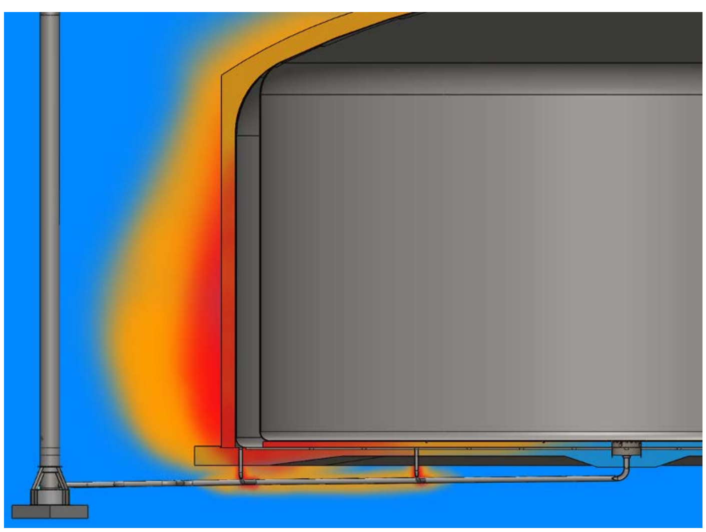

FIGURE XV: Plausible Thermal Profile (Theoretical) Vacuum and Water Intrusion

The liquid level rise stops during the periods when the annulus exhaust is shut down and the vacuum is off (see Figure XVI). This correlation suggests that the vacuum drawing air into the drain system plays a role in the intrusion. The rate of intrusion does not appear to vary with seasonal temperature fluctuations.

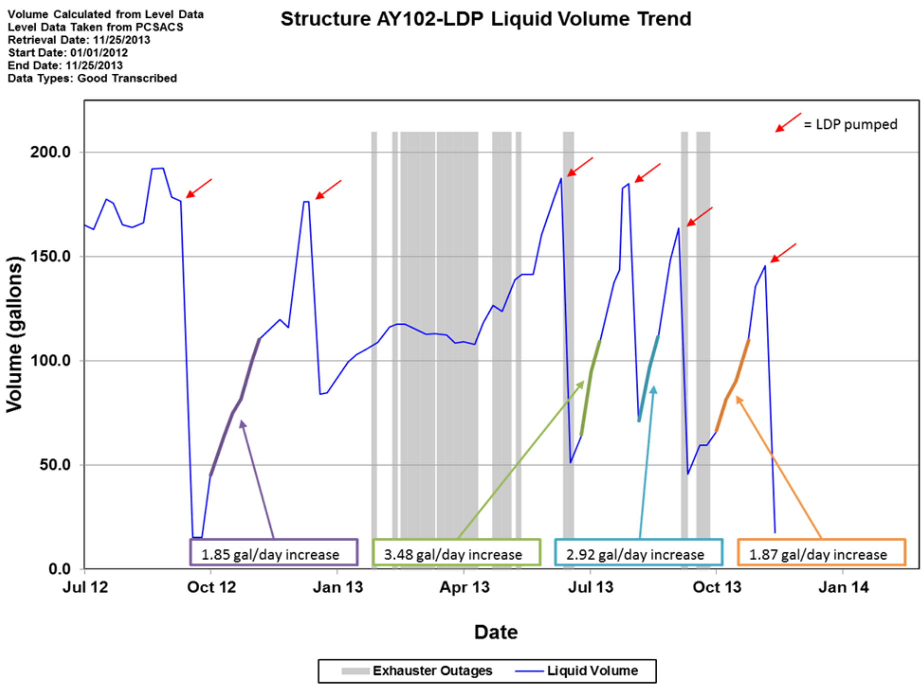

FIGURE XVI: Tank AY-102 LDP Level Trend Showing In-leakage Correlation to Exhauster Outages

Airflow through the Drain Line

There is airflow through the drain line, seen as bubbles, when the liquid level rises to the top of the drain; there is also positive indication when using a physical item to detect airflow. The motive force for the airflow is a connection with the annulus exhaust ventilation system via a 2 in (50.8 mm) pipe that routes from the LDP riser to the 6 in (152.4 mm) annulus vent header. The airflow stops when the liquid level rises to a point such that the 6 in (152.4 mm) drain line is submerged.

Condensation in LDP

Prior visual inspections of AY and AZ Farm LDPs show condensation in the form of droplets in the sump tank, along the wall of the riser, and in the pump pit near-grade. The visual inspections show fogging conditions in the riser on some occasions. These condensation droplets are formed due to the air rising in the 24 in (609.6 mm) riser towards grade. As the warm, moist air rises and cools to the temperature of the surrounding structure, an ideal environment for surface condensation is created once the dew point is reached.

Moisture Sources

There are two potential sources of moisture at the tank; humid air in the soil and liquid. Most of the single-shell tank (SST) farms exhibit higher soil moisture profiles compared to native soil. The original excavation has a layer of low-moisture permeability soil at the base of the excavation. Although water-saturated soil is not expected, the air present in the pore-space of the soil that may be drawn in at the foundation level is likely be at 100 percent relative humidity (Hillel 1998).

Additionally, the tank domes creates an umbrella effect that directs moisture into the soil next to the tank. Past construction reviews have shown the rainfall and snowmelt flow through a construction joint in the dome concrete and enter the annulus. This finding shows that adequate quantities of moisture exist from the umbrella effect of dome runoff to be present at the foundation groove.

Possible Intrusion Pathways

The following is a list of potential water intrusion pathways and are discussed in this section:

- A crack or pit in the sump tank;
- A crack or pit in the drain line; or
- Air in-leakage through the concrete wall/foundation joint and condensation in the LDP.

Sump Tank

Cracks or pits in the sump tank above the normal liquid level could be possible based on the age and service of the system. The previous inspections showed the LDP sump is in relatively good condition, taking into account the presence of stagnant water and the humid atmosphere for long periods of time. There is no supporting visual evidence of cracking or pitting from the visual inspection or the previous inspections. Intrusion at or above the liquid level ceiling would be visible by stains around the crack or pit and by streaks from flow of the liquid down to the sump. There are some streaks on the wall, but these streaks occur near the condensation transition point. This transition point was observed in previous inspections when the camera was lowered and condensation occurred on the camera lens.

The sump itself is well below this transition and offers no temperature differential to support a condensation mechanism in the sump. Below the liquid ceiling level there is no evidence of leakage or loss of liquid level, which should occur when the ventilation system is shut down. The leakage should happen under this condition, because equilibrium established with the ventilation would have shifted and the water would seek a new equilibrium level.

Drain Line

As with the sump tank, cracks or pits could potentially be present in the drain line, but no evidence of either defect was found in the visual inspection.

In the dry portions of the line, any defects would show the presence of liquid such as pooling or flow patterns. The inspection did not find any such patterns.

In the wet section, as with the dry section, there was no evidence of cracks or pits in the portion observed. If defects were present in the portion not observed or potentially under the mud present in this section, this liquid would have to move through the dry portion of the drain line. There is no evidence of moisture from the center of the tank flowing into the LDP sump.

Air In-leakage/Condensation

Vacuum applied to the LDP system may be pulling moisture from the surrounding soil through the 6 in drain line into the sump and the 24 in (607 mm) riser. The pathway is likely at the polysulfide-sealed slide plate joint between the footing and the bottom of the concrete side wall. The soil in this location is warmed by contact with the tank wall. This relatively warm, moist air is drawn in 57 ft (17.4 m) below-grade and can condense in cooler parts of the LDP drain system if the temperature differential is sufficient.

The 4 in (102 mm) drains coming into the 6 in (152 mm) drain line draw from warmer areas of the secondary liner bottom and concrete foundation and showed no condensation. These warmer areas would heat the moist air, reducing the relative humidity below the saturation point and account for the dry condition in the 4 in (102 mm) drains and the central portion of the drain line.
When the ventilation system is operating, the coolest part of the tank bottom and foundation is the tank center, which is directly below the supply point for the inlet air stream. The cooler areas underneath the tank center and outside the tank perimeter can condense moisture, which then collects in the LDP.
When the vacuum is off, or when the LDP level is high enough to block airflow out of the drain system into the LDP riser, there is no water accumulation because no more humid air can be pulled into the foundation slots and drain system.

Humidity levels 60 to 70 ft (18.3 to 21.3 m) below-grade are at, or near, saturation. As a rough approximation, a 10 to 15 °F (Δ 2.7 °C) temperature drop in saturated air and 10 to 20 ft^3/min (283 to 566 L/min) of airflow does produce a condensation rate near the observed LDP fill rate of 2 to 3 gal/day (7.6 to 11.4 L/day). Based on the observations from the inspection and the analysis above, the "air in-leakage/condensation" pathway offers the best explanation.

CONCLUSIONS

The inspection of the drain line for the Tank AY-102 LDP has not definitively identified the source of moisture in the LDP. Conditions in the LDP drain line indicate a high probability that a significant leak through secondary containment would be collected in the LDP. To date the LDP still fills with water and must be routinely pumped. Sampling the contents of LDP prior to transfer will confirm whether or not waste material has entered the pit.

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