

## **Hanford Single-Shell Tanks Leak Causes and Locations – 15509**

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### **ABSTRACT**

Historically 67 assumed and known leaking tanks in the single-shell tank (SST) system were identified at the Hanford Site. The US DOE, Washington River Protection Solutions LLC., and the State of Washington, Department of Ecology identified 25 of the 67 tanks as likely having had liner leaks by a comprehensive review of current and historical data. The remaining tanks are those with potential leaks from sources other than liner failures such as overfilling the tanks or the failure of process lines connecting SSTs.

The location of the leaks was determined, based largely on logging radiological data from drywells installed around the tank and/or radiological data from laterals installed under select tanks. The drywells and laterals provide the best indication of the vicinity of the leak location, but not necessarily the exact location of the leak. Twenty of the 25 liner leaks appear to have occurred at or near the bottom of the tanks. Many of the tanks appeared to have multiple leak locations. Leak locations could not be determined for all tanks with the available data. Three of the tanks showed apparent sidewall leaks.

Potential causes for liner leaks that were evaluated included tank design features, tank construction conditions, waste temperature, tank waste chemistry conducive to different types of corrosion (uniform corrosion, nitrate induced stress corrosion cracking, pitting, crevice, and liquid-air interface corrosion), and bulges in the tank bottom.

### **INTRODUCTION**

To improve the understanding of the single-shell tanks (SSTs) integrity, Washington River Protection Solutions LLC. (WRPS), the US DOE Hanford Site tank contractor, developed an enhanced Single-Shell Tank Integrity Project (SSTIP) in 2009. An expert panel on SST integrity was created to provide recommendations supporting the project. The panel developed 33 recommendations in four main areas of interest: structural integrity, liner degradation, leak integrity and prevention, and mitigation of contamination migration. Seventeen of these recommendations were used to develop the basis for the M-45-10-1 Change Package for the Hanford Federal Facility Agreement and Compliance Order, also known as the Tri-Party Agreement.

The recommendations pertaining to the leak integrity of the tank liners were grouped under a single interim milestone, M-045-91F, which was supported by four target milestones. This group of activities provides a basis for improving the understanding of the mechanisms that have caused tank liner failures in the past and to investigate a new approach to identify leak sites. One of the targets, M-045-91-T04, was to identify the leak causes and locations for the 100-series leaking tanks as well as estimating the leak rates. The results from this work could provide recommendations for improved leak detection and monitoring of the SSTs as well as retrieval technology selection decisions. These results will be combined with the results from the other targets for interim milestone M-045-91F in a separate document

which will evaluate and provide possible recommendations to improve leak detection and monitoring of the SSTs.

A team was assembled and a series of meetings was held with the US DOE Office of River Protection (ORP) and the State of Washington, Department of Ecology (Ecology) to present and discuss information reviewed pertaining to tank leak inventory estimates to be included in leak inventory assessment reports [1]. During the collaboration effort, participants discovered that some of the tanks identified as “assumed leakers” may not have leaked and liquid level decreases in the tanks and/or gamma activity discovered in the vadose zone may be attributed to sources other than a tank liner leak [2]. For example, some of the tanks were filled above spare inlet lines or cascade lines and releases previously reported to be attributed to liner leaks appear to be releases from these locations. Conversely, it was discovered that some tanks classified as “sound” tanks may have leaked [2]. The team recommended one of three possible categories for each tank analyzed; the tank should be classified as “sound”, the tank was identified as having a liner leak, or the tank should be further analyzed in more detail. Out of the 149 SSTs, the team identified 25 tanks as having a liner leak out of the 67 SSTs identified as an “assumed leaker.” Other tanks are recommended for integrity evaluations [1].

In accordance with TPA target M-045-91F-T04 (T04), further evaluation was performed for the 25 tanks identified as having a liner leak. The T04 target states that each tank identified as having a liner leak will be analyzed to identify possible leak causes, leak locations, and leak rates. Performing these analyses would establish a permanent archive of the leaking SSTs for retrieval technology selection and possibly enhance prediction tools for evaluating risks in the remaining sound SSTs.

Historical evaluations of liner failures have generally focused on corrosion failure mechanisms [3,4]. In a limited number of cases, bulges of the tank liner bottom have also been explored for the relation of bulging to liner failure [5]. However, tank liners may fail due to any of a number of mechanisms [6]. This paper considers the broadest set of mechanisms that could reasonably cause or play a supportive role in causing liner failure. Where appropriate an explanation is given why a particular mechanism is not considered a significant factor contributing to liner failure. Those mechanisms which are potentially significant are subsequently examined in greater detail and form the basis for the detailed evaluation of factors contributing to liner failure.

## **METHODS**

The review process started with an assessment of the individual tank information including operating and construction histories, tank design and the materials used during construction, construction conditions, etc. Historical documents were reviewed to identify possibly characteristics that may have predisposed the specific tank to failure. A review of the construction history may identify unfavorable conditions that were not anticipated by the design. Review of tank materials and operating histories would identify conditions that could lead to accelerated corrosion and/or overloads. Then the individual tank farm information was reviewed to understand the differences between the failed tank which may have predisposed that tank in the tank farm to leak and possibly indicate where they leaked.

In-tank and ex-tank leak detection information was reviewed in an effort to identify leak location and leak rates. This provided the basic data identifying where and when the first leaks were detected. In-tank leak detection consists of liquid level measurements that can be augmented with photographs which provide an indication of the vertical levels liquids reached on the tank sidewall. Other in-tank parameters reviewed included temperature of the supernatant and sludge, types of waste stored, and chemical composition based on transfer records or sample analyses. Ex-tank leak detection for the tanks consists of surveillance and characterization data from leak detection laterals, drywells, and leak detection pits were available.

Ex-tank information was assembled from many sources including design media, construction conditions, technical specifications, and other sources.

Potential leak causes that may have contributed to liner stress or weakening of the tank liner were also assessed using the in-tank and ex-tank information. However, more focus was placed on tank materials and construction, temperatures, and corrosive properties of the waste if a primary cause could not be identified. Leak causes assessed included: Tank design features, tank construction difficulties, ambient and waste temperature, tank waste chemistry conducive to different types of corrosion (uniform corrosion, nitrate induced stress corrosion cracking, pitting, crevice, and liquid-air interface corrosion), and bulges in the tank bottom. Waste temperature, liner bulges, and induced stresses typically were the primary cause of liner failure. However, some or all of these factors can act serially or together to contribute to tank liner failure.

Historical SST leak rates were estimated using two different methods. The first method analyzed the change in historic surface level data with time multiplied by gallons per inch of tank height, and the second method divided the previously determined leak volume estimates by an assumed leak duration. Tanks with high confidence determination of low leak rates could be candidate for less costly waste retrieval by modified sluicing.

Data sources reviewed included data sheets, plots of data, internal letters, documents, and monthly–quarterly–semi-annual–annual reports. The preferred source was the actual data sheets but they were not available for all cases. In some cases, little or no information was available for a given tank or time frame.

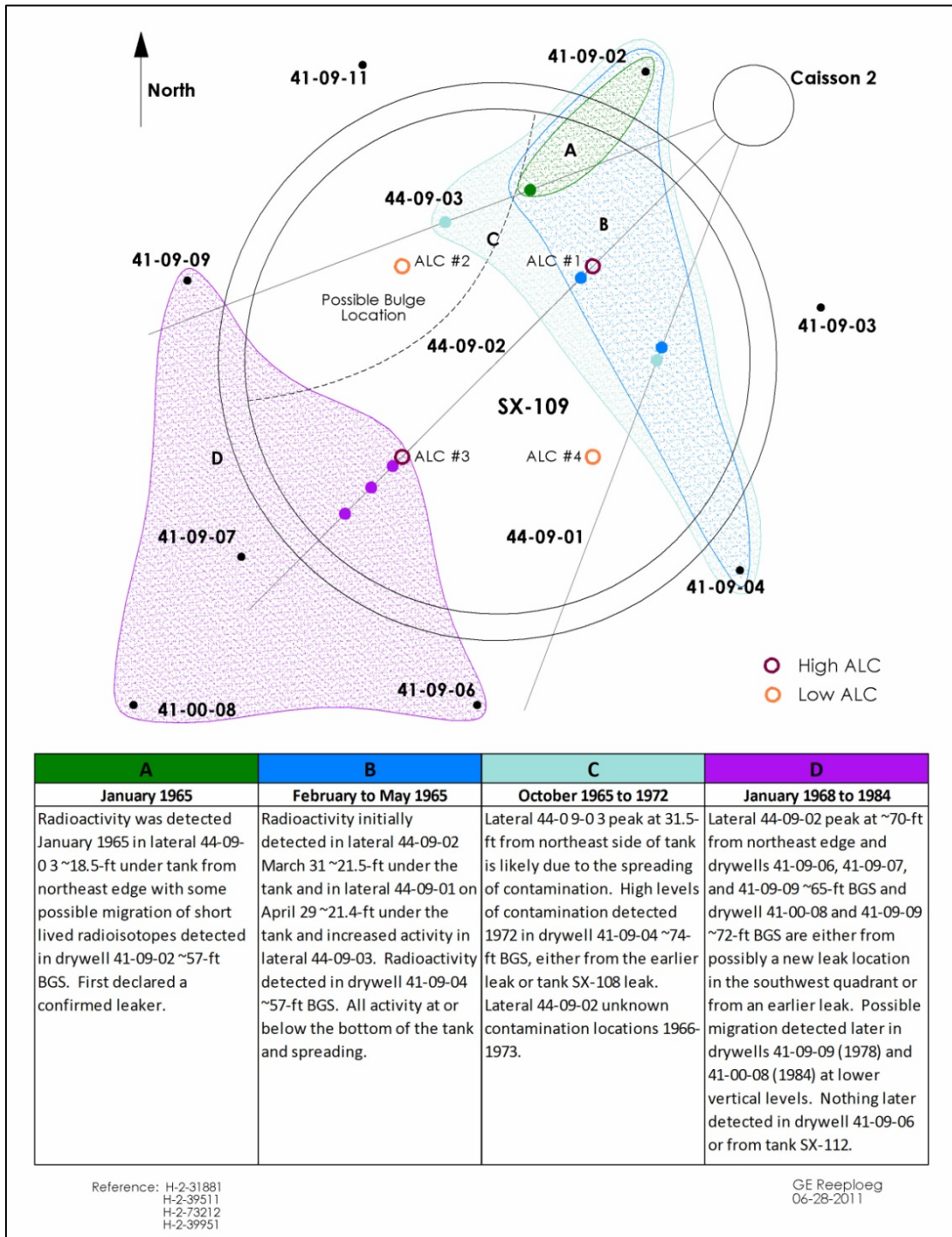
## RESULTS AND CONCLUSIONS

Twenty-five SSTs were analyzed to identify leak causes, leak locations, and leak rates [7]. Twenty of 25 of the liner leaks occurred at or near the bottom of the tanks. Many of the tanks appeared to have multiple leak locations. Three of the tanks showed apparent sidewall leaks only. Leak locations could not be determined for two tanks (T-111 and TY-104). See Fig. 1 for an example of a leak location diagram from tank SX-109. A similar figure was developed for each of the tanks (except for the two tanks that leak locations could not be determined) and represents the chronological time frame of the leak site(s) and the possible migration. If a liner bulge was reported or possible then the approximate location was also overlaid in this figure. It should be noted that Fig. 1 shows the leak detection laterals originating from Caisson 2. Leak detection laterals were installed approximately 10-ft underneath some of the SSTs containing self-boiling waste in A and SX Farms. Probes were driven to the end of the lateral with compressed air then slowly withdrawn to gather a radiation profile below the bottom of the tank. Laterals, where available, were used to determine leak locations and lateral radioactivity almost always indicates a leak at or near the bottom of the tank.

The leak rates were estimated based on leak volumes and durations. The average estimated leak rates ranged from less than -6 gal/day to over -6,000 gal/day [8]. Leak rate estimates were not prepared for the two tanks in C Farm since this farm is undergoing retrieval. In many cases the leak volumes associated with leak rates based on level change rates vary significantly from volumes previously developed [1, 2], and these differences result from assumptions and data uncertainties used for each analysis.

TABLE I illustrates the relative contribution of each leak cause for the tanks evaluated; a large dot indicates greater importance and a small dot less importance. The main causes of the liner leaks fit into five general categories: tank design, tank construction conditions, bulging liner, thermal conditions, and waste chemistry. These categories are discussed in further detail below. The column labeled “Other” in

TABLE I describes other possible leak causes that do not necessarily fit into one of the five general leak causes categories. Details on the other possible leak causes are provided in the footnote of TABLE I.

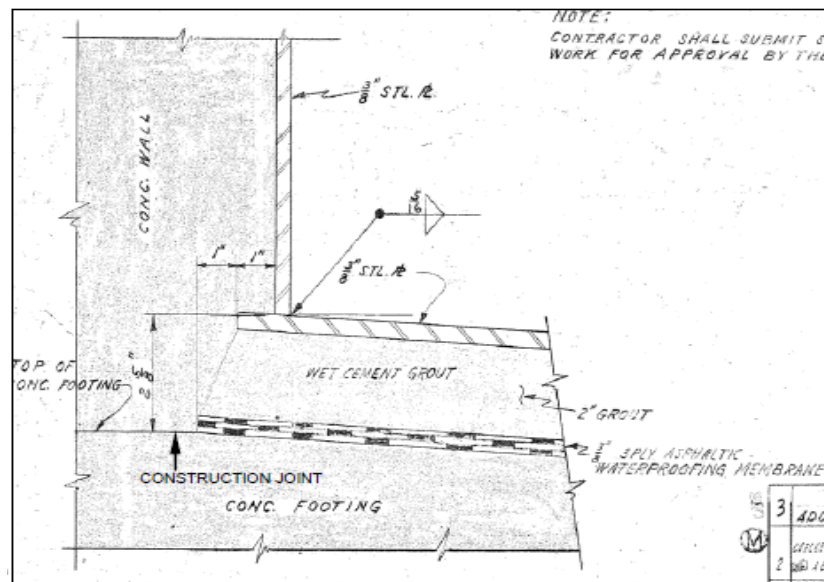


**Fig. 1. Example Leak Location Map for Tank SX-109 [9]<sup>1</sup>**

<sup>1</sup> Note: ALC = air lift circulator  
BGS = below grade surface.

## Tank Design

Tank design was identified as a contributing cause to liner failure primarily based on design features limiting thermal expansion of the bottom liner with addition of high heat waste. For A and SX Farms, the orthogonal transition between the tank bottom and tank sidewall was deemed less desirable compared to the earlier tank farm design of a rounded knuckle transition. Fig. 2 shows this orthogonal transition of the SX Farm tanks. A fillet weld was used to close the seam where the sidewall and tank bottom liners meet versus the butt welding of the knuckle transition of earlier tank designs. A review of the basic differences between fillet and butt welds indicates that the superior butt welds would be preferred for the tank farm waste tanks. Other design specifications changes for A and SX Farms were weld inspection techniques. Welds were inspected using the Vacuum Soap Test at 10 in. of mercury versus the superior full penetration X-Ray weld testing. These design changes applied to A and SX Farms were identified as features that could likely cause liner failure.



**Fig. 2. SX Farm Tank Bottom Liner to Sidewall Design Detail**

## Thermal Construction Conditions

Temperatures during construction of the tank farms were examined to determine if the tank liner fabrication occurred at or below the metal ductile-to-brittle temperature transition. Any low temperatures experienced during construction at or less than the 18°F ductile-to-brittle transition temperature where impact loading (e.g. a dropped tool or piece of equipment from scaffolding) had the potential for creating micro-fissures may have triggered fissures in the steel liner. It was determined that the most severe temperatures occurred during construction of SX Farm [9]. A photograph of the SX Farm under construction (see Fig. 3), taken January 20, 1954 (high 11°F low -6°F), shows several of the tanks full of water either undergoing leak testing or for concrete wall pouring. During this cold period snow covered ice is seen in the water filled tanks. Other tank farms experienced less severe temperatures than those recorded during SX Farm construction.



**Fig. 3. SX Farm Construction Photograph Taken January 20, 1954**

### **Bulging Liners**

Rapid filling with hot waste could heat any water in the grout beneath the bottom liner of the tank or organics from the asphalt wrap existing below the grout potentially trapping pressurized vapor [10]. Several of the design changes lead to thermal expansion limiting characteristics which could result in forces that cause the liner to deform (bulge). The design of the orthogonal sidewall to bottom joint was postulated to trap the pressurized vapor under the liner because the liner edge was embedded in the structural concrete, preventing pressure release up the sidewalls. This phenomenon in turn increased the temperature due to the lower vapor space heat transfer coefficient and decreased the heat transfer from the bottom of the tank, could increase the severity of the condition. Thermal expansion relieved by bulging of land locked liner, in extreme created cracks or invited localized stress corrosion cracking. Episodic bulging occurred in some tanks.

### **Thermal Conditions**

High temperatures or high temperature rate of rise within SSTs potentially can create conditions under which a mechanical or chemical tank liner failure mechanism is more likely to occur. Two elevated temperature related conditions have been identified as potential mechanisms that could contribute to tank liner failure. The conditions considered are elevated temperature and excessive thermal gradient (temperature rate of rise) within the waste and tank structure.

### **Corrosion**

The common corrosion threats to carbon steels includes general corrosion, pitting corrosion and stress corrosion cracking (SCC). The only one of these forms of corrosion that is believed to be a common factor contributing to liner failure is nitrate-induced SCC. Stress corrosion cracking requires an appropriate aggressive environment (chemistry, high temperature) and tensile stress in the liner (lack of

post weld stress relieving, steel grain size, high temperature). The waste types associated with nitrate-induced stress corrosion cracking are:

- Tri-Butyl Phosphate (TBP) waste from uranium recovery - this waste was high in nitrate, very low in hydroxide, and was discharged at high temperature.
- REDOX waste – this waste was high in nitrate and also high heat generating and subject to self-concentration.
- Nitrate leached REDOX waste – leaching REDOX sludge to recover sodium nitrate would lower inhibitors in an already aggressive waste.

For example, there were five tanks that underwent nitrate leaching. Shortly after removing the leachate waste which would have reduced the amount of corrosion inhibitors present, these tanks were filled with high heat REDOX waste. All five of these tanks in SX Farm that were nitrate leached were identified as having a liner leak.

### **Summary**

The main causes for the liner leaks were: high tank operating temperatures and high rates of temperature increases that exceeded design parameters, tank construction design factors limiting thermal expansion of liners, and storage of waste types with chemistry conducive to corrosion of the tank liner [4]. The predominant corrosive waste types were tri-butyl phosphate waste, REDOX waste, and nitrate leached REDOX waste. All of these waste types fail to meet current double-shell tank chemistry specifications. An additional cause was a bulge in the tank liner. It is possible that no one particular cause could in isolation from the other have resulted in failure. Some or all of the causes can act serially or together to contribute to tank liner failure.

These results will be combined with the results from the other targets for interim milestone M-045-91F in a separate document which will evaluate and provide possible recommendations to improve leak detection and monitoring of the SSTs.

TABLE I. Tank Leak Cause Matrix<sup>1</sup> [7]

Tank	Design	Tank Construction Conditions	Bulging Liner	Thermal Conditions	Waste Chemistry	Other <sup>2</sup>	Other than a Liner Leak
A-104	●	●	●	●	●	—	—
A-105	●	●	●	●	●	● <sup>3</sup>	—
B-107	—	—	—	●	●	—	—
BY-103	—	●	—	●	●	—	—
C-101	—	—	—	●	●	—	Spare inlet and/or cascade outlet line leak
C-105	—	—	—	●	●	—	Spare inlet, cascade inlet line, Line V103, and/or condenser leak
SX-107	●	●	●	●	●	—	—
SX-108	●	●	●	●	●	—	—
SX-109	●	●	●	●	●	—	—
SX-111	●	●	●	●	●	—	—
SX-112	●	●	●	●	●	—	—
SX-113	●	●	●	●	●/-	—	—
SX-114	●	●	●	●	●	—	—
SX-115	●	●	●	●	●	—	—
T-106	—	—	—	●	●	● <sup>4</sup>	—
T-111	—	—	—	●	●	● <sup>4</sup>	—
TX-107	—	—	—	●	●	—	—
TX-114	—	—	—	●	●	—	—



**TABLE I. Tank Leak Cause Matrix<sup>1</sup> [7]**

Tank	Design	Tank Construction Conditions	Bulging Liner	Thermal Conditions	Waste Chemistry	Other <sup>2</sup>	Other than a Liner Leak
TY-103	–	•	–	•	●	–	–
TY-104	–	•	–	•	●	–	–
TY-105	–	•	–	•	●	–	–
TY-106	–	•	–	•	●	–	–
U-104	–	–	●	•	–	–	–
U-110	–	–	–	•	•	–	–
U-112	–	–	–	•	●	• <sup>5</sup>	–

1. Probable cause(s) for liner leaks illustrated by relative size of circles.
2. The Other column refers to leak causes that do not fall in the previous columns categories.
3. Initial grout vapor pressure possibly greater than the hydrostatic pressure in January 1963.
4. Replacement of T Farm bottom liners
5. Possible bottom liner buckling.

## REFERENCES

1. Field, J.G. (2013). RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure*, Rev. 2, Washington River Protection Solutions LLC., Richland, Washington.
2. Weyns, D.I. (2014). HNF-EP-0182, *Waste Tank Summary Report for Month Ending August 31, 2014*, Rev. 320, Washington River Protection Solutions LLC., Richland, Washington.
3. Anantatmula, R. P. and Schwenk, E. B. (1994). WHC-EP-0772, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
4. Edgemon, G. L. and Anantatmula, R. P. (1995). WHC-SD-WM-ER-414, *Hanford Waste Tank System Degradation Mechanisms*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
5. Beard et al. (1967). ARH-78, *PUREX Tk-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control*, Atlantic Richfield Hanford Company, Richland, Washington.
6. Bandyopadhyay et al. (1997). BNL-52527, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*, Brookhaven National Laboratory, Upton, New York.
7. Field, J.G. (2014). RPP-RPT-54909, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*, Rev. 0, Washington River Protection Solutions LLC., Richland, Washington.
8. Schofield, J.S. (2014). RPP-RPT-54921, *Estimation of Past Leak Rates for Selected Hanford Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions LLC., Richland, Washington.
9. Girardot, C.L. (2014). RPP-RPT-54910, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: 241-SX Farm*, Rev. 0, Washington River Protection Solutions LLC., Richland, Washington.
10. General Electric Company (1958). HW-57274, *Instability of Steel Bottoms in Waste Storage Tanks*, Richland, Washington.