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Single-Shell Tank Leak Integrity Summary

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Abstract: This document summarizes and evaluates the information in the Hanford Tri-Party Agreement Interim Milestone M-045-91F targets, completed between 2010 and 2015, (1) common factors of SST liner failures (M-045-91F-T02), (2) the feasibility of testing for ionic conductivity between the inside and outside of SSTs (M-045-91F-T03), and (3) the causes, locations, and rates of leaks from leaking SSTs (M-045-91F-T04).

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Contractor for the U.S. Department of Energy
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EXECUTIVE SUMMARY

This document addresses the *Hanford Federal Facility Agreement and Consent Order (HFFACO) – Tri-Party Agreement (TPA)*[1] interim milestone M-045-91F. The interim milestone requires preparation of a summary of the information and conclusions developed for the Single-Shell Tank Integrity Project (SSTIP) submitted in all M-045-91F interim milestone targets (M-045-91F-T02 through -T04). The document is specifically directed at the interim milestone targets but also includes interrelated single-shell tank (SST) integrity investigations conducted concurrently.

The M-045-91F targets, completed between 2010 and 2015, addressed: (1) common factors of SST liner failures (M-045-91F-T02), (2) the feasibility of testing for ionic conductivity between the inside and outside of SSTs (M-045-91F-T03), and (3) the causes, locations, and rates of leaks from leaking SSTs (M-045-91F-T04). Target milestone M-045-91F-T02 called for an investigation of historical waste storage factors that could possibly cause liner failure. A comprehensive list of all projected factors was included in the investigation that might contribute to liner failures. Target milestone M-045-91F-T03 was designed to test the feasibility of determining tank integrity by detecting ionically conductive pathways in tank liners. Detecting conductivity could possibly indicate the loss of tank liner integrity. Target milestone M-045-91F-T04 examined leak causes and locations of possible leaking SSTs and the determination of estimated leak rates. This effort was designed to provide additional information on SST leaking tanks for future reference and guidance. A total of 25 SSTs with possible liner leaks were previously identified in the individual tank farm leak assessments using the guidelines established in RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*,[2] document requirements.

Interrelated SST integrity investigations addressing SST intrusion, level loss, and corrosion testing were conducted during the work on the M-045-91F milestone targets. The SST intrusion evaluations and the review of the long-term liquid increases and decreases identified tanks with surface levels that needed to be evaluated in detail. The detailed evaluation of surface level decreases for the 30 SSTs screened for evaluation indicated that one of the tanks, T-111,[3] was leaking. Corrosion testing includes "noncompliant" waste,[4] ammonia inhibition effects, and testing of wastes identified in the common factors M-045-91F-T02 and -T04 reports that may have been caused by stress corrosion cracking (SCC). Initial testing of current SST aggressive waste layers determined to be noncompliant with the double-shell tank (DST) corrosion prevention specifications has been completed. Results indicate that none of the current SST tank chemistries that have been examined have the propensity for SCC at the current waste storage conditions. However, some of the tested chemistries exhibited propensities for pitting or localized corrosion.

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[1] Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement (TPA)*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

[2] RPP-32681, 2013, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

[3] Individual tanks and tank farms are referred to in this document without the "241-" preceding the tank/tank farm designator (e.g., Tank 241-T-111 is referred to as Tank T-111, and 241-T Tank Farm is referred to as T Farm).

[4] There are no corrosion prevention specifications for SSTs; noncompliant wastes are current SST waste compositions that would not comply with DST specifications.

Additional work is planned to better understand this behavior. Ammonia inhibition testing refers to understanding the ammonia concentrations that have been found in the past to inhibit vapor space and liquid-air interface corrosion.

The overall investigations into SST leak integrity represent a comprehensive effort to identify past leak causes and locations and to determine those factors that could contribute to future failures. The primary conclusions are:

- Large leaks from SSTs in the future are not likely due to decreasing waste temperatures, reduced free liquid volumes, less aggressive waste chemistries, and reduced potential for additional liner cracking.
- Application of SST level trending and analysis and the judicious identification of all factors contributing to level change allowed improved evaluation of SST tank leaks and water intrusion. These techniques will be useful in evaluating future SST level changes.
- Although the investigations represent a “best effort” summary of SST failures based on existing information, it is unlikely that additional information exists or is practically recoverable that would alter the conclusions.

Recommendations were compiled from the evaluations in four areas:

1. TFC-ENG-CHEM-D-42[5] tank leak assessments – There are currently 48 SSTs requiring a formal TFC-ENG-CHEM-D-42 leak assessment identified from the tank farms leak inventory assessments. The outstanding formal tank leak assessments should be performed based on a to-be-developed prioritization strategy encompassing risk, waste retrieval timing, and tank closure.
2. Leak detection, monitoring, and mitigation (LDMM) improvements – LDMM-related improvements include trending and analysis that are mentioned above.
3. Continuing SST integrity requirements – Continuing the SST integrity requirements includes dome deflection surveys, visual inspections, improvements in leak detection and monitoring (functions and requirements), intrusion mitigation, and improved understanding of corrosion.
4. Related recommendations – Related recommendations includes documenting recently retrieved historical data in the surveillance analysis computer system and the possibility of updating the common factors and leak causes, locations, and rates documents as needed. Lessons learned and best management practices are also included.

[5] TFC-ENG-CHEM-D-42, 2013, “Tank Leak Assessment Process,” Rev. B-7, Washington River Protection Solutions, LLC, Richland, Washington.

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TERMS

Acronyms

DBTT	ductile-to-brittle transition temperature
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EPOC	Expert Panel Oversight Committee
FY	fiscal year
HFFACO	Hanford Federal Facility Agreement and Consent Order
HRR	high resolution resistivity
ILL	interstitial liquid level
LAI	liquid-air interface
LD	liner degradation
LDMM	leak detection, monitoring, and mitigation
LIP	leak identification and prevention
LOW	liquid observation well
MCM	mitigation of contamination migration
ORP	Office of River Protection
PUREX	plutonium uranium extraction facility
REDOX	reduction-oxidation
SCC	stress corrosion cracking
SI	structural integrity
SL	surface level
SST	single-shell tank
SSTIP	Single-Shell Tank Integrity Project
TBP	tributyl phosphate
TPA	Tri-Party Agreement
WRPS	Washington River Protections Solutions, LLC

Units

°C	degrees Celsius
°F	degrees Fahrenheit
gal	gallon
in.	inch
ksi	kilopound per square inch
m	meter
mA/cm^2	milliamp per square centimeter
Mgal	million gallons
mV	millivolt
ppm	parts per million
s	second

1.0 INTRODUCTION

The purpose of this single-shell tank (SST) leak integrity summary report is to address the *Hanford Federal Facility Agreement and Consent Order (HFFACO) – Tri-Party Agreement (TPA)* (Ecology et al, 1989) interim milestone M-045-91F.

> *DOE shall provide to Ecology, for approval, a report (Summary Conclusions Report on Leak Integrity) summarizing and evaluating the information submitted under M-045-91F-T02 through –T04.*

The interim milestone requires preparation of a summary of the information and conclusions developed for the Single-Shell Tank Integrity Project (SSTIP) submitted in all interim milestone targets M-045-91F-T02 through -T04. The targets address: (1) determining any common factors of SST liner failures (M-045-91F-T02), (2) testing the feasibility of using ionic conductivity between the inside and outside of SSTs to detect leakage (M-045-91F-T03), and (3) determining the leak causes, locations, and rates from SSTs previously identified as having probable liner leaks (M-045-91F-T04). The summary report was intended to improve the overall understanding of the Hanford SSTs liner integrity by summarizing and evaluating the information in all targets and the relevant conclusions.

In addition to the above interim milestone targets, a summary of parallel evaluations addressing SST intrusion, level loss, and corrosion testing are included as appendices. The investigations used innovative analysis techniques and determined minimum detection conditions to identify tank intrusions and possible tank liner failures. Ongoing SST corrosion testing stems from expert panel recommendations and includes testing current SST wastes that would be noncompliant with respect to DST corrosion prevention specifications, understanding the effect of ammonia to inhibit corrosion, and testing wastes identified in the common factors M-045-91F-T02 report that may have caused stress corrosion cracking (SCC).

2.0 BACKGROUND

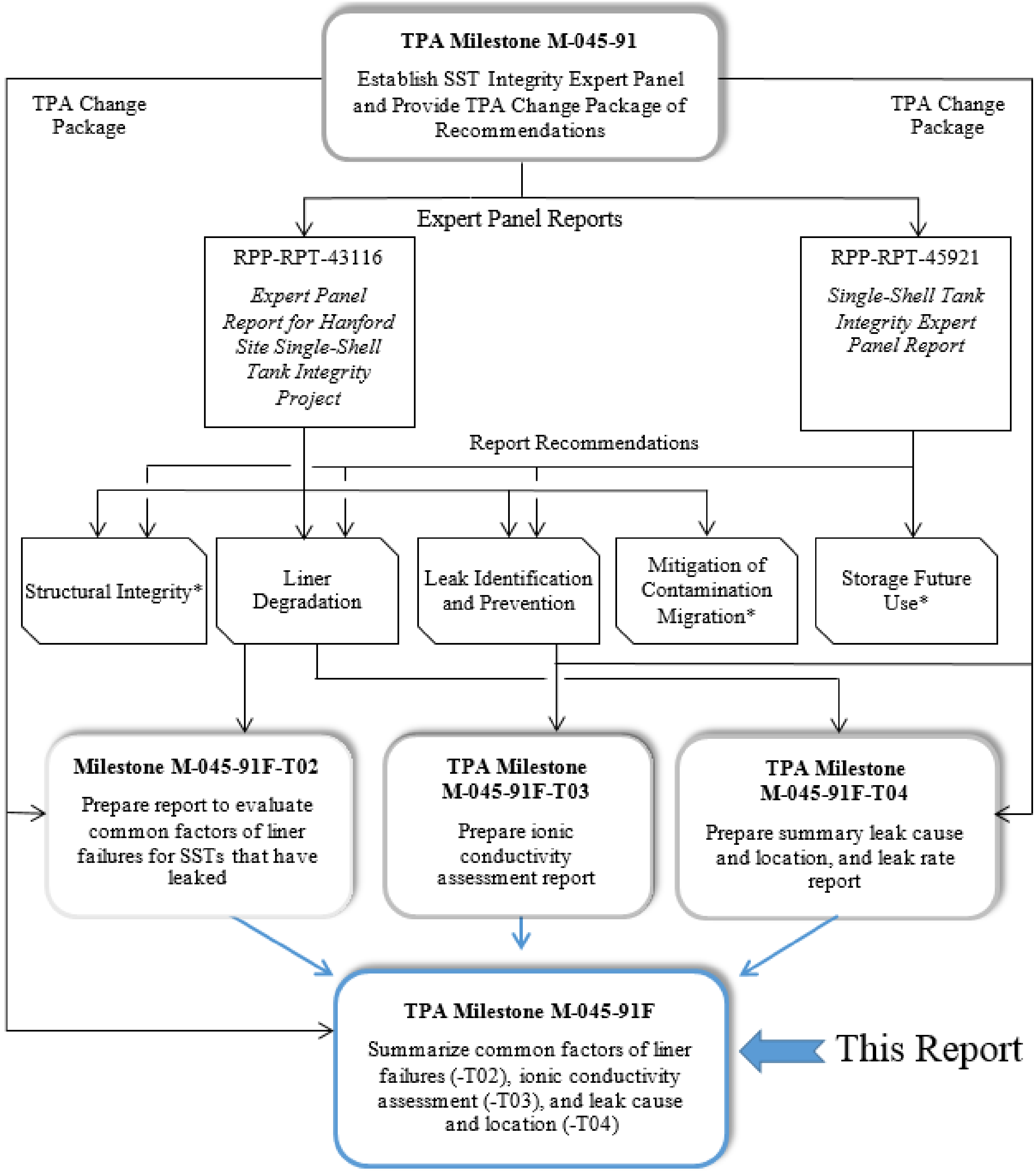
The TPA milestone, M-045-91, was completed September 27, 2010, and documented in 10-ESQ-286, "Completion of Hanford Federal Facility Agreement and Consent Order (HFFACO) Interim Milestone M-045-91, Due September 30, 2010" (Brockman 2010). The milestone required that the U.S. Department of Energy (DOE), Office of River Protection (ORP) establish a panel of technical and nationally recognized experts to provide a report on SST integrity for review and submittal to Washington State Department of Ecology (Ecology) and an agreement change package with HFFACO interim milestones to implement the Panel's recommendations. Brockman (2010) documented the completion of the requirement, providing two Single-Shell Tank Integrity Expert Panel reports, a TPA change package with interim milestones for approval, and an implementation plan.

The two Panel reports, RPP-RPT-43116, *Expert Panel Report for Hanford Single-Shell Tank Integrity Project*, and RPP-RPT-45921, *Single-Shell Tank Integrity Expert Panel Report*, completed the first part of interim milestone M-045-91 (i.e., provide a report on SST integrity). The second part of M-045-91 (i.e., submit TPA change package with interim milestones) was completed by transmittal of TPA change package M-45-10-01, "Hanford Federal Facility Agreement and Consent Order Tri-Party Agreement Change Package M-45-10-01," in January 2011 (Price 2011). The implementation plan, RPP-PLAN-45082, *Implementation Plan for the Single-Shell Tank Integrity Project*, was also included for information.

The TPA interim milestones and target dates regarding SST integrity were established based on the Panel's recommendations and negotiations between ORP and Ecology. The eight interim milestones, established via TPA change package M-45-10-01, covered recommendations from the Panel under the key elements structural integrity (SI), liner degradation (LD), leak identification and prevention (LIP), and mitigation of contamination migration (MCM). The Panel prioritized its recommendations in two ways: (1) overall prioritization, and (2) prioritization within the four key elements. The prioritization resulted in 10 primary recommendations, and Washington River Protections Solutions, LLC (WRPS) identified six of the 23 secondary recommendations for further investigation (RPP-PLAN-45082). The results of one of the primary recommendations (LD-1) and two of the secondary recommendations (LD-6 and LIP-8) are addressed in this document.

The TPA interim milestone M-045-91F, one of the eight interim milestones, originally contained four targets, M-045-91F-01 through -04. Target M-045-91F-T01 (LIP-5) was modified via TPA change control form M-45-13-01 "…to de-emphasize the reference to Savannah River Site leak rate assessments." The scope was transferred to M-045-91F-T04, and refocused on leak rates for the 25 100-series SSTs identified as probably leaking by the process defined in RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*. Target M-045-91F-T02 (LD-6) called for an investigation of current waste compositions that could cause liner failure through corrosion and included a comprehensive list of all projected factors that might contribute to liner failures. Target M-045-91F-T03 (LIP-8) was designed to test the feasibility of determining tank integrity using ionically conductive pathways in tank liners. Target M-045-91F-T04 (LD-1) examined leak causes, locations, and included rates as mentioned above.

Figure 2-1 graphically indicates the flowdown from milestone M-045-91 to interim milestone M-045-91F.



*See Interim Milestone M-045-91G (Structural Integrity) and Milestones M-045-92 and M-045-56 (Mitigation of Contamination Migration).

Figure 2-1. Hanford Tri-Party Agreement Interim Milestone M-045-91F

Parallel SST integrity evaluations related to intrusion, level loss, and SST corrosion testing were conducted during the work done on the above milestone targets. The results of these evaluations also affect conclusions about SSTIP activities.

The SST visual inspection plans originally focused on assessing dome integrity per expert panel structural integrity recommendation SI-4. Intrusion evidence was part of the dome integrity evaluation. Subsequently, a review of historical long-term increases in surface level incorporated visual inspections for possible evidence of water intrusion. A plan was developed to evaluate the level data increases and was later issued as RPP-PLAN-55112, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan*. RPP-PLAN-55112 was updated yearly through 2014. The plans resulted in an evaluation of 30 tanks provided in RPP-RPT-50799, *Suspect Water Intrusion in Hanford Single Shell Tanks*.

The expert panel made two recommendations related to tank chemistry that would aid in assessing the likelihood of future tank liner degradation: (1) examine “noncompliant” wastes at 25°C (LD-3), and (2) determine ammonia corrosion control concentration (LD-5). Noncompliant wastes are SST wastes that fail to meet specific temperature, nitrite, nitrate, and hydroxide concentration criteria for the double-shell tanks (DST) given in OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks*. Ammonia in sufficient concentrations has the potential to inhibit liner corrosion. Laboratory testing is designed to determine the concentration of ammonia required to control corrosion in the liquid phases of the solid and supernatant layers at the liquid-air interface (LAI) and on the exposed liner in the vapor spaces. For efficiency, this testing is integrated with the DST testing program.

Additional recommendations related to SST waste chemistry were made in the report discussing common factors of SST liner failures (RPP-RPT-55804, *Common Factors Relating to Liner Failures in Single-Shell Tanks*). This report proposed three aggressive waste chemistries that potentially caused tank failure. To validate those claims, corrosion testing was recommended. This “common factors” corrosion testing, which is currently being conducted, was designed to determine propensity for SCC at historical waste concentrations and temperatures using modern testing techniques. SST corrosion testing is integrated with the DST corrosion testing program and guided by corrosion and chemistry experts on the DST Expert Panel Oversight Committee (EPOC).

Sections 3.0 and 4.0 describe the performance of the work for each of the three targets, along with the conclusions. Section 5.0 provides a discussion of some of the important features relevant to the preceding sections, including some of the improvements in developing techniques to analyze data for the reports. Section 6.0 describes lessons learned and best management practices. Most of the recommendations were derived from improvements in developing techniques to analyze data and identify minimum detection conditions for the reports, especially centering on monitoring for leak detection by improved surface level monitoring. There is also information in this section on the continuing SST integrity requirements and related documents.

The summary document approach and preliminary outline were reviewed with ORP and Ecology on January 15, 2015 (Appendix A).

3.0 TARGET REPORT SUMMARIES

The M-045-91F-T02, -T03, and -T04 target reports are summarized in this section. These reports provide a basis for improving the understanding of the mechanisms that have caused tank liner failures in the past and investigate a new approach to identify tank leak mechanisms. The results provide conclusions and recommendations for possible leak causes, leak locations, leak rates, improved leak detection and monitoring of the SSTs, and input to retrieval decisions.

Prior to initiating work on M-045-91F-T02 and -T04 targets, a team was assembled and a series of meetings were held with ORP and Ecology to present and discuss information reviewed pertaining to tank leak inventory estimates to be included in leak inventory assessment reports (RPP-32681). During the collaborative effort, participants discovered that some of the tanks identified as "assumed leakers" may not have leaked, and the 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. 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. The team recommended one of three possible categories for each tank analyzed: (1) the tank should be classified as "sound," (2) the tank should be classified as an assumed leaker, or (3) the tank should be analyzed in more detail. Out of the 149 SSTs, the team identified 25 tanks as having a probable liner leak out of the 67 SSTs identified as an "assumed leaker." Other tanks are recommended for a formal leak assessment per TFC-ENG-CHEM-D-42, "Tank Leak Assessment Process." The M-045-91F-T02 and -T04 targets focused on the 25 SSTs identified as having probable liner leaks but also included other SSTs in the analysis.

3.1 M-045-91F-T02 – RPP-RPT-55804, *COMMON FACTORS RELATING TO LINER FAILURES IN SINGLE-SHELL TANKS*

The M-045-91F-T02 target requires DOE to provide a report to Ecology on the SSTs identified in the RPP-32681 tank farms leak assessment inventory reports as having leaked. RPP-RPT-55804 was prepared to meet that target. The M-045-91F-T02 target states:

> *DOE shall provide to Ecology as a HFFACO secondary document a report, evaluating the common factors of liner failures for SSTs that have leaked and will provide recommendations as appropriate, such as enhanced leak detection, monitoring, and mitigation. For purposes of this milestone, the SSTs that have leaked are identified through the RPP-32681, Rev. 0, Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning.*

The objective of RPP-RPT-55804 was to identify the common factors that may have contributed to liner failure in SSTs that leaked and to identify tanks that may be at higher risk of future leakage. This analysis was conducted for the 149 Type I, Type II, Type III, and Type IV SSTs. The evaluation compared the conditions of tanks with known liner failures to tanks not known to have liner failures to determine the commonality of possible causes for those known failures.

3.1.1 Method for Evaluating Common Factors of Single-Shell Tank Liner Failures

The method used to evaluate common factors of SST liner failures is illustrated in Figure 3-1. The first step in the methodology consisted of identifying the broadest set of mechanisms (i.e., a series of events or processes) that could reasonably cause or play a supportive role in causing liner failure.

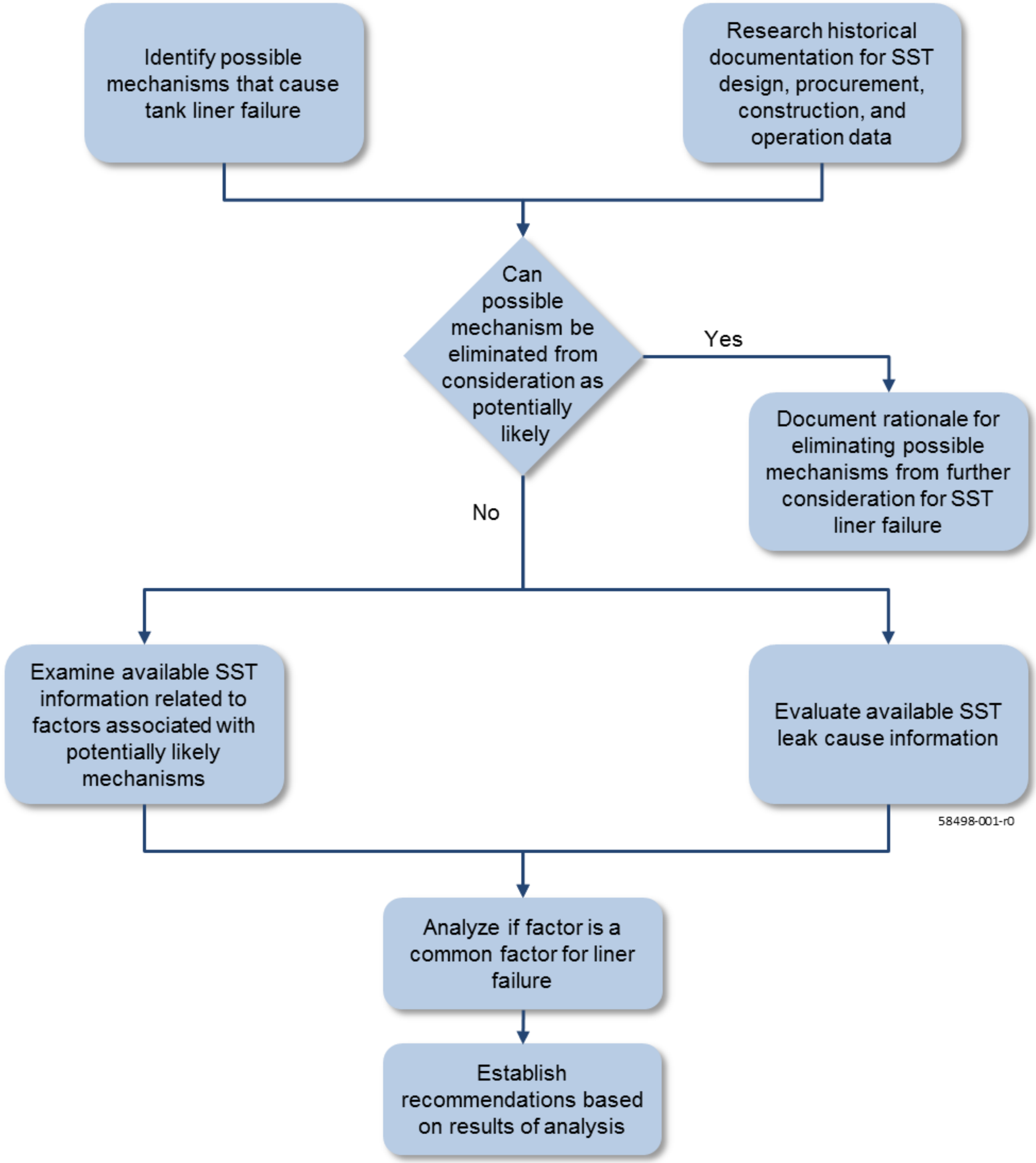


Figure 3-1. Methodology for Identifying Common Factors Contributing to Liner Failures

The mechanisms considered were derived from a number of sources, most notably:

- BNL-52527, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*
- *ASME Boiler and Pressure Vessel Code*, Section II – Materials, Part D – Properties, non-mandatory Appendix A, "Issues Associated with Materials Used in ASME Code Construction"
- Historical Hanford Site documents associated with past SST failures.

Historical SST documentation associated with these mechanisms was then collected.

The second step of the process was to evaluate each mechanism against SST historical information to determine if the factors necessary for the mechanism to occur might be present. If known that those factors were not present or were not significant, those mechanisms were eliminated as not being likely. All other remaining mechanisms were considered potentially likely. At this point in the evaluation, the mechanisms are considered potentially likely because they have not been evaluated in detail to determine if the mechanism was a likely factor contributing to liner failure.

For the mechanisms deemed potentially likely, the presence of the factors causing the mechanism was evaluated in greater detail to see if the underlying factors associated with a particular mechanism were indeed present. This step of the process involved collecting and reviewing available historical information regarding the design, procurement, construction, and operation of the SSTs that was related to factors associated with each of the potentially likely mechanisms. Some of this information was available via the work performed under TPA target M-045-91F-T04, thus eliminating duplication of effort.

The next step of the methodology was to analyze the detailed information to determine if a particular factor was a common factor in tank liner failures. The analysis, where possible, relied on statistical tests for dichotomous categorical data (i.e., liner failure vs. no liner failure). The analysis was hampered by the relatively large number of variables that could not be eliminated from consideration and the relatively small data set available. The analysis was also constrained by the limited availability of historical information.

3.1.2 M-045-91F-T02 Report Conclusions

Out of the extensive list of mechanisms identified, a total of 28 mechanisms were considered as potential contributors to SST liner failures. Available historical information was examined for SSTs relative to the 28 potential failure mechanisms. Statistical analyses were performed, where appropriate, to determine what factors were significant in causing or contributing to SST liner failures. Adequate historical information was not available for 14 of the 28 potentially likely failure mechanisms. For these 14 mechanisms, no determination could be made if the failure mechanism was a likely or unlikely factor contributing to liner failure. Of the remaining 14 failure mechanisms analyzed, six mechanisms were evaluated as likely factors contributing to liner failure and the remainder were unlikely. The 28 failure mechanisms, and whether each was a likely or unlikely factor or it was indeterminate, are listed in Table 3-1.

Table 3-1. Analysis Results of Potentially Likely Failure Mechanisms

Liner failure mechanisms	Indeterminate	Unlikely	Likely
Design and Design Modification Flaws			
Lack of post-weld stress relieving			✓
Liner bottom to wall transition design			✓
Exterior finish of tank liner	✓		
Lack of vent path for gases formed below tank liner		✓	
Procured Material Defects			
Properties of liner materials			
Carbon equivalent		✓	
Yield strength			✓
Material standard and grade	✓		
Liner plate thickness	✓		
Steel liner plate defects	✓		
Weld material defects	✓		
Tank Fabrication Defects			
Brittle fracture or crack propagation during fabrication		✓	
Cold working and strain aging (shop-fabricated knuckles and weld peening)		✓	
Weld joint discontinuities and defects	✓		
Operational Service Related Failure Mechanisms			
Low-cycle fatigue		✓	
Temperature-induced failure			
Rate of rise	✓		
High temperature			✓
Corrosion			
General or uniform corrosion		✓	
Pitting corrosion	✓		
Crevice corrosion	✓		
Stress-corrosion cracking			
Nitrate-induced			✓[a]
Caustic cracking		✓	
Carbonate-induced	✓		
Concentration cell corrosion			
Liquid-air interface	✓		
Solid-liquid interface	✓		
Solid-solid interface		✓	
Vapor space corrosion	✓		
Differential temperature cell corrosion	✓		
External Environmental Failure Mechanisms			
Pressurization external to tank liner			✓

[a] Nitrate-induced stress-corrosion cracking is likely for three waste types: tributyl phosphate waste, if it is the first waste in a tank; REDOX concentrated and neutralized salt waste; and in-farm nitrate leaching. Nitrate-induced stress-corrosion cracking is unlikely for other waste types considered, except for PUREX 1970 thoria campaign waste for which the analysis was indeterminate.

Some general conclusions regarding this work include the following.

- Lack of post-weld stress relieving and tank liner bottom-to-wall transition design for Type IV tanks are likely design and construction features contributing to certain SST liner failures.
- Yield strength, which may be considered a surrogate for grain size, appears to be a common factor contributing specifically to liner failure due to nitrate-induced SCC.
- High operational temperature associated with boiling waste is a likely common factor contributing to liner failure.
- The only form of corrosion that is known 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 SCC are:
  - Uranium recovery tributyl phosphate (TBP) waste, provided this waste was the first waste introduced to the SST. If TBP waste was subsequently added to a tank that previously held another waste type, there is no such relationship to liner failure.
  - Reduction-oxidation (REDOX) concentrated and neutralized waste, in the absence of combined coating removal waste.
  - In-farm nitrate leaching waste.
  - The in-farm nitrate leached tanks also received REDOX concentrated and neutralized waste prior to nitrate leaching, making these waste types confounding variables to each other.

Some of the conclusions limit precise predictions as follows:

- Small sample sets of tanks with and without a particular mechanism present limit confidence in the results.
- Because the evaluations are based on field data rather than carefully controlled “experiments,” a number of confounding variables may be present that mask the real common factors contributing to liner failure.
- Precise identification of the cause of each of the 25 known liner failures is not possible with the available information.
- Little information is available regarding the properties of the materials used for the SST liners, which generally does not allow determination of the role played by the materials in liner failure.

Table 3-2 summarizes the six mechanisms that are likely common factors contributing to SST liner failure. With the exception of the lack of post-weld stress relieving, none of these factors were present in all 25 tanks with probable liner failures. For clarity, the nitrate-induced SCC mechanism is split into three entries for the three different waste types causing nitrate-induced SCC.

Table 3-2. Single-Shell Tank Liner Failure Common Factors

Condition	Comments
Tank not post-weld stress relieved	None of the single-shell tanks were post-weld stress relieved. Because of this, there is no way of quantifying the impact on tank liner failure. Post-weld residual stress is considered a significant source of tensile stress in the steel liner, which is necessary for stress-corrosion cracking. This was also the case in tank liner failures at the Savannah River Site.
Liner bottom to wall transition design	Relatively weak orthogonal fillet weld joints were used in the 21 tanks in the SX and A Farms. The failure rate in these two tank farms is much higher than the overall population failure rate. Tanks with small and large radius knuckles and relatively strong butt weld joints were used in all other tank farms.
Yield strength ≤ 27 ksi	Lower minimum yield strength material (<27 ksi) is found in TX, BY, S, TY, SX, and A Farm tanks. Yield strength may be considered a surrogate for grain size, with inverse relationship between yield strength and grain size. A larger grain size lowers the resistance to SCC of carbon steel in nitrate solutions. Due to the presence of confounding factors, it is not possible to determine this unequivocally.
High temperature	Boiling waste was stored in the 10 tanks of A and AX Farms, 11 of the 15 tanks in SX Farm (all but SX-102, SX-103, SX-105, SX-106), and in Tanks S-101, S-104, and U-104. Waste typically contained a layer of settled sludge on the tank bottom. These solids were at higher temperatures than the liquid due to conductive heat transfer in the solids. Higher temperatures are associated with higher stresses in the tank liner and can also initiate or generate faster rates of corrosion, including SCC.
Nitrate-induced SCC – First waste is TBP waste	Tanks TY-103, TY-104, TY-105, and TY-106 were the only tanks that first received TBP waste generated prior to in-plant scavenging. All of these tanks have probable liner leaks. TBP waste contained high nitrate concentration, but low hydroxide concentration and little or no nitrite conducive to SCC.
Nitrate-induced SCC – Received REDOX waste	There are 32 tanks that received REDOX concentrated and neutralized salt waste segregated from coating waste. These tanks are in SX, TX and U Farms. Eight of the 11 probable failures are in SX Farm, with one in TX Farm and two in U Farm. REDOX concentrated and neutralized salt waste contained high nitrate concentration, but low hydroxide and nitrite concentrations conducive to SCC.
Nitrate induced SCC – Contained nitrate leaching waste	Tanks SX-107, SX-108, SX-111, SX-114, and SX-115 were the only tanks in which nitrate leaching of sludge from REDOX concentrated and neutralized waste was performed. All of these tanks have probable liner failures. Tank SX-105 also held the waste from nitrate leaching but did not have a liner failure. Waste from nitrate leaching contained high nitrate concentration, but low hydroxide and nitrite concentrations conducive to SCC.
Primary indication of a bulged liner	Tanks U-104, SX-108, SX-113, SX-115, and A-105 all have primary indication of a bulged liner (through photographic evidence or tank bottom depth sounding). A bulge can result in a tear in the liner or increased stresses. All of these tanks have probable liner leaks. Other tanks may have bulged, but documentation providing primary indication of a bulge was not found.

REDOX = reduction-oxidation.
SCC = stress corrosion cracking.
TBP = tributyl phosphate.

The comment section of the table shows that all of the factors were present in SX Farm tanks, except TBP waste. All of the factors were present in the A Farm tanks, with the exception of waste causing nitrate-induced SCC. Generally, the operational mechanisms (e.g., high temperature, nitrate-induced SCC, external pressurization) do not show up or show up infrequently in the earliest SSTs.

The identification of SCC as a common factor is in some conflict with historical corrosion testing reported for many waste types and storage conditions that generally showed favorable results. These tests, especially those related to SCC, were limited and lack the sensitivity of modern corrosion testing. Therefore, testing of select waste types using modern testing methods designed to detect SCC is planned to gauge the propensity for SCC.

Historical general and pitting corrosion test results are available for the major waste types and generally show low corrosion rates. Lack of corrosion test data for certain waste types and lack of data covering all waste conditions results in a level of uncertainty in understanding the full extent of past corrosion. Based on available historic sample data, a small fraction of the waste material samples would not meet current DST corrosion prevention specifications that are preventive of general corrosion (< 1 mil/year), pitting corrosion, and SCC.

The 48 tanks currently awaiting formal leak assessments per the TFC-ENG-CHEM-D-42 procedure are considered sound for the purpose of the common factors analysis. The number of additional tanks with probable liner failures is indeterminate and could have an impact on this analysis if a significant number are found to have probable liner failures.

3.2 M-045-91F-T03 – RPP-ASMT-51526, *TRI-PARTY AGREEMENT TARGET MILESTONE M45-91F-T-03 IONIC CONDUCTIVITY ASSESSMENT*

The M-045-91F-T03 target requires that DOE provide a report to Ecology on the feasibility of using ionic conductivity to detect ionically conductive pathways in the tank liners. The current retrieval tank leak detection system, high resolution resistivity (HRR), measures the decrease in resistance if waste starts leaking from a tank. Ionic conductivity uses the presence of ions from previous waste leaks to detect ionically conductive pathways in the tank liners, which would provide an indication of the loss of liner integrity without necessarily increasing the amount of waste in the vadose zone. If successful, this technique would allow the integrity determination prior to retrieval operations instead of during operations. The specific M-045-91F-T03 target states:

> *DOE shall provide to Ecology, as a HFFACO secondary document, a report assessing the feasibility of testing for ionic conductivity between the inside and outside of SSTs.*

The ionic conductivity feasibility study was conducted through the Ohio State University and its supporting laboratory at the DNV-GL facility in Columbus, Ohio. The study was split into three different tasks of increasing complexity (RPP-ASMT-51526, *Tri-Party Agreement Target Milestone M45-91F-T-03 Ionic Conductivity Assessment*). The first task was to develop an equivalent electrical circuit to simulate response of the system with and without the presence of a crack in the wall of test cans.

Benchtop experiments were performed in the second task using small test cans (4-in. or 6-in. diameter cans, as shown in Figure 3-2) embedded in dirt and filled with waste simulants. The third task consisted of performing a larger-scale test if the results of Task 1 and Task 2 were encouraging. This larger-scale test used a 26-gal container (also shown in Figure 3-2).

Changes in the conductivity measurements of the system can be correlated to the presence of cracks intentionally created in the cans. A basic schematic of how this electrochemical impedance spectroscopy system could be deployed in waste tanks is shown in Figure 3-3.

Figure 3-2. Three Test Systems Used in the Ionic Conductivity Feasibility Study (4-in. and 6-in. Diameter Cans and a 26-gal Container)

The electrochemical impedance spectroscopy response was similar to that predicted by the equivalent circuit developed in the first task, which validated the parameters used to determine the model circuit element values. The experiments and the simulation modeling predict that the approach would only be able to detect defects such as cracks or holes in the SST steel liner if the area of the defect is relatively large.

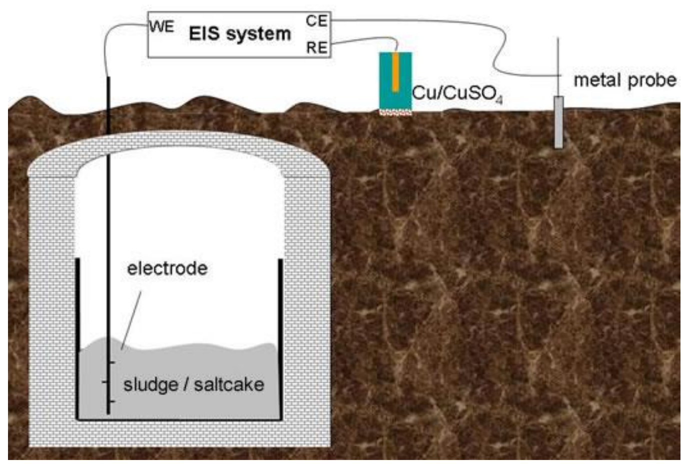


Figure 3-3. Schematic of an Electrochemical Impedance Spectroscopy System to Measure Ionic Pathways

The resistance to current flow through the intact part of a can or tank liner decreases as the area increases. Therefore, the approach is viable for detecting defects in a small container, but is not suitable for detecting small defects in large waste tanks. This method should be able to detect a defect with an area that is more than about 1,000 times smaller than the exposed tank area, but not if the defect area is 10,000 times smaller than the exposed tank area. At 1,000 times smaller, a typical stress corrosion crack width in a half-full 1 Mgal SST would be ~1 m in length. Task 3 (performed on a large 25.6-gal drum) supported this conclusion, as a small hole in the drum had little influence on the electrochemical impedance spectroscopy response. Therefore, the use of ionic conductivity to identify tank failures prior to retrieval was concluded to not be a practical method.

3.3 M-045-91F-T04 – RPP-RPT-54909, *HANFORD SINGLE-SHELL TANKS LEAK CAUSES, LOCATIONS, AND RATES: SUMMARY REPORT*

In accordance with the M-045-91F-T04 target, further evaluation was performed for the 25 tanks identified as having a probable liner leak in the RPP-32681 process. The M-045-91F-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.

> *DOE shall provide to Ecology, as a HFFACO secondary document, a report on the 100-series single-shell tanks which have been or will be identified as having leaked in RPP-32681… The report will include identification and evaluation of leak locations and leak causes (including chemistry stress corrosion cracking – SCC) as well as leak rates for the 100-series tanks currently identified as having leaked and include a recommendation whether to update and revise the leak assessment reports to include the leak information…*

Performing these analyses would establish a permanent archive of the leaking SSTs for retrieval decisions 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 (WHC-EP-0772, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*, and WHC-SD-WM-ER-414, *Hanford Waste Tank System Degradation Mechanisms*). In a limited number of cases, bulges of the tank liner bottom have also been explored for the relation of bulging to liner failure (ARH-78, *PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control*). However, tank liners may fail due to any of a number of mechanisms (BNL-52527).

Leak cause(s), leak location(s), and leak rate(s) were determined for each of the 25 100-series tanks identified as having a probable liner leak. For detailed information on these analyses, Table 3-3 lists the appropriate report for each tank. A summary document (RPP-RPT-54909, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*) was prepared to compile the results from the nine reports on leak causes, leak locations, and leak rates that fulfilled the M-045-91F-T04 target requirements.

Table 3-3. Tank Farm Leak Causes and Locations, and Leak Rates Reports

Farm	Tank(s)	Leak causes and locations report[a]	Leak rate report[a]
A	A-104	RPP-RPT-54912	RPP-RPT-54921, App. A
	A-105	RPP-RPT-54912	RPP-RPT-54921, App. A
B	B-107	RPP-RPT-54913	RPP-RPT-54921, App. B
BY	BY-103	RPP-RPT-54911	RPP-RPT-54921, App. B
C	C-101	RPP-RPT-54914	RPP-RPT-54921, App. C
	C-105	RPP-RPT-54914	RPP-RPT-54921, App. C
SX	SX-107	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-108	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-109	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-111	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-112	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-113	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-114	RPP-RPT-54910	RPP-RPT-54921, App. D
	SX-115	RPP-RPT-54910	RPP-RPT-54921, App. D
T	T-106	RPP-RPT-54916	RPP-RPT-54921, App. E
	T-111	RPP-RPT-54916	RPP-RPT-54921, App. E
TX	TX-107	RPP-RPT-54917	RPP-RPT-54921, App. E
	TX-114	RPP-RPT-54917	RPP-RPT-54921, App. E
TY	TY-103	RPP-RPT-54911	RPP-RPT-54921, App. E
	TY-104	RPP-RPT-54911	RPP-RPT-54921, App. E
	TY-105	RPP-RPT-54911	RPP-RPT-54921, App. E
	TY-106	RPP-RPT-54911	RPP-RPT-54921, App. E
U	U-104	RPP-RPT-54915	RPP-RPT-54921, App. F
	U-110	RPP-RPT-54915	RPP-RPT-54921, App. F
	U-112	RPP-RPT-54915	RPP-RPT-54921, App. F

[a] Full references are provided in Section 7.0.

3.3.1 Process to Assess Liner Leak Causes, Leak Locations, and Leak Rates

The review process started with an assessment of the individual tank information, including operating and construction histories, tank design, materials used during construction, and construction conditions. Historical documents were reviewed to identify possible 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. The individual tank farm information was then reviewed to understand the differences in the failed tank conditions, which may have predisposed that tank to leak.

In-tank and ex-tank leak detection information was reviewed to identify leak location and leak rates. This review provided the basic data identifying where and when the first leaks were detected. In-tank leak detection consists of liquid level measurements augmented with photographs that provide an indication of the vertical levels liquids reached on the tank sidewall. Other in-tank parameters reviewed include temperature of the supernatant and solids, 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 when 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 include tank design features, tank construction difficulties, ambient and waste temperature, tank waste chemistry conducive to different types of corrosion (uniform corrosion, nitrate-induced SCC, pitting, crevice, and LAI corrosion), and bulges in the tank bottom. Waste temperature 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 determined in the RPP-32681 process by an assumed leak duration.

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

3.3.2 M-045-91F-T04 Conclusions

Twenty-five SSTs were analyzed to identify leak causes, leak locations, and leak rates and are summarized in RPP-RPT-54909. Of the probable liner leaks, 20 of 25 SST 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).

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 (RPP-RPT-54921, *Estimation of Past Leak Rates for Selected Hanford Single-Shell Tanks*). Leak rate estimates were not prepared for two of the leaking tanks in C Farm, since this farm was undergoing retrieval. In many cases, the leak volumes associated with leak rates based on level change rates vary significantly from volumes previously developed in the RPP-32681 process. These differences result from assumptions and data uncertainties used for each analysis.

Although significant differences were observed, due to uncertainties in both methods, no updates to the leak volume estimates from the RPP-32681 process are warranted for any of the tanks evaluated. Tanks with sufficiently low leak rates could be candidates for less costly waste retrieval by modified sluicing or saltcake dissolution, with minimal impact to the environment.

Table 3-4 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.

Table 3-4. Tank Leak Cause Matrix (2 pages)

Tank	Design[a]	Tank construction conditions	Bulging liner	Thermal conditions	Waste chemistry	Other	Other than a liner leak
A-104	●	·	·	●	•	–	–
A-105	●	·	●	•	·	● [b]	–
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	●	•	•	●	·/–	–	–

Table 3-4. Tank Leak Cause Matrix (2 pages)

Tank	Design[a]	Tank construction conditions	Bulging liner	Thermal conditions	Waste chemistry	Other	Other than a liner leak
SX-114	⬤	•	·	⬤	●	–	–
SX-115	⬤	•	·	⬤	●	–	–
T-106	–	–	–	·	·	· [c]	–
T-111	–	–	–	·	·	· [c]	–
TX-107	–	–	–	·	•	–	–
TX-114	–	–	–	•	•	–	–
TY-103	–	·	–	·	●	–	–
TY-104	–	·	–	·	●	–	–
TY-105	–	·	–	·	●	–	–
TY-106	–	·	–	·	●	–	–
U-104	–	–	●	·	–	–	–
U-110	–	–	–	·	·	–	–
U-112	–	–	–	·	•	· [d]	–

Source: RPP-RPT-54909, 2014, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

[a] Probable cause(s) for liner leaks illustrated by relative size of circle.
[b] Other possible cause includes initial grout vapor pressure greater than hydrostatic pressure in January 1963.
[c] Other possible cause includes replacement of the T Farm bottom liners during construction.
[d] Other possible cause includes bottom liner buckling.

Tank Design

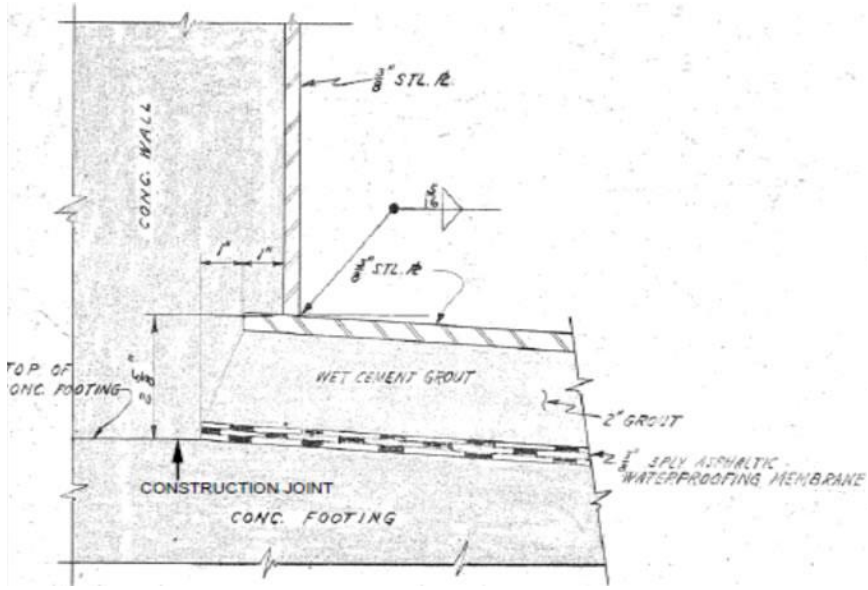


Figure 3-4. SX Farm Tank Bottom Liner to Sidewall Design Detail

Tank design was identified as a contributing cause to liner failure primarily based on design features limiting thermal expansion of the bottom liner with the 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. Figure 3-4 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.

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. The most severe temperatures were determined to have occurred during construction of SX Farm (RPP-RPT-54910, *Hanford Single-Shell Tank Leak Causes and Locations – 241-SX Farm*). A photograph of the SX Farm under construction (Figure 3-5), 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.

Figure 3-5. SX Farm Construction (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 (HW-57274, *Instability of Steel Bottoms in Waste Storage Tanks*). Several of the design changes led 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, which could increase the severity of the condition. Thermal expansion relieved by bulging of the land-locked liner, in the extreme, created cracks or invited localized SCC. Episodic bulging occurred in some tanks.

Thermal Conditions

High temperatures or a high temperature rate of rise within the SSTs can potentially create conditions in which a mechanical or chemical-corrosion 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 include general corrosion, pitting corrosion, and SCC. Only one of these forms of corrosion, nitrate-induced SCC, is believed to be a common factor contributing to liner failure. SCC 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 SCC are:

- TBP waste from uranium recovery – This waste was high in nitrate, very low in hydroxide, and 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 that 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.

4.0 PARALLEL INVESTIGATIONS

Interrelated SST integrity investigations were conducted during the work that was done on the milestone targets discussed in Section 3.0. These parallel evaluations address SST intrusion, level loss, and corrosion testing. The results, lessons learned, and best management practices from the evaluations are relevant to the improvements in the SSTIP summarized in this document.

The SST intrusion evaluations and review of the long-term liquid increases and decreases identified tanks with decreasing surface levels to be evaluated in detail (Appendix B). A surface-level change presents the possibility of masking a liner leak. The detailed evaluation of surface level loss for the initial set of 20 SSTs screened (21 actually evaluated), and later for an additional nine tanks, indicated that one of the tanks (T-111) was leaking (Appendix C). The conclusion does not mean that the other tanks are not leaking, but that there is no basis to conclude that they are leaking.

The SST corrosion testing includes “noncompliant” waste, ammonia inhibition effects, and wastes identified in the common factors M-045-91F-T02 and -T04 reports that may have been caused by SCC (Appendix D). Testing of current SST aggressive waste layers determined to be noncompliant with respect to the DST corrosion prevention specifications provides information on the propensity of SCC in SSTs at current waste compositions and temperatures, and on corrosion in general. Results indicate that none of the current SST waste chemistries that have been examined have the propensity for SCC under current waste storage conditions.

Ammonia inhibition testing refers to developing a protocol to understand the ammonia concentrations that have been found in the past to inhibit vapor space and LAI corrosion. Testing has focused on developing a reliable technique to initiate corrosion and then supplying ammonia to inhibit the corrosion. Preliminary results indicate the ammonia appears to provide an inhibiting effect.

Three waste types (TBP, REDOX, and nitrate leached) were identified in the M-045-91F-T02 and -T04 target reports as likely having caused SCC. Using modern testing methods designed to detect SCC, testing is being conducted to gauge the propensity of these waste types for SCC at appropriate temperature intervals to define historic corrosion.

5.0 SINGLE-SHELL TANK LEAK INTEGRITY EVALUATION

Interim milestone targets M-045-91F-T02 and -T04 proved useful in determining probable causes of SST liner failures, either acting alone or with one or more of the other potential causes, and in determining probable leak rates. However, the evaluations were hampered by insufficient detailed historical documentation, preventing a more comprehensive analysis. Examples include the number of individual formal tank leak assessments awaiting evaluation per the TFC-ENG-CHEM-D-42 leak assessment process, which may identify additional probable leaking tank liners potentially affecting both M-045-91F-T02 and -T04, and the number of common factor failure mechanisms judged indeterminate for lack of historical information. Notwithstanding these deficiencies, the documentation for the two targets achieved the goal of the targets within the limits of the available information. In addition, the compiled references for the issued documents should provide an excellent source of information for future inquiry, along with the compiled information on 200 Area historical processes and wastes.

The parallel investigations, not directly associated with interim milestones involving SST intrusion and level loss, have been performed using advanced analysis techniques developed for the effort, with emphasis on ensuring timely and accurate data. The SST corrosion testing was initiated to determine the propensity of SCC in historical waste solutions at storage temperatures and under current waste storage conditions using modern testing methods. An additional related task was to evaluate corrosion inhibition by ammonia formed in the tanks.

The following evaluations centered on predictive capability; enhanced leak detection, monitoring, and mitigation (LDMM); and formal leak assessments per TFC-ENG-CHEM-D-42.

5.1 PREDICTIVE CAPABILITY

The investigations of leak causes from M-045-91F-T02 and -T04 provided insight into the causes of past liner leaks. Both efforts identified the same core set of leak causes (summarized in Table 5-1). Some primary causes were related to historically aggressive operating conditions, primarily high temperature and the presence of chemistry conducive to SCC, both of which are decreasing in importance as waste storage temperatures decrease. Stress levels on the tank liners are also likely to decrease with time and the lower waste temperatures. The expert panel previously recommended analysis or examination of stress relaxation of the tank liners to determine if SCC is possible in the future. This recommendation has not been adopted, but corrosion testing of aggressive waste layers for SCC potential has been examined (Appendix D). None of the tank chemistries examined showed the potential for SCC at current waste storage temperatures.

Other causes identified from the M-045-91F-T02 and -T04 targets are related to fixed conditions, such as tank design that restricted thermal expansion, material selection, or construction conditions. Some of these causes, combined with aggressive operating conditions, contributed to tank liner failure.

Table 5-1. Comparison of Leak Causes for Single-Shell Tanks from M-045-91F-T02 and M-045-91F-T04 Efforts

M-045-91F-T04 SST leak cause, location, and leak rate summary report[a]	M-045-91F-T02 Common factors relating to liner failures in SST[b]	Comments
–	Lack of post-weld stress relief	Fixed condition common to all SSTs
Tank design limiting thermal expansion	Liner-to-wall transition design	Fixed design for A and SX Farms
–	Lower yield strength steel plate	Potentially confounded by other aggressive conditions (aggressive waste, high temperature)
High operating temperature and high rate of rise	High temperature was likely, high rate of rise was indeterminate	Temperatures often exceeded specifications at the time. Several sound tanks experienced high rates of rise. Current SST temperatures are much lower.
Corrosive waste types • TBP waste • REDOX waste • Nitrate-leached REDOX waste	Nitrate-induced stress corrosion cracking • TBP waste • Redox waste (without coating waste) • Nitrate leaching waste	General conditions were high nitrate, low nitrite, and high temperature. REDOX waste with coating waste was far less aggressive. Current SST waste chemistry is less aggressive and storage conditions are more benign.
Bottom liner bulge	Tank bottom bulging (external pressurization)	Bulges are transient conditions and indeterminate as to cause or effect of liner failure
Brittle fracture of steel during extreme cold weather construction (DBTT)	Brittle fracture determined to be unlikely based on statistical analysis	Failure requires impact to occur during period of cold weather

[a] RPP-RPT-54909, 2014, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.
[b] RPP-RPT-55804, 2015, *Common Factors Relating to Liner Failures in Single-Shell Tanks*, Washington River Protection Solutions, LLC, Richland, Washington.

DBTT = ductile-to-brittle transition temperature.
REDOX = reduction-oxidation.
SST = single-shell tank.
TBP = tributyl phosphate.

Future failure mechanisms of SSTs may be unrelated to past failure mechanisms, and instead may be more related to corrosion failures by pitting or general corrosion if timeframes for waste storage are exceedingly long. However, even corrosion by these mechanisms will occur at lower rates as waste storage temperatures decrease. In addition, the reduced liquid level and inventory in most of the SSTs as a result of interim stabilization has reduced the driving force for tank leaks. The possibility of either future large SST liner leaks or catastrophic liner failures like those seen in the past seems unlikely.

5.2 ENHANCED LEAK DETECTION, MONITORING, AND MITIGATION

The planning for the common factors analysis M-045-91F-T02 target included language to make recommendations, as appropriate, for LDMM. As noted in the common factors analysis, there were no findings or conclusions to question the current LDMM activities, and no specific recommendations were made. As a result, activities associated with other SST integrity work were examined for possible recommendations for enhanced LDMM.

The ionic conductivity feasibility study for the M-045-91F-T03 milestone specifically looked at the expert panel's recommended new technology for leak detection. Although feasible, the method lacks the sensitivity for SSTs that is required to be considered an improvement over existing practices.

The SST leak cause, location and leak rate analysis for the M-045-91F-T04 milestone makes no recommendations for LDMM, although two characteristics of tank leaks are noted.

- Most tank leaks were detected at or near the tank bottom.
- The estimated leak rates of most tanks are very small, tens to hundreds of gallons per day, and only a handful of tanks had very large leak rates, >1,000 gal/day.

These characteristics should be considered for LDMM and future tank leak assessments.

The leak rate analysis employed detailed techniques for evaluation of level change based on the in-tank level monitoring that was done at the time. These techniques should be employed in any future leak rate analysis.

Other parallel activities related to SST leak integrity from SST level increase and decrease evaluations are discussed in Appendix B and Appendix C and recommend improving existing leak detection with improved level monitoring techniques and data evaluation using existing level monitoring systems. These recommendations are included in Table 6-1 and will enable better use of existing information and provide a better understanding of all mechanisms that contribute to a tank surface level change.

5.3 TFC-ENG-CHEM-D-42 FORMAL TANK LEAK ASSESSMENTS

From the tank farms leak inventory assessments, 48 SSTs are currently identified as requiring a formal leak assessment per procedure TFC-ENG-CHEM-D-42. This large number of outstanding tank leak assessments could impact the common factors analysis and the leak cause, location, and leak rate analysis, if a large number of these SSTs are found to have probable liner leaks. Per TFC-ENG-CHEM-D-42, a formal leak assessment will also be performed if:

- An anomalous level data point (below allowable tolerance) is verified and no viable alternative explanation is identified.
- Direction is received through the appropriate contracting process requesting that the Tank Operations Contractor perform a leak assessment on a particular tank (e.g., if spectral logging data indicate that a tank currently classified as "sound" may have leaked, direction may be received from ORP.)
- An unexplained HRR anomaly is deemed to exist for a tank in retrieval status.
- A formal leak assessment is requested by WRPS management.

If future TFC-ENG-CHEM-D-42 leak assessments conclude that a liner leak is probable, the assessments will include an estimate of the leak cause, location, and leak rate. On a periodic basis (e.g., biannually), the leak cause, location, and leak rate summary can be amended to reflect a complete list of the SSTs with probable liner leaks.

The outstanding formal tank leak assessments should be performed based on a to-be-developed prioritization strategy. This strategy should include input from interested parties in the following areas:

- Risk/threat
  - Volume of drainable liquid
  - Potential for leak (from common factors)
  - Tank farms leak assessment reports
  - Ease of assessment
  - Groupings of tanks using common data sets
  - Other
- Waste retrieval timing
- Tank closure considerations.

Formal tank leak assessments will require extensive investigation of historical information to develop further understanding of the underlying basis needed for a TFC-ENG-CHEM-D-42 probabilistic leak/no-leak analysis. Inspections of tank interiors and surface level information using advanced analysis techniques will need to be considered. Drywell logging of existing or other characterization of sub-surface contamination may also need to be performed to provide a more recent understanding of ex-tank conditions.

6.0 RESULTS AND RECOMMENDATIONS

The investigations into SST leak integrity summarized in this document represent a comprehensive effort to identify past leak causes and locations and identify those factors that could contribute to future failures. The primary conclusions from the collective effort are:

- Large leaks from SSTs in the future are not likely due to decreasing waste temperatures, reduced free liquid volumes, less aggressive waste chemistries, and reduced potential for additional liner cracking.
- Application of SST level trending and analysis and the judicious identification of all factors contributing to level change allowed improved evaluation of SST tank leaks and water intrusion. These techniques will be useful in evaluating future SST level changes.
- Although the investigations represent the "best effort" summary of SST failures based on existing information, it is unlikely that additional information exists or is practically recoverable that would alter the conclusions.

A comprehensive list of improvements derived from the process of developing the investigation techniques and the results of the interim milestone targets M-045-91F-T02 and -T04 and parallel investigations was compiled and categorized. The list provided the basis for the following lessons learned, best management practices, and recommendations, along with a list of continuing SST integrity requirements and related documents.

Recommendations were compiled from the evaluations in four areas, which are summarized in Table 6-1. The first area deals with completion of the tank farms leak assessments by addressing the tanks that were designated in the RPP-32681 process as needing formal leak assessments per TFC-ENG-CHEM-D-42. The second area deals with improvements to LDMM that were primarily derived from improved techniques developed to analyze data and identification of minimum detection conditions for the analysis. The third area covers the SSTIP requirements and related documents to ensure continued knowledge of SST integrity conditions into the future. The fourth includes two miscellaneous recommendations.

Table 6-1. Single-Shell Tank Leak Integrity Recommendations (2 pages)

Source	Recommendations
TFC-ENG-CHEM-D-42[a] tank assessments	• Develop a risk-based prioritization strategy and schedule to perform outstanding leak assessments • Assess TFC-ENG-CHEM-D-42[a] designated tanks as required
LDMM-related improvements	• Determine current passive breathing rate and better quantify evaporation losses • Improve understanding of current sludge and saltcake porosity • Provide a documented basis for any level monitoring sloping baseline change • Periodically reevaluate tank liquid level data trends to enable an understanding of the changes in the data • Periodically reevaluate tank LOW neutron scan data to enable selection of the best liquid level feature • Improve understanding of the Enraf plummet location for correct interpretation of surface level trends

Table 6-1. Single-Shell Tank Leak Integrity Recommendations (2 pages)

Source	Recommendations
Continuing SST integrity requirements and related documents	• Continue SST dome deflections surveys (TFC-ENG-FACSUP-C-10,[b] RPP-RPT-55202[c]) • Perform annual visual inspection of a number of SSTs (RPP-PLAN-46847[d]) • Continue improvement in SST leak detection and monitoring functions and requirements (RPP-9937[e]) • Mitigate intrusion by use of portable exhausters for evaporation of supernatant (RPP-PLAN-57554[f]) • Improve understanding of SST corrosion through investigation of SST aggressive waste layer testing and testing of the waste types from common factors analysis responsible for past failures
Related recommendations	• Incorporate the recently retrieved and accumulated historical data into the surveillance analysis computer system for future use • Revise SST leak cause, location, and leak rate summary on a periodic basis (such as biannually), including any new probable leakers from results of any TFC-STD-CHEM-D42[a] analysis • Revise RPP-RPT-55804[g] if a significant number of probable tank leakers are identified per the TFC-ENG-CHEM-D-42[a] tank leak assessments

[a] TFC-ENG-CHEM-D-42, 2013, "Tank Leak Assessment Process," Rev. B-7, Washington River Protection Solutions, LLC, Richland, Washington.
[b] TFC-ENG-FACSUP-C-10, 2014, "Control of Dome Loading and SSC Load Control," Rev. C-23, Washington River Protection Solutions, LLC, Richland, Washington.
[c] RPP-RPT-55202, 2013, *Dome Survey Report for Hanford Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.
[d] RPP-PLAN-46847, 2014, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.
[e] RPP-9937, 2014, *Single-Shell Tank System Leak Detection and Monitoring Functions and Requirements Document*, Rev. 3E, Washington River Protection Solutions, LLC, Richland, Washington.
[f] RPP-PLAN-57554, 2014, *Portable Exhauster Usage Plan for Evaporation of Supernatant Liquid in Selected Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.
[g] RPP-RPT-55804, 2015, *Common Factors Relating to Liner Failures in Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

LDMM = leak detection, monitoring, and mitigation.
LOW = liquid observation well.
SST = single-shell tank.

The lessons learned and best management practices that became evident during the analyses are summarized below. Some of the lessons learned are self-evident now but were not always being done at the time or not known to be required. New SSTs are not being considered; however, some of the lessons learned are applicable to new tank construction. Other practices are related to better management of existing wastes going forward.

Lessons Learned

- Control waste temperatures per specifications to lower stresses
- Perform post-weld stress relieving to lower residual stress on tank liner
- Design requirements
  - Use designs that minimize the buildup of thermal stresses
  - Use proper material selection to ensure best corrosion resistance
- Long-term waste storage requires periodic waste chemistry analysis to track the effect of change in chemistry parameters important to corrosion prevention:
  - Nitrite, which will increase with time
  - Ammonium, which is generated based on in-tank conditions
  - Hydroxide, which is depleted by atmospheric CO_2 absorption
  - pH, tied directly to hydroxide, but influenced by carbonate and other ions
  - Chemical reactions in general
- Records need to be cataloged and accessible throughout the operating lifetime
  - Construction material property test results
  - Archived samples of construction materials, including samples of the tank steel liners
  - Construction records, especially quality assurance/quality control inspection records
  - Operational data, specifically operating temperatures and levels
  - Sample and analytical results.

Best Management Practices

- Leak rate trend analysis improvements
  - Use data smoothing and curve-fitting techniques when a sufficient number of data points are available to remove the effect of “noisy” data
  - Compare tank breather filter isolation to passive breathing to determine the effects on liquid level.

7.0 REFERENCES

ARH-78, 1967, *PUREX TK-105-A Waste Storage Tank Liner Instability and its Implications on Waste Containment and Control*, Atlantic Richfield Hanford Company, Richland, Washington.

ASME, 2013, *Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, New York.

BNL-52527, 1997, *Guidelines for Development of Structural Integrity Programs for DOE High Level Waste Storage Tanks*, Brookhaven National Laboratory, Upton, New York.

Brockman, D. A., 2010, "Completion of Hanford Federal Facility Agreement and Consent Order (HFFACO) Interim Milestone M-045-91, Due September 30, 2010," (Letter 10-ESQ-286 to J. A. Hedges, Washington State Department of Ecology, September 27), U.S. Department of Energy, Office of River Protection, Richland Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement (TPA)*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

HW 57274, 1958, *Instability of Steel Bottoms in Waste Storage Tanks*, General Electric, Richland, Washington.

OSD-T-151-00007, 2014, *Operating Specifications for the Double-Shell Storage Tanks*, Rev. 13, Washington River Protection Solutions, LLC, Richland, Washington.

Price, J. B., 2011, "Hanford Federal Facility Agreement and Consent Order Tri-Party Agreement Change Package M-45-10-01," (Letter 0093555 to T. W. Fletcher, U.S. Department of Energy, Office of River Protection, January 6), Washington State Department of Ecology, Richland Washington.

RPP-9937, 2014, *Single-Shell Tank System Leak Detection and Monitoring Functions and Requirements Document*, Rev. 3E, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-32681, 2013, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-ASMT-51526, 2012, *Tri-Party Agreement Target Milestone M45-91F-T-03 Ionic Conductivity Assessment*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-45082, 2010, *Implementation Plan for the Single-Shell Tank Integrity Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-46847, 2014, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-55112, 2013, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-57554, 2014, *Portable Exhauster Usage Plan for Evaporation of Supernatant Liquid in Selected Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-43116, 2009, *Expert Panel Report for Hanford Single-Shell Tank Integrity Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-45921, 2010, *Single-Shell Tank Integrity Expert Panel Report*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-50799, 2015, *Suspect Water Intrusion in Hanford Single-Shell Tanks*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54909, 2014, *Hanford Single-Shell Tanks Leak Causes, Locations, and Rates: Summary Report*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP RPT-54910, 2014, *Hanford Single-Shell Tank Leak Causes and Locations – 241-SX Farm*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54921, 2014, *Estimation of Past Leak Rates for Selected Hanford Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55202, 2013, *Dome Survey Report for Hanford Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55804, 2015, *Common Factors Relating to Liner Failures in Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ENG-CHEM-D-42, 2013, "Tank Leak Assessment Process," Rev. B-7, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ENG-FACSUP-C-10, 2014, "Control of Dome Loading and SSC Load Control," Rev. C-23, Washington River Protection Solutions, LLC, Richland, Washington.

WHC-EP-0772, 1994, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ER-414, 1995, *Hanford Waste Tank System Degradation Mechanisms*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Appendix A

MEETING MINUTES – JANUARY 15, 2015

MEETING SUMMARY

washington river protection solutions

From: T. J. Venetz
Phone: 376-9669
Location: Ecology Office
Date: January 15, 2015
Subject: SST Common Factors and Preliminary Leak Summary Report

To: Distribution

Jim Alzheimer, ECOLOGY*
Jeff Lyons, ECOLOGY
Mike Barnes, ECOLOGY
Joe Caggiano, ECOLOGY*
Alan Carlson, WRPS*
Dennis Washenfelder, WRPS/AEM
Dan Baide, WRPS*
Crystal Girardot, WRPS*
Don Harlow, WRPS/AEM*
Jeremy Johnson, ORP*
Ted Venetz, WRPS*

*Attended Meeting

PURPOSE:

The purpose of this meeting was to discuss the status and summary of the SST Common Factors report that was prepared to satisfy the M-045-91F-T02 target and the overall SST Leak Integrity Summary Report that will be submitted for approval for the M-045-91F interim milestone. The Summary Report will capture and summarize the information submitted under the T02 through T04 targets.

SST Common Factors Status (91F-T02 Target)

The SST Common Factors document, RPP-RPT-55804, *Common Factors Relating to Liner Failures in Single-Shell Tanks*, was approved for public release and submitted to ORP January 13, 2015. The status and summary of the SST Common Factors document was presented (see Attachment 1).

The six common factors that were determined to be factors that likely contributed to tank liner failure were discussed in detail. In the analysis, over 60 potential mechanisms were considered and only 28 were determined to be possible for the SSTs. Of the 28 possible liner failure mechanisms, 14 were considered indeterminate due to inadequate historical data available. Of the remaining 14 mechanisms that were analyzed, eight were considered to be unlikely and six were considered likely. The six factors include: lack of post-weld stress relieving, liner bottom to wall transition design, lower yield strength steel plate, high temperature waste storage, nitrate-induced stress corrosion cracking, and external pressurization (bulging of tank bottom).

The table of contents, conclusions, and recommendations of the RPP-RPT-55804 were distributed to the meeting attendees. A summary of the conclusions and recommendations were also discussed in the meeting. It was discussed whether any of these conclusions would affect SST retrieval decisions. It was determined that this document might be of use to the retrieval team but would likely be a reference document for them and even a useful tool for public information. One of the recommendations the SST Common Factors document makes is there is no need to revisit the analysis unless future TFC-ENG-CHEM-D-42 analyses identify a significant number of probable SST liner failures with which Ecology agreed.

SST Leak Integrity Summary Report (M-045-91F)

The status of the summary document was provided which included the preliminary outline of the document, evaluation topics, and recommendations (see Attachment 1). There was some discussion on how the results of the SST intrusion, level loss, and aggressive waste layers corrosion testing will be included in the summary report as they were not initially thought to be included when the interim milestone was being negotiated. A summary of the three interim milestone targets have been drafted in the document.

It was discussed how insufficient detailed historical documentation prevented a more comprehensive analysis of the three interim milestone targets. Examples include; the number of individual formal tank leak assessments awaiting evaluation per the TFC-ENG-CHEM-D-42 tank leak assessment procedure which may identify additional probable leaking tank liners potentially affecting both T-02 and T-04 interim milestone targets, and the number of potential common factor failure mechanisms for which no failure mechanisms could be determined for lack of historical information. However, the compiled references for the issued documents should provide an excellent source of information for any future inquiry as well as some of the compiled information on 200 Area historical processes and wastes.

Preliminary evaluation topics that need to be finalized include predictive capability, TFC-ENG-CHEM-D-42 leak assessments, and enhanced leak detection, monitoring, and mitigation (LDMM). Preliminary recommendations were discussed including lessons learned, best management practices, and applicability to future projects and existing SSTs which will be addressed in a section of the document.

A point was subsequently made indicated the driving force for leaks has been significantly reduced due to interim stabilization. Interim stabilization also reduced the amount of free liquid and lowered waste levels, in some cases, possibly below the level of liner degradation. The effects of interim stabilization will also be discussed in the report.

The final draft of the document will be discussed in the next meeting tentatively planned for mid-March. The interim milestone M-045-91F is due 6/30/2015.

ACTIONS:

1. All: Review and provide comments on the meeting summary by 1/29/2015.
   Status: Complete

Attachment 1 : Single-Shell Tank Common Factors and Leak Integrity Summary presentation washington river protection solutions

Single-Shell Tank Common Factors and Leak Integrity Summary

Vintage Early Single-Shell Tank Under Construction

Ted Venetz
Washington River
Protection Solutions

January 15, 2015

Agenda

- SST Common Factors Report (M-045-91F-T02)
  - Status
  - Summary
- SST Leak Integrity Summary Report (M-045-91F)
  - Status
  - Evaluation
  - Preliminary Findings/Recommendations

SST Common Factors - Status

M-045-91F-T02

DOE shall provide to Ecology as a HFFACO secondary document a report, evaluating the common factors of liner failures for SSTs that have leaked and will provide recommendations as appropriate, such as enhanced Leak Detection, Monitoring, and Mitigation. For purposes of this milestone, the SSTs that have leaked are identified through the RPP-32681, Rev 0, Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning.

- Status – RPP-RPT-55804, released/approved for public release and submitted to ORP January 13, 2015

SST Common Factors Summary - Analysis

- Included all SSTs in analysis
  - 25 SSTs with Probable Liner Leaks (from RPP-32681)
- Over 60 Potential Mechanisms Considered
- 28 Possible Liner Failure Mechanisms Identified
  - Inadequate Historical Information to Analyze 14 of the Possible Mechanisms (Indeterminate)
  - Remaining 14 Mechanisms Analyzed
    - Six identified as Likely Common Factors Contributing to Tank Liner Failure
    - Eight identified as Unlikely

SST Common Factors Summary – Likely Factors

- Six Common Factors Likely Contributed to Tank Liner Failure
  - Lack of Post-Weld Stress Relieving
    - No SSTs were post-weld stress relieved. High tensile stresses could initiate stress corrosion cracking
  - Liner Bottom to Wall Transition Design
    - 241-SX & 241-A tanks built with orthogonal bottom to wall joint with fillet weld which is inferior for dynamic loads to butt weld joints used in all other SSTs
  - Lower Yield Strength Steel Plate
    - 241-TX, -BY, -S, -TY, -SX & -A farms used lower yield strength steel plate. Lower yield strength associated with larger grain size. Larger grain size lowers the resistance to stress corrosion cracking

Likely Common Factors – Continued

- High Temperature Waste Storage
  - Boiling waste stored in 241-A, 241-AX, most of 241-SX, S-101, S-104 & U-104. Higher temperatures associated with higher stresses and higher corrosion rates.
- Nitrate Induced Stress Corrosion Cracking – 3 waste types
  - TBP waste when 1st waste in a tank (4 failed 241-TY tanks)
  - REDOX waste without Coating Waste (tanks in 241-SX, 241-TX, 241-U)
  - Nitrate Leaching waste (241-SX-107,-108,-111,-114,-115)
- External Pressurization (Bulging of Tank Bottom)
  - 241-U-104, SX-108, SX-113, SX-115, A-105 all have photographic evidence or bottom depth measurements indicating a bulge. These tanks have all failed. A-105 has photographic evidence of torn liner.

SST Common Factors Summary – Conclusions

- General Considerations – Common Factors
  - Small sample sets of tanks with and without a particular mechanism present limit the confidence in the results
  - Evaluations are based on field data rather than carefully controlled "experiments", a number of confounding variables may be present masking the real common factors
  - Precise identification of the cause of each of the 25 known liner failures is not possible with the available information
  - Little information regarding the properties of the materials used for the SST liners generally do not allow determining the role played by the materials in liner failure
  - Some or all of the factors may be acting individually or together to result in tank liner failure

SST Common Factors Summary - Conclusions

- Tanks awaiting CHEM-D42 leak assessment that are found to have probable leaks could affect the analysis
- Some tanks may have liner flaws (pits, cracks) but with no detectable waste loss
  - Contained by asphalt/concrete
  - Plugged by waste solids/sludge
  - Not detected ex-situ
- Declining waste temperatures reduce corrosion potential

SST Common Factors Summary – Recommendations

- No basis to recommend improved LDMM from Common Factors analysis
- Improvements going forward
  - Maintain complete and accurate records
  - Archive material specimens
  - Avoid certain design features
- Common Factors Corrosion Testing
  - Continue aggressive waste layer testing to understand threat from current waste composition
  - Confirm propensity for SCC using historical waste compositions and conditions
- No need to revisit analysis unless future CHEM-D42 analysis identify significant numbers of probable SST liner failures

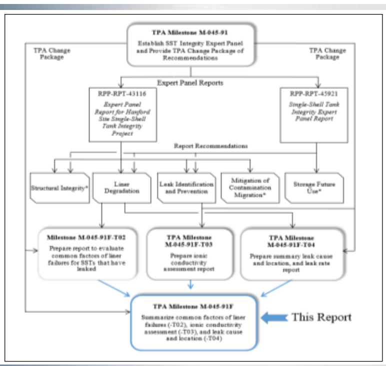
SST Leak Integrity Summary - Status

M-045-91F

DOE shall provide to Ecology, for approval, a report (Summary Conclusions Report on Leak Integrity) summarizing and evaluating the information submitted under M-045-91F-T02 through –T04.

Status: All targets complete and summarized, currently evaluating findings and formulating overall recommendations

SST Leak Integrity Summary Flowchart



SST Leak Integrity Summary

- Preliminary Document Outline
  - Executive Summary
  - Purpose
  - Background
  - Target Report Summaries
  - Evaluation of Leak Integrity Targets and Related Activities
  - Recommendations
  - References
  - Appendices

SST Leak Integrity Summary - Continued

- Related Parallel Activities
  - SST Intrusion
  - SST Level Loss
  - SST Aggressive Waste Layers Corrosion Testing
- Plan short discussion of each in an appendix

SST Leak Integrity Summary – Individual Targets

- M-045-91F-T01 Target – SST Leak Rates RPP-RPT-54921 (results were incorporated into -T04 summary)
  - Wide range of leak rates from 5000 gal/day to barely detectable
  - Captured useful historical data on levels, temperatures
  - Developed advanced level evaluation techniques
  - No apparent correlation to tank type, waste type, operating history
- M-045-91F-T02 Target – SST Common Factors
  - Previously discussed

SST Leak Integrity Summary – Individual Targets

- M-045-91F-T03 Target – Ionic Conductivity Study –RPP-RPT-51526
  - Technique would rely on existence of actual liner defects
  - Study showed cracks must be about 1 meter long in an SST liner
- M-045-91F-T04 Target – SST Leak Cause, Location and Leak Rate Summary RPP-RPT-54909
  - Supported by individual reports by farm
  - 25 tanks identified as having leaked by liner failure
  - Most tanks leaked at the bottom
  - Principal causes – High operating temperature and high rate of rise, tank design features, waste chemistry conducive to corrosion, bottom bulges, cold-weather construction

SST Leak Integrity Summary – Preliminary Evaluation Topics

- Predictive Capability
  - Leak Cause Investigations were useful in understanding past causes but limited in predicting future leak potential
  - Aggressive temperatures and waste types that caused cracking are no longer present
  - Current waste temperatures are cooler, resulting in lower pitting and general corrosion rates
- TFC-ENG-CHEM-D42 Leak Assessments
  - Identification of all probable leaking tanks is incomplete
  - Future efforts will include leak cause, location and leak rate estimate
  - A prioritization strategy for performing D-42s could consider risks from common factors

SST Leak Integrity Summary – Preliminary Evaluation Topics

- Enhanced Leak Detection, Monitoring, and Mitigation (LDMM)
  - Not driven by common factors or SST leak cause, location, or leak rate
  - Ionic Conductivity lacks sensitivity
  - SST waste level change investigations result in improved use of existing information and improve understanding of all mechanisms that can change tank level
  - Not new technology but improvements to existing processes
    - Advanced techniques for level change evaluation.
    - Determination of the surface level conditions
    - Frequent monitoring of existing level instruments sufficient to allow for data smoothing and averaging to better detect long term trends.
    - Understanding and compensating for the effect of evaporation with improved analysis.

SST Leak Integrity Summary – Preliminary Recommendations

- Lessons Learned
  - What practices to avoid in design, construction, and operations
- Best Management Practices
  - Advanced data evaluation techniques, level change analysis
- Applicability to future projects
  - Better record keeping
  - Archive material specimens
- Existing SSTs
  - Execution and prioritization for D-42s
  - Completion of corrosion testing
  - Aggressive waste layers, common factors, potential crevices

SST Leak Integrity Summary – Path Forward

- Complete Evaluations
- Finalize Recommendations
- Next Meeting with Ecology
  - Mid March
- Interim Milestone Date – 6/30/2015

Backup Slides

Analysis Results of Possible Failure Mechanisms Page 1

Liner Failure Mechanisms	Indeterminate	Unlikely	Likely
Design and Design Modification Flaws			
Lack of Post-Weld Stress Relieving			X
Liner Bottom to Wall Transition Design			X
Exterior Finish of Tank Liner	X		
Lack of Vent Path for Gases Formed Below Tank Liner		X	
Procured Material Defects			
Properties of Liner Materials			
Carbon Equivalent		X	
Yield Strength			X
Material Standard and Grade	X		
Liner Plate Thickness	X		
Steel Liner Plate Defects	X		
Weld Material Defects	X		
Tank Fabrication Defects			
Brittle Fracture or Crack Propagation During Fabrication		X	
Cold Working and Strain Aging (shop fabricated knuckles and weld peening)		X	
Weld Joint Discontinuities and Defects	X		
Operational Service Related Failure Mechanisms			
Low-Cycle Fatigue		X	
Temperature Induced Failure			

Backup Slides

Analysis Results of Possible Failure Mechanisms Page 2

Liner Failure Mechanisms	Indeterminate	Unlikely	Likely
Rate of Rise	X		
High Temperature			X
Corrosion			
General or Uniform Corrosion		X	
Pitting Corrosion	X		
Crevice Corrosion	X		
Stress-Corrosion Cracking			
Nitrate-Induced			X[1]
Caustic Cracking		X	
Carbonate-Induced	X		
Concentration Cell Corrosion			
Liquid-Air Interface	X		
Solid-Liquid Interface	X		
Solid-Solid Interface		X	
Vapor Space Corrosion	X		
Differential Temperature Cell Corrosion	X		
External Environmental Failure Mechanisms			
Pressurization External to Tank Liner			X

[1] Nitrate-induced stress-corrosion cracking is likely for three waste types: TBP waste if it is the first waste in a tank; REDOX concentrated and neutralized salt waste; and, in-farm nitrate leaching. Nitrate-induced SCC is unlikely for other waste types considered, except for PUREX 1970 Thoria Campaign waste for which the analysis was indeterminate.

Appendix B

SINGLE-SHELL TANK INTRUSION

SINGLE-SHELL TANK LEVEL INCREASE EVALUATIONS

Single-shell tank (SST) in-tank videos were performed in fiscal years (FY) 2010 and FY 2011 as a result of Single-Shell Tank Integrity Expert Panel recommendation SI-4 listed in RPP-PLAN-45082, *Implementation Plan for the Single-Shell Tank Integrity Project*. The focus of the videos was primarily on tank concrete dome integrity (identification of cracks greater than 1/16 in. and rust stains on the dome interior), but intrusion evidence was also a factor considered to assess dome integrity. The results of the FY 2010 and FY 2011 evaluations are reported in RPP-RPT-48194, *Fiscal Year 2010 Visual Inspection Report for Single-Shell Tanks*, and RPP-RPT-51404, *Fiscal Year 2011 Visual Inspection Report for Single-Shell Tanks*. The SST integrity program was suspended in FY 2012, and no SST integrity videos were obtained that year.

In mid-2011, Washington River Protection Solutions, LLC (WRPS) reviewed historical monitoring data for the 149 SSTs for long-term increases in surface levels (SL) and interstitial liquid levels (ILL) that could be indicative of water intrusion. Tanks with opposing increasing and decreasing SL and ILL trends were excluded from the group. The review was reported in RPP-RPT-50799, *Suspect Water Intrusion in Hanford Single-Shell Tanks* (Rev. 0).

In mid-2012, the SL and ILL data were reviewed again with the intent of filtering out explainable or obvious instrumentation data spikes, and encompassing all tanks, including those with SL and ILL changes opposing each other. Tanks in the C Farm and Tank S-112 were excluded from the 2012 review, since these tanks had either completed waste retrieval, were in the retrieval process, or planned for retrieval in the near future.

A plan was made to evaluate the causes of the level data increases. The plan was originally provided as an attachment to WRPS-1203139 R1 (Simpson 2012). This attachment was subsequently released as RPP-PLAN-55112, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan*. This plan listed 66 SSTs with increasing SL and/or ILL data trends, and selected a minimum of 20 SSTs to receive in-tank videos to assess the potential for liquid intrusion. Twenty-one tanks were eventually evaluated for intrusion.

Table B-1 lists the 66 tanks in which the data trendline indicated an SL or ILL change rate greater than 0 in. per year in RPP-PLAN-55112. The tanks were sorted into the following categories:

- Category 1 – Tanks with both ILL and SL increases
- Category 2 – Tanks with SL increase but no ILL increase or no ILL
- Category 3 – Tanks with ILL increase and SL decrease or negligible SL change.

A nominal level data change rate of 0.07 in./year was selected as an initial filter to concentrate on the tanks with larger increase rates. A level data change rate of 0.070 in./year is just slightly above 1/16 in. (0.0625 in.)/year.

Table B-1. List of Single-Shell Tanks with Increasing Interstitial Liquid Level or Surface Level Data Trends*

Category 1 Tanks with both ILL and SL increase (10 tanks evaluated)			Category 2 Tanks with SL increase and no ILL increase or No LOW (6 tanks evaluated)			Category 3 Tanks with ILL increase and SL decrease or negligible SL change (5 tanks evaluated)		
Tank	SL increase (in./year)	ILL increase (in./year)	Tank	SL increase (in./year)	ILL increase (in./year)	Tank	SL increase (in./year)	ILL increase (in./year)
S-109	0.625	0.751	T-201	0.250	no LOW	BY-106	-0.133	3.024
A-103	0.045	0.557	BX-101	0.162	no LOW	SX-106	-0.046	2.008
BY-101	0.595	0.512	B-202	0.130	no LOW	S-111	-0.350	1.932
BY-103	0.015	0.423	BX-103	0.125	no LOW	S-106	-0.335	1.346
BY-102	0.096	0.327	A-102	0.112	no LOW	S-108	-0.177	1.003
U-111	0.062	0.253	TY-102	0.073	no LOW	TX-112	-0.083	0.898
BY-111	0.737	0.195	BX-106	0.061	no LOW	SX-104	-0.233	0.864
B-109	0.020	0.115	B-201	0.051	no LOW	TX-115	-0.121	0.615
T-101	0.051	0.095	B-112	0.041	no LOW	U-102	-0.081	0.562
BX-110	0.070	0.075	T-107	0.034	no LOW	A-101	NA	0.557
BY-110	0.006	0.046	T-108	0.024	no LOW	TX-114	-0.109	0.469
S-110	0.118	0.020	BX-104	0.023	no LOW	BY-105	-0.688	0.398
TX-103	0.090	0.017	B-103	0.019	no LOW	TX-113	-0.234	0.373
BY-109	0.064	0.015	BX-107	0.016	no LOW	TX-111	-0.063	0.326
BX-109	0.021	0.013	S-103	0.015	-0.002	U-107	-0.341	0.251
B-105	0.073	0.011	TY-104	0.015	no LOW	TX-117	-0.717	0.235
TX-104	0.001	0.006	S-107	0.015	0.000	S-105	-0.071	0.235
			TY-106	0.002	no LOW	TX-105	-0.027	0.219
						TX-116	-0.193	0.159
						TX-118	-0.070	0.157
						TX-106	-0.020	0.127
						T-104	-0.057	0.114
						TX-109	0.000	0.100
						U-105	-0.034	0.096
						BX-111	-0.075	0.085
						SX-105	-0.126	0.042
						T-110	-0.025	0.037
						SX-103	-0.220	0.009
						U-103	0.000	0.008
						SX-101	-0.120	0.003
						T-109	0.000	0.001

* Change rates current as of late July - early August 2012.

ILL = interstitial liquid level.
SL = surface level.
LOW = liquid observation well.

The unshaded tanks in Table B-1 are those with a nominal ILL change rate greater than 0.070 in./year for Category 1 tanks or an SL change rate greater than 0.070 in./year for Category 2 tanks. The filter level for Category 3 tanks was based on engineering judgment since the ILL and SL data were going in opposite directions. If the tanks with level data change rates less than the initial filter value of 0.070 in./year would be evaluated was decided after the tanks with change rates greater than 0.070 in./year were looked at.

The change rates in Table B-1 are the estimated level data change for the tanks as of mid-2012. The period over which the change rates were estimated was based on engineering judgment. For some tanks, the change rate was essentially constant for over 20 years. For other tanks, the change rate was for recent years only. For many tanks, the change rate is asymptotic, but the change rate for all tanks was simplified as a linear rate.

Evaluation of the tanks for intrusions resulted in the restart of tank integrity videos in FY 2013. A total of 21 tanks were evaluated for liquid intrusion per RPP-PLAN-55112 in FY 2013 and FY 2014. Thirteen of the 21 tanks had confirmed intrusions.

An additional nine SSTs received in-tank videos in FY 2013 and FY 2014 for reasons other than selection based on RPP-PLAN-55112. Two of these nine tanks also had observed intrusions.

Table B-2 lists the 30 SSTs receiving in-tank videos in FY 2013 and FY 2014 (excluding SSTs with in-tank videos for waste retrieval related reasons) and indicates the tanks where intrusions are confirmed.

RPP-RPT-50799 (Rev. 1) provides intrusion evaluations for the 12 tanks reviewed for intrusion in FY 2013 per RPP-PLAN-55112. RPP-RPT-50799 (Rev. 2), planned for release in early FY 2015, provides updated intrusion evaluations for all 30 tanks in Table B-2 receiving in-tank videos in FY 2013 and FY 2014.

With the issuance of RPP-RPT-50799 (Rev. 2), the intrusion investigations initiated by RPP-PLAN-55112 are completed. Intrusion evidence (or lack of) in SSTs receiving future integrity-based videos will be described in the corresponding tank inspection reports, along with other tank-related information.

The 24 tanks inspected in FY 2010 and FY 2011 tanks were selected to provide a reasonable cross-section of tank conditions for estimating the general tank concrete dome integrity level. Twenty-one of the tanks inspected in FY 2013 and FY 2014 were selected based on level data increase rates. The remaining nine tanks inspected in FY 2013 and FY 2014 were selected based on level decrease or level data concerns.

The tanks selected for FY 2015 have been based on both shaded tanks in Table B-1 and tanks with questionable level data trends. Tanks for post-FY 2015 inspections are assumed to be based on additional shaded tanks from Table B-1, tanks with questionable data trends, or as requested for other reasons. When all shaded tanks in Table B-1 have been inspected and/or there are no tanks with questionable data warranting inspection, the tanks selected will be based on engineering judgment or as requested for other reasons until all SSTs have been inspected. A nominal 12 in-tank videos are currently planned per year as part of the SSTIP.

Table B-2. List of Single-Shell Tanks with In-Tank Videos in FY 2013 and FY 2014 and Intrusion Evaluation Results

Tank	Reason for video	Video year	Intrusion confirmed
A-102	RPP-PLAN-55112[a]	FY 2014	Yes
A-103	RPP-PLAN-55112[a]	FY 2013 and& FY 2014	No
B-109	RPP-PLAN-55112[a]	FY 2014	No
B-202	RPP-PLAN-55112[a]	FY 2014	Yes
B-203	Level decrease	FY 2013	No
B-204	Level decrease	FY 2013	No
BX-101	RPP-PLAN-55112[a]	FY 2013	Yes
BX-103	RPP-PLAN-55112[a]	FY 2013	Yes[b]
BX-110	RPP-PLAN-55112[a]	FY 2013	Yes[b]
BX-111	Level data change	FY 2014	No
BY-101	RPP-PLAN-55112[a]	FY 2013	No
BY-102	RPP-PLAN-55112[a]	FY 2013	Yes
BY-103	RPP-PLAN-55112[a]	FY 2014	Yes
BY-106	RPP-PLAN-55112[a]	FY 2014	No
BY-111	RPP-PLAN-55112[a]	FY 2013	No
S-106	RPP-PLAN-55112[a]	FY 2014	Yes
S-109	RPP-PLAN-55112[a]	FY 2013	No
S-111	RPP-PLAN-55112[a]	FY 2013	No
SX-102	Level data change	FY 2014	Yes
SX-106	RPP-PLAN-55112[a]	FY 2013	Yes
T-101	RPP-PLAN-55112[a]	FY 2014	Yes
T-102	Evaluate Enraf location	FY 2014	No
T-111	Level decrease	FY 2013 and FY 2014	Yes
T-201	RPP-PLAN-55112[a]	FY 2014	Yes
T-203	Level decrease	FY 2013	No
T-204	Level decrease	FY 2013	No
TX-112	RPP-PLAN-55112[a]	FY 2013	No
TY-102	RPP-PLAN-55112[a]	FY 2014	Yes[b]
TY-105	Level decrease	FY 2013	No
U-111	RPP-PLAN-55112[a]	FY 2013 and FY 2014	Yes

[a] RPP-PLAN-55112, 2013, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

[b] No drips observed for these tanks, intrusion confirmed by level change evaluation and liquid pool change from previous videos or in-tank photos.

Lessons learned from the level increase evaluations include:

- Half of the 30 tanks inspected had intrusions. The average of one out of every two SSTs inspected since November 2012 showing an intrusion may decrease as more tanks are inspected. The 21 tanks evaluated per RPP-PLAN-55112 were selected because level change data indicated they had a higher probability of having an intrusion than the remaining SSTs. For the 15 intrusions observed:
  - Ten were drips coming from pit risers, pit drains, or the central pit opening.
  - The intrusion in Tank SX-106 was from the unused SX Farm tank vent header.
  - The intrusion in Tank T-111 was observed to be coming from numerous drips from the tank central dome area. It could not be determined if the Tank T-111 intrusion originated from the central caisson opening.
  - Three tanks were concluded to have intrusions based on continual level data increase and the presence of liquid on the surface, but no drips were observed at the time of the inspection.
- Periodic observation of in-tank conditions is necessary to understand conditions in the tank.
- Periodic reevaluation of level data trends is needed for each tank to ensure that personnel understand the tank data trends.
- Knowledge of the resting location for the Enraf plummet is necessary to enable interpretation of SL trends.

REFERENCES

RPP-PLAN-45082, 2010, *Implementation Plan for the Single-Shell Tank Integrity Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-55112, 2013, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-48194, 2010, *Fiscal Year 2010 Visual Inspection Report for Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-50799, 2012, *Suspect Water Intrusion in Hanford Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-50799, 2013, *Suspect Water Intrusion in Hanford Single-Shell Tanks*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-50799, 2015, *Suspect Water Intrusion in Hanford Single-Shell Tanks*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-51404, 2012, *Fiscal Year 2011 Visual Inspection Report for Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Simpson, C. A., 2012, "Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Suspect Intrusion Evaluation Plan to the U.S. Department of Energy, Office of River Protection," (Letter WRPS-1203139 R1 to S. E. Bechtol, U.S. Department of Energy, Office of River Protection, September 13), Washington River Protection Solutions, LLC, Richland, Washington.

Appendix C

SINGLE-SHELL TANK LEVEL LOSS

SINGLE-SHELL TANK LEVEL DECREASE EVALUATIONS

During the 2012 reevaluation of single-shell tank (SST) surface level (SL) and interstitial liquid level (ILL) data described in Appendix B, a number of SSTs displaying decreasing ILLs and/or SLs were noted. A plan was developed to investigate these level data decrease trends. The plan was provided in WRPS-1301005 (Simpson 2013). This attachment was subsequently released as RPP-PLAN-55113, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*. This plan listed 83 SSTs with decreasing SL and/or ILL data trends and selected a minimum of 20 SSTs to be evaluated for level decrease.

The 83 SSTs included the 28 Category 3 intrusion tanks listed in Table B-1 of Appendix B because these tanks had decreasing SL data trends (with increasing ILL trends). Inclusion of the 28 Category 3 intrusion tanks as level decrease tanks was for completeness only. Since the 28 tanks had increasing ILL data trends, the level data did not indicate the tanks were leaking. The ILL data takes precedence over the SL data for evaluation of the liquid trend in a tank unless the Enraf plummet providing the SL data is floating on liquid. The Enraf plummet is not expected to be floating on liquid in any of these 28 tanks.

Table C-1 lists the 83 tanks in which the data trendline indicated an SL or ILL decrease greater than 0 in. per year in RPP-PLAN-55113. The tanks were sorted into the following groups:

- Group 1 – Tanks with both ILL and SL decreases
- Group 2 – Tanks with ILL decrease but no SL decrease
- Group 3 – Tanks with SL decrease but no ILL decrease or no liquid observation well (LOW) used for obtaining ILL data.

A nominal level data change rate of -0.07 in./year was selected as an initial filter to concentrate on the tanks with larger decrease rates. The unshaded tanks in Table C-1 are those with a nominal ILL change rate greater than -0.070 in./year for Group 1 and Group 2 tanks or an SL change rate greater than -0.070 in./year for Group 3 tanks. If shaded tanks with level data change rates less than the initial filter value of -0.070 in./year would be evaluated was decided after the tanks with change rates greater than -0.070 in./year were reviewed.

The change rates in Table C-1 are the estimated level data change for the tanks in October to November 2012, or February 2013, as stated in the footnote at the end of the table. The period over which the change rates were estimated was based on engineering judgment. For some tanks, the change rate was essentially constant for more than 10 years. For other tanks, the change rate was for recent years only. For some tanks, the change rate was asymptotic, but the change rate for all tanks was simplified as a linear rate.

Table C-1. List of Single-Shell Tanks with Decreasing Interstitial Liquid Level or Surface Level Data Trends[a,b] (3 pages)

Group 1 Tanks with both ILL and SL decrease			Group 2 Tanks with ILL decrease and no SL decrease			Group 3 Tanks with SL decrease and no ILL decrease or no LOW		
Tank	ILL change (in./year)	SL change (in./year)	Tank	ILL change (in./year)	SL change (in./year)	Tank	ILL change (in./year)	SL change (in./year)
SX-102	-0.664	-0.466	A-106	-0.731	0	SX-114[a]	no LOW	-0.139
T-111[a]	-0.611	-0.884	AX-103	-0.572	0	A-102	no LOW	-0.132
TY-105[a]	-0.256	-0.292	AX-101	-0.312	0	TY-101[a]	no LOW	-0.115
SX-105	-0.161	-0.128	BY-108[a]	-0.287	0	U-104[a]	no LOW	-0.110
U-108	-0.136	-0.043	U-110[a]	-0.045	0.003	T-203	no LOW	-0.089
S-104[a]	-0.122	-0.071	B-110[a]	-0.032	0	B-203[a]	no LOW	-0.075
TY-103[a]	-0.094	-0.022	B-101[a]	-0.024	0	T-204	no LOW	-0.071
B-104	-0.058	-0.016	TX-110[a]	-0.014	0	B-204[a]	no LOW	-0.070
TX-102	-0.043	-0.059	BY-112	-0.011	0	TX-108	no LOW	-0.070
B-107[a]	-0.034	-0.009	SX-111[a]	-0.004	0.064	BX-112	no LOW	-0.057
U-106	-0.028	-0.035	S-107	-0.003	0.015	TX-107[a]	no LOW	-0.045
S-101	-0.013	-0.008				B-111[a]	0	-0.032
SX-112[a]	-0.008	-0.022				BX-102[a]	no LOW	-0.012
U-109	-0.003	-0.222				SX-110[a]	no LOW	-0.009
						U-204	no LOW	-0.009
						T-102	no LOW	-0.009
						T-202	no LOW	-0.008
						TY-106[a]	no LOW	-0.007
						T-112	no LOW	-0.007
						T-103[a]	no LOW	-0.004
						SX-108[a]	no LOW	-0.003
						BX-108[a]	no LOW	-0.002
						T-105	no LOW	-0.002
						SX-109[a]	no LOW	-0.001
						C-110[a]	no LOW	-0.517
						C-203[a]	no LOW	-0.455
						C-104	no LOW	-0.133
						C-105	no LOW	-0.063
						C-112	no LOW	-0.037
						C-102	no LOW	-0.013

Table C-1. List of Single-Shell Tanks with Decreasing Interstitial Liquid Level or Surface Level Data Trends[a,b] (3 pages)

Group 1 Tanks with both ILL and SL decrease			Group 2 Tanks with ILL decrease and no SL decrease			Group 3 Tanks with SL decrease and no ILL decrease or no LOW		
Tank	ILL change (in./year)	SL change (in./year)	Tank	ILL change (in./year)	SL change (in./year)	Tank	ILL change (in./year)	SL change (in./year)
						The following 28 tanks are also intrusion Category 3 tanks. They are included here for completeness only as they have a decreasing SL change, but not suspected of having a tank leak since the ILL in the tank shows a positive change.		
						TX-117[a]	0.233	-0.704
						BY-105	0.400	-0.686
						S-106	1.312	-0.364
						U-107	0.294	-0.338
						S-111	1.908	-0.324
						SX-104	0.838	-0.245
						SX-103	0.003	-0.218
						S-108	1.003	-0.191
						TX-116[a]	0.159	-0.186
						S-112	0.800	-0.147
						TX-115[a]	0.610	-0.141
						BY-106[a]	2.719	-0.135
						SX-101	0.003	-0.119
						TX-113[a]	0.370	-0.113
						TX-114[a]	0.470	-0.109
						T-104	0.122	-0.090
						U-102	0.584	-0.087
						TX-112	0.896	-0.079
						BX-111[a]	0.085	-0.075
						S-105	0.235	-0.071
						TX-118	0.159	-0.069
						TX-111	0.326	-0.050
						U-105	0.094	-0.041
						SX-106	2.139	-0.038
						TX-105[a]	0.218	-0.030
						T-110	0.058	-0.025

Table C-1. List of Single-Shell Tanks with Decreasing Interstitial Liquid Level or Surface Level Data Trends[a,b] (3 pages)

Group 1 Tanks with both ILL and SL decrease			Group 2 Tanks with ILL decrease and no SL decrease			Group 3 Tanks with SL decrease and no ILL decrease or no LOW		
Tank	ILL change (in./year)	SL change (in./year)	Tank	ILL change (in./year)	SL change (in./year)	Tank	ILL change (in./year)	SL change (in./year)
						TX-106	0.127	-0.020
						U-103	0.008	-0.015

[a] Tanks are assumed leaking tanks per HNF-EP-0182, 2013, *Waste Tank Summary Report for Month Ending December 31, 2012*, Rev. 297, Washington River Protection Solutions, LLC, Richland, Washington.

[b] The SL and ILL change rates for most tanks are based on data through late October to mid-November 2012. For Tanks A-102, B-203, B-204, BY-108, T-111, T-203, T-204, and TY-105, the data used are current through mid-February 2013.

ILL = interstitial liquid level.
LOW = liquid observation well.
SL = surface level.

The 20 unshaded tanks in Table C-1 were evaluated by:

- Estimating a volume change rate for each tank based on the fraction of surface liquid in the tank and the assumed porosity of the waste solids
- Evaluation of a variety of other factors, including retained gas growth, water additions, waste chemical changes, intrusion potential, and data validity
- In-tank videos were obtained in six of the 20 tanks (Tanks B-203, B-204, T-111, T-203, T-204, and TY-105) to better ascertain the tank waste surface conditions, including around the Enraf surface level gauge plummet in these tanks
- Estimating evaporation rates for each tank
- Estimating heat generation rates for each tank
- Comparing the estimated evaporation rate with the estimated volume change rate and estimating a leak potential as a function of intrusion.

No intrusions were noted during the six videos, although an intrusion was missed in the Tank T-111 videos and not noted until additional Tank T-111 videos were taken in fiscal year (FY) 2014. A later review of the FY 2013 Tank T-111 videos also showed evidence of an intrusion occurring during the FY 2013 videos.

The level decrease evaluations for the 20 tanks were reported in:

1. RPP-RPT-54964, *Evaluation of Tank 241-T-111, Level Data and In-Tank Video Inspections* (Rev. 0)
2. RPP-RPT-54964, *Evaluation of Tank 241-T-111, Level Data and In-Tank Video Inspections* (Rev. 1)
3. RPP-RPT-54964, *Evaluation of Tank 241-T-111, Level Data and In-Tank Video Inspections* (Rev. 2)

4. RPP-RPT-54981, *Evaluation of Fourteen Tanks with Decreasing Level Baselines Selected for Review in RPP-PLAN-55113, Revision 1*
5. RPP-RPT-55263, *Evaluation of Tank 241-TY-105 Level Data and In-Tank Video Inspection*
6. RPP-RPT-55264, *Evaluation of Tanks 241-T-203 and 241-T-204 Level Data and In-Tank Video Inspections*
7. RPP-RPT-55265, *Evaluation of Tanks 241-B-203 and 241-B-204 Level Data and In-Tank Video Inspections*.

The conclusion of the first three documents is that Tank T-111 was leaking. The conclusions of the last four documents for the remaining 19 tanks are summarized as follows.

- The tank SL change rate in Table C-1 for Tank A-102 was invalid due to Enraf gauge problems. A reevaluation showed the Tank A-102 SL data change rate was essentially flat at +0.004 in./year, and there was no basis to assume a tank leak.
- The tank ILL change rate in Table C-1 for Tank SX-102 was invalid due to use of an inadequate feature in the neutron count rate data used for estimating where the ILL is. A reevaluation showed the Tank SX-102 ILL was actually increasing. The ILL had not yet equilibrated following saltwell pumping, and there was no basis to assume a tank leak.
- The tank ILL change rate in Table C-1 for Tanks SX-105 and U-108 were significantly overestimated due to a long trend period being used initially, while the level data for these two tanks had almost leveled off in the past three (or more) years. The estimated evaporation rates for the tanks exceeded the estimated volume change rates, and there was no basis to assume a tank leak.
- Only SL data are available for Tank SX-114, but the SL change rate cannot be relied on for estimating a volume change rate since the waste surface is extremely dry. With the high waste temperature for the past 40 years since supernatant liquid was pumped from the tank and no liquid evident in the tank in 1989 photos, only a nominal 1 percent of the estimated heat generation rate in the tank is necessary to evaporate water at a rate equal to a very rough estimate liquid loss rate based on SL change. There should be very little drainable liquid left in the tank, and thus little or no liquid to leak. There was no basis to assume a tank leak.
- The tank SL change rates in Table C-1 for Tanks TX-108 and TY-101 were obtained from Enraf plummets sitting on dry waste, and thus of little use for estimating volume change rates. However, bare minimum and estimated rough approximate liquid loss rates were estimated for the tanks based on the SL data change, and the estimated evaporation rates for these tanks exceeded both the bare minimum and estimated rough approximate liquid loss rates. There was no basis to assume a leak from either tank.

- The estimated evaporation rate for the remaining 12 tanks exceeded the estimated volume change rate for the tank, and there was no basis to assume a leak from the tank.
  Note: The estimated evaporation and volume change rates are very rough at best. Because an evaporation rate estimate exceeds a liquid loss estimate does not mean there is an intrusion occurring that makes the two balance out. All the comparison means is that the two rough estimates show evaporation can account for the apparent liquid loss from the tank.

Table C-2 summarizes the results of the level decrease evaluations.

With the issuance of documents 1 through 7, the level decrease investigations initiated by RPP-PLAN-55113 are completed, and there is no need to evaluate any of the remaining 35 level decrease tanks (83 level decrease – 20 evaluated tanks – 28 intrusion Category 3 tanks = 35 tanks). The level decrease rates for these remaining 35 tanks were all less than the level decrease rates for the 20 tanks that were evaluated. Therefore, the conclusion for the remaining 35 tanks was assumed to be the same as for the tanks with higher level decrease rates where the estimated evaporation rate exceeded the estimated volume change rate.

This does not mean that the conclusion is none of the 54 tanks besides Tank T-111 are leaking. The conclusion is only that there is no basis to state any of the tanks are leaking. The estimated evaporation rates and volume change rates are based on the best information readily available. The Tank T-111 leak rate is estimated in RPP-RPT-54964 (Rev. 2) to be approximately 1.8 gal/day.

From June 2013 through June 2014, the inlet breather filters for Tanks T-203 and T-204 were shut to further evaluate evaporation from these tanks. The results for Tank T-203 showed a zero volume change for the tank for the year, with the conclusion that this tank did not leak. The results for Tank T-204 showed significant reduction in the volume change rate for the tank in the year compared to previous years, but data problems with the Tank T-204 Enraf gauge resulted in significant data scatter, with some previous years actually showing a level increase. The marginal data for Tank T-204 prevented showing a similar conclusion for this tank as for Tank T-203. The results of the breather filter test are provided in RPP-RPT-57960, *Results of June 2013 to June 2014 Breather Filter Inlet Valve Closure Test for Tanks 241-T-203 and 241-T-204*.

Lessons learned from the level decrease evaluations include the following.

- The use of all current increasing and decreasing slope baselines for SST level monitoring were discontinued in March 2013. Sloping baselines can be used in the future only with an approved basis.
- Periodic reevaluation of level data trends is needed for each tank to ensure that personnel understand the tank data trends.
- Knowledge of the resting location for the Enraf plummet is necessary to enable interpretation of SL trends.
- Closing breather filter valves for a year can help show if a tank with a liquid surface under the Enraf gauge plummet is leaking or not, depending on the conditions in the tank.
- Periodic reevaluation of tank LOW neutron scan data is needed to ensure that the best feature is being selected for the nominal ILL location.

Table C-2. Single-Shell Tanks Level Decrease Evaluation Results

Tank	Result
A-102	SL data invalid, level change rate essentially zero at +0.004 in./year. No basis for tank leak.
A-106	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
AX-101	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
AX-103	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
B-203	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
B-204	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
BY-108	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
S-104	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
SX-102	ILL data invalid, ILL increasing, still equilibrating following saltwell pumping. No basis for tank leak.
SX-105	Estimated level decrease rate significantly less than given in Table C-1, evaporation rate > estimated volume decrease rate. No basis for tank leak.
SX-114	SL data inadequate to estimate volume change rate, but tank waste is hot and only 1% of estimated heat generation rate needed to give estimated maximum evaporation rate. No basis for tank leak.
T-111	Tank is currently leaking.
T-203	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak. The 12-month closed breather filter test showed zero volume change for the year and provides proof the tank was not leaking.
T-204	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak. Twelve-month closed breather filter test showed significant reduction in tank volume change rate, but Enraf gauge problems prevented the same proof as for Tank T-203 that the tank was not leaking.
TX-108	SL data inadequate to estimate volume change rate, but estimated evaporation rate > estimated bare minimum and rough approximate liquid loss rates. No basis for tank leak.
TY-101	SL data inadequate to estimate volume change rate, but estimated evaporation rate > estimated bare minimum and rough approximate liquid loss rates. No basis for tank leak.
TY-103	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
TY-105	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
U-104	Estimated evaporation rate > estimated volume decrease rate. No basis for tank leak.
U-108	Estimated level decrease rate significantly less than given in Table C-1, evaporation rate > estimated volume decrease rate. No basis for tank leak.

ILL = interstitial liquid level.
SL = surface level.

REFERENCES

HNF-EP-0182, 2013, *Waste Tank Summary Report for Month Ending December 31, 2012*, Rev. 297, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54964, 2013, *Evaluation of Tank 241-T-111, Level Data and In-Tank Video Inspection*, Revs. 0 and 1, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54964, 2014, *Evaluation of Tank 241-T-111, Level Data and In-Tank Video Inspection*, Rev. 2, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-54981, 2013, *Evaluation of Fourteen Tanks with Decreasing Level Baselines Selected for Review in RPP-PLAN-55113, Revision 1*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55263, 2013, *Evaluation of Tank 241-TY-105 Level Data and In-Tank Video Inspection*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55264, 2013, *Evaluation of Tanks 241-T-203 and 241-T-204 Level Data and In-Tank Video Inspections*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55265, 2013, *Evaluation of Tanks 241-B-203 and 241-B-204 Level Data and In-Tank Video Inspections*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-57960, 2014, *Results of June 2013 to June 2014 Breather Filter Inlet Valve Closure Test for Tanks 241-T-203 and 241-T-204*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

Simpson, C. A., 2013, "Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Level Decrease Evaluation Plan to the U.S. Department of Energy, Office of River Protection," (Letter WRPS-1301005 R0 to S. E. Bechtol, U.S. Department of Energy, Office of River Protection, March 18), Washington River Protection Solutions, LLC, Richland, Washington.

Appendix D

SINGLE-SHELL TANK AGGRESSIVE WASTE LAYERS CORROSION TESTING

CONTENTS

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TERMS

Acronyms

CPP	cyclic potentiodynamic polarization
DST	double-shell tank
Ecology	Washington State Department of Ecology
EPOC	Expert Panel Oversight Committee
LAI	liquid-air interface
LPR	linear polarization resistance
MEA	multi-electrode array
OCP	open circuit potential
SCC	stress corrosion cracking
SRNL	Savannah River National Laboratory
SSR	slow strain rate
SST	single-shell tank

D1.0 INTRODUCTION

The Single-Shell Tank Integrity Expert Panel made two recommendations related to tank chemistry and corrosion that aid in assessing the likelihood of future tank liner degradation. The recommendations are summarized below.

> ***Recommendation LD-3, Examine "non-compliant" wastes at 25°C****: The Panel recommends selected "non-compliant" SST waste simulants be examined at 25°C. "Non-compliant" wastes are those that fail to meet specific temperature, nitrite, nitrate, and hydroxide concentration criteria. The examinations will provide information on the propensity for pitting, cracking, and corrosion at the liquid-air interface (LAI) or corrosion of the liner in the vapor space. This testing should be coordinated with the DST testing program.*

> ***Recommendation LD-5, Determine Ammonia Corrosion Control Concentration****: Ammonia in sufficient concentrations has the potential to inhibit liner corrosion. The Panel recommends laboratory testing to determine the concentration of ammonia required to control corrosion in the liquid phases of the solid and supernatant layers, at the LAI and on the exposed liner in the vapor spaces. This testing should be coordinated with the DST testing program.*

Testing pertaining to the Panel recommendations listed above was described by a data quality objective process in RPP-49674, *Single-Shell Tanks Corrosion Chemistry Data Quality Objectives*. This document, along with RPP-PLAN-50077, *Test Plan to Evaluate the Propensity for Corrosion in Single-Shell Tanks*, was developed with Washington State Department of Ecology (Ecology) input and submitted to Ecology to meet milestone M-045-91C. Single-shell tank (SST) corrosion testing is integrated with the double-shell tank (DST) corrosion testing program and guided by corrosion and chemistry experts on the DST Expert Panel Oversight Committee (EPOC).

Initial testing to examine the corrosion propensity for noncompliant liquid wastes for the first recommendation, LD-3, has been completed. This testing focused on the corrosion propensity of liquid simulants rather than the vapor space and liquid-air interface (LAI), and was done as a first step to reliably assess the corrosion propensity of the liquid simulants. The results indicated that a majority of the tested liquids showed a propensity for localized corrosion. Additional testing of the LAI and vapor space corrosion will be included in the second recommendation, LD-5, which is currently underway.

Other recommendations related to SST waste chemistry were made in a report discussing common factors of SST liner failures (RPP-RPT-55804, *Common Factors Relating to Liner Failures in Single-Shell Tanks*). This report proposed three aggressive waste chemistries believed to have caused tank liner failure. To validate those claims, corrosion testing was recommended, and that testing is currently underway.

D2.0 NONCOMPLIANT WASTES

The noncompliant wastes, or aggressive waste layers, were identified by comparing the SST waste compositions to:

- The hydroxide and nitrate DST chemistry specifications in OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks*, for waste temperatures <75°C
- The nitrite-to-nitrate ratio of 0.1 identified in RPP-RPT-43116, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project*.

The waste compositions identified as noncompliant were then organized into different categories based on chemistry types, as shown in Table D-1. These categories were created so that only one or two representative tanks from each category could be chosen for testing to create a more manageable number of corrosion tests.

Table D-1. Aggressive Waste Layer Tanks Selected for Investigation

High Temperature Group, ~40°C	
241-B-101 241-S-104	
Low Temperature Group, 25°C	
High [NO_3^-] with 1.0 M OH^- and High (NO_2^-/NO_3^-)	**High [NO_3^-] with 1.0 M OH^- and Low (NO_2^-/NO_3^-)**
241-B-108 241-BX-110	241-B-107 241-TX-116
High [NO_3^-] with 0.3M to 1.0M OH^- and High NO_2^-	**3.5M [NO_3^-] and similar chemistry**
241-TX-104 241-U-106	241-B-102 241-B-106 241-T-109 241-B-103 241-B-109 241-TX-117 241-B-104 241-T-108 241-TY-101 241-B-105
1.0M to 3.0M [NO_3^-] and Acceptable (NO_2^-/NO_3^-)	**Less than 1.0M [NO_3^-]**
241-T-102 241-U-203	241-B-203 241-T-201 241-B-204 241-U-204 241-C-110
Less than 0.3M [NO_3^-]and No NO_2^-	
241-T-110	

D2.1 TESTING RESULTS

The aggressive liquid waste layers were tested for propensity for cracking or localized corrosion. Slow strain rate (SSR) testing was used to test for stress corrosion cracking (SCC), and cyclic potentiodynamic polarization (CPP) was used to test for localized corrosion like pitting and crevice corrosion.

Slow Strain Rate

The waste compositions for the following tanks were tested using SSR and ASTM A537 steel specimens: Tanks B-101, S-104, BX-110, B-107, TX-116, U-106, TX-117, U-203, B-203, and T-110. Historical steel specimens were not available for use. They were all tested in accordance with ASTM G129-00, *Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking*.

These tests were performed to evaluate the propensity for SCC in the various SST liquid simulant environments. Testing was performed in simulants at current tank temperatures (i.e., 40°C for Tanks B-101 and S-104, and 30°C for the remaining simulants). Tests were conducted at open circuit potential (OCP) and at an applied potentials of OCP + 50 mV or more and pulled to failure. After failure, the specimens were examined visually and by scanning electron microscopy.

In all tests, there was no evidence of SCC at the specimen fracture surface (as seen by the ductile fracture surface in Figure D-1); however, at positive applied potentials, corrosion was observed for six of the compositions. An example of this corrosion is shown in Figure D-2, and complete results are provided in RPP-RPT-56141, *FY2013 DNV DST and SST Corrosion and Stress Corrosion Cracking Testing Report*. This corrosion phenomenon was investigated using follow-on CPP tests.

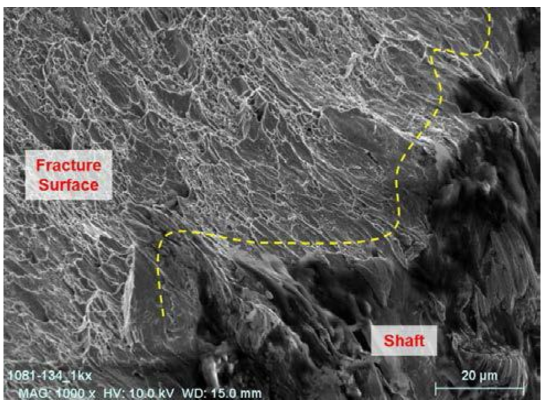


Figure D-1. Example of Ductile Fracture Surface from Tank TX-117 Slow Strain Rate Test

Figure D-2. Severe Corrosion on Tank TX-117 Specimen at +50 mV above Open Circuit Potential

Cyclic Potentiodynamic Polarization

CPP testing was conducted to determine the propensity for localized corrosion of the aggressive SST waste compositions. A total of 11 chemistries were tested; the same ten from the SSR testing, plus Tank T-102 composition as an additional test. The testing was performed in accordance with ASTM G61-86, *Standard Test Method for Conducting Cyclic Potentiodynamic Polarization Measurements for Localized Corrosion Susceptibility of Iron-, Nickel-, or Cobalt-Based Alloys*. Prior to CPP testing, the OCP was monitored for two hours. The potential scan was then started at -100 mV vs. OCP, and a scan rate of 0.167 mV/s was used. The scan reversed at 1 V vs. saturated calomel electrode or when the current reached a current density of 1 mA/cm^2. After completion of the test, the specimen was removed and analyzed for evidence of corrosion attack.

Pitting corrosion and a positive or mixed hysteresis was observed for the tanks that exhibited corrosion during the SSR tests, such as the Tank TX-117 result shown in Figure D-3.

Tank BX-110 simulant showed evidence of crevice corrosion, but the other tanks tested showed no evidence of localized corrosion and exhibited negative hysteresis. A summary of the CPP results are included in Table D-2, and additional information is provided in RPP-RPT-56141 and LAB-PLN-10-00001, *Test Plan for the Examination of Simulated Non-Compliant Waste from Hanford Single-Shell Tanks*.

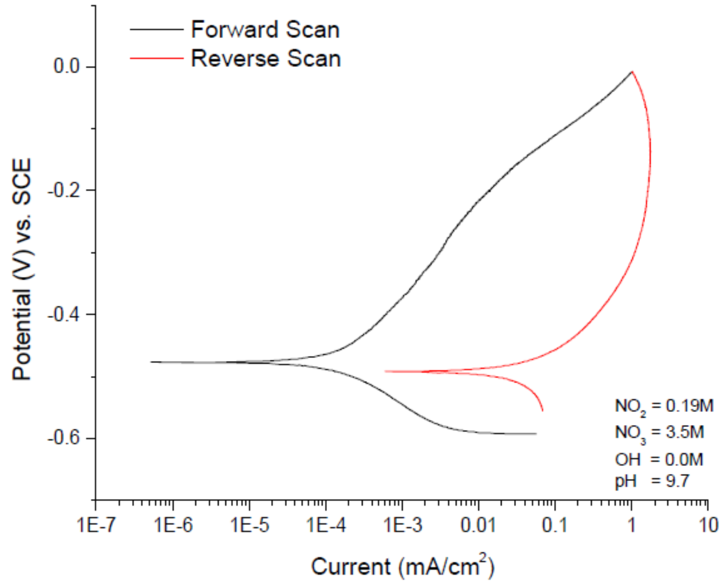
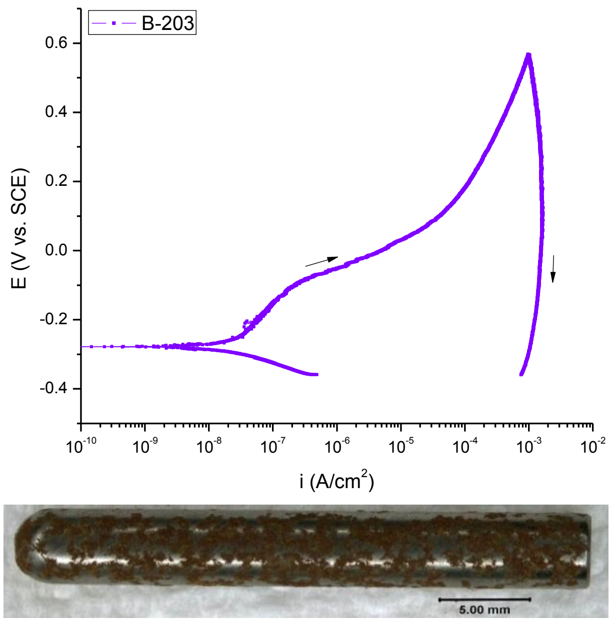


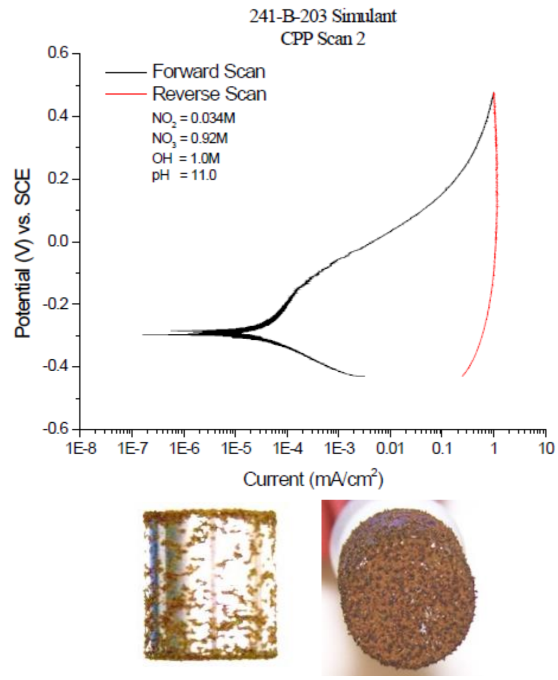
Figure D-3. Cyclic Potentiodynamic Polarization for Tank TX-117 Simulant

Table D-2. Summary of Cyclic Potentiodynamic Polarization

Pitting Corrosion		**Crevice Corrosion**	
B-107	T-110	BX-110	
B-203	TX-116	**No Localized Corrosion**	
S-104	TX-117	B-101	U-106
		T-102	U-203

Note that aggressive waste layer CPP testing was conducted at two laboratories: 222-S Laboratory and DNV-GL. The results showed good agreement between the laboratories for the simulants that were tested because they use the same testing protocol. To illustrate this point, Figure D-4 shows the results comparison for the Tank B-203 simulant. Current and future testing can have confidence that the results are reproducible regardless of the laboratory used.





DNV-GL B-203 cyclic potentiodynamic curve (top) and electrode optical micrograph (bottom)

222-S Laboratory B-203 cyclic potentiodynamic curve (top) and electrode optical micrograph (bottom)

Figure D-4. Cyclic Potentiodynamic Polarization Results for B-203 Simulant Comparing DNV-GL (Left) and 222-S Laboratory (Right)

D2.2 SUMMARY

Testing to date has indicated that the aggressive waste layers show no propensity for cracking, and some waste types show a potential for localized corrosion in the liquid waste solution, which is continuing to be investigated.

D2.3 FUTURE TESTING

The majority of necessary testing for aggressive waste layers is complete. Two additional tests will be conducted to complete the evaluation of corrosion propensity of the aggressive waste layers. Tanks B-107 and TX-116 will be tested once more for SCC. This time, instead of an SSR test, a crack growth rate test will be used. In this test, a pre-cracked steel specimen is exposed to an environment known to cause cracking, and then the specimen is cyclically loaded to introduce a crack. After a consistent crack is established, the environment is changed to the simulant of choice, and the crack is monitored to determine if the crack is inhibited or perpetuated. The results of this testing will confirm the results from SSR testing.

D3.0 AMMONIA CONTROL

In previous corrosion testing of DST wastes, ammonia in the vapor space and LAI was found to inhibit corrosion. Additional testing is currently underway to develop a reliable protocol for producing corrosion and determining what ammonia concentration will inhibit corrosion.

D3.1 TESTING COMPLETED

The first round of testing has been completed for both vapor space and LAI corrosion testing related to DST simulants. The focus of the testing to date has been on producing corrosion and how to add ammonia to inhibit it. No testing has been completed using SST waste simulants.

Vapor Space

Vapor space testing was completed by Savannah River National Laboratory (SRNL). A testing apparatus was created by exposing steel coupons at three different levels above a DST simulant solution: 36 in., 18 in., and 1 in. The coupons were exposed for four months, with coupons removed every month. The tests were conducted at vapor space ammonia levels of 50 and 550 ppm. The results indicate that for both ammonia concentrations and at all height levels, there was no apparent vapor space corrosion. These results indicate that even 50 ppm ammonia was sufficient to inhibit vapor space corrosion for the DST simulants.

Liquid-Air Interface

LAI testing was conducted by both SRNL and DNV-GL. The SRNL testing involved submerging coupons 50 percent in a liquid simulant representing different DST compositions. The coupons were exposed in the simulant for four months and measured for OCP, pH, and weight loss. Corrosion appeared to be more of a general attack, and corrosion rates were near 1 mil/year or less. Weak or no distinct LAI occurred on any of the coupons.

DNV-GL created a multi-electrode array (MEA) that used 16-pin electrodes in a 4 × 4 array and one large plate electrode (Figure D-5). The MEA was partially submerged and the current was monitored for each of the 16 electrodes. The purpose of this test was to determine the feasibility of using this technique for further LAI and vapor space corrosion testing using ammonia inhibition.

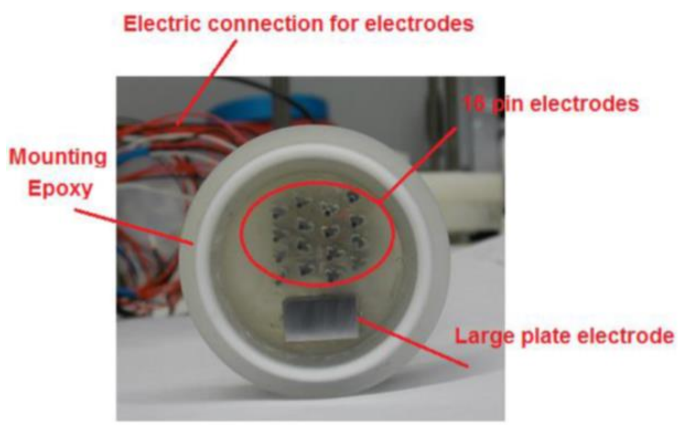


Figure D-5. Multi-Electrode Array for Liquid-Air Interface Corrosion Testing

Corrosion was not initiated at OCP after 48 days, so the MEA was polarized to accelerate the corrosion. Corrosion initiated in the large plate electrode and two-pin electrodes in the bulk solution, but not at the LAI. A 50 ppm and 500 ppm ammonia purge was used similar to the vapor space testing completed at SRNL, and the ammonia appeared to stifle the corrosion that was occurring in the bulk solution.

D3.2 SUMMARY

To date, the testing related to vapor space and LAI ammonia inhibition has focused on developing a reliable technique for initiating corrosion and then supplying ammonia to inhibit it. There have been difficulties producing noticeable and distinct LAI or vapor space corrosion in the testing. However, qualitatively, the ammonia does appear to provide an inhibiting effect.

D3.3 FUTURE TESTING

A reliable testing protocol is still being developed to produce corrosion and then determine what concentration of ammonia is necessary to inhibit that corrosion. Near-term testing will focus on testing an SST composition known to produce corrosion: Tank TX-116. First, linear polarization resistance (LPR) and CPP tests will be run on the simulant with 0 ppm as a baseline. The LPR and CPP will be run on Tank TX-116 simulant with 50 ppm ammonia in the headspace and the equilibrium concentration in the liquid.

After successful completion of LPR and CPP testing, long-term testing will be initiated, similar to the vapor space testing discussed in Section D3.1. Multiple metal coupons will be staged in and above the simulant. In one test, no ammonia would be added to the vapor space, and in the second test, the vapor space would be adjusted to 50 ppm or a concentration expected to be sufficient to inhibit corrosion. The coupons would be removed after three, six, and nine months exposure duration. Weight loss would be measured to determine long-term corrosion rates. If this testing is successful, additional SST simulants would be tested.

Once a reliable LAI testing setup and protocol is developed, testing will focus on determining what concentration of ammonia is necessary to inhibit corrosion in the SSTs and DSTs for particularly aggressive waste compositions. Testing will be conducted for both vapor space and LAI corrosion.

D4.0 COMMON FACTORS TESTING

Three SST waste chemistries found to be likely common factors in past SST failure—TBP waste, REDOX wastes, and nitrate leaching waste—were proposed for corrosion testing to determine their propensity to induce SCC. The testing will be conducted using simulated waste types at historical waste temperatures using SSR test procedures similar to the noncompliant waste testing. This testing is currently underway.

D5.0 REFERENCES

ASTM A537, 2013, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*, ASTM International, West Conshohocken, Pennsylvania.

ASTM G61-86, 2014, *Standard Test Method for Conducting Cyclic Potentiodynamic Polarization Measurements for Localized Corrosion Susceptibility of Iron-, Nickel-, or Cobalt-Based Alloys*, ASTM International, West Conshohocken, Pennsylvania.

ASTM G129-00, 2013, *Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking*, ASTM International, West Conshohocken, Pennsylvania.

LAB-PLN-10-00001, 2010, *Test Plan for the Examination of Simulated Non-Compliant Waste from Hanford Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

OSD-T-151-00007, 2014, *Operating Specifications for the Double-Shell Storage Tanks*, Rev. 13, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-49674, 2011, *Single-Shell Tanks Corrosion Chemistry Data Quality Objectives*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-50077, 2011, *Test Plan to Evaluate the Propensity for Corrosion in Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.

RPP-RPT-43116, 2009, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-55804, 2015, *Common Factors Relating to Liner Failures in Single-Shell Tanks*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-56141, 2014, *FY2013 DNV DST and SST Corrosion and Stress Corrosion Cracking Testing Report*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.