

Progress of the Enhanced Hanford Single Shell Tank (SST) Integrity Project – 15497

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ABSTRACT

To improve understanding of the single-shell tanks (SSTs) integrity, Washington River Protection Solutions, LLC (WRPS), the USDOE Hanford Site tank contractor, developed an enhanced Single-Shell Tank Integrity Project (SSTIP) in 2009. An expert panel on SST integrity, consisting of various subject matter experts in industry and academia, was created to provide recommendations supporting the development of the project. This panel developed 33 recommendations in four main areas of interest: structural integrity, liner degradation, leak integrity and prevention, and mitigation of contamination migration. In late 2010, seventeen of these recommendations were used to develop the basis for the M-45-10-1 Change Package for the Hanford Federal Agreement and Compliance Order, which is also known as the Tri-Party Agreement.

The change package identified two phases of work for SST integrity. The initial phase was focused on efforts to envelope the integrity of the tanks. The initial phase was divided into two primary areas of investigation: structural integrity and leak integrity. If necessary, based on the outcome from the initial work, second phase would be focused on further definition of the integrity of the tanks and liners. Combined these two phases are designed to support the formal integrity assessment of the Hanford SSTs in 2018 by an Independent Qualified Registered Engineer. As the initial phase of this work completes in early 2015, this paper summarizes the project formation and status the work of the past few years associated the implementation of the Phase one recommendations.

Work in the initial phase to further define the DOE's understanding of the structural integrity SSTs involved preparing a modern Analysis of Record (AOR) using finite element analysis. Structural analyses of the SSTs have been conducted since 1957, but these analyses used analog calculations, less rigorous models, or focused on individual structures. As such, an integrated understanding of all of the SSTs has not been developed to modern expectations. In support of this effort, other activities addressed the visual inspection of tank internal conditions and the collection of concrete core samples from the tanks, including a full height tank sidewall core, for analysis of current mechanics properties.

The work on the liner leak integrity has examined leaks from 25 tanks with known liner failures. Individual leak assessments were developed for each tank to identify the leak cause and location and estimate historic leak rates. A common cause/failure analysis study was performed to take data from individual tanks to look for trends in the causes of failure. A separate activity is being conducted to examine the propensity for corrosion in select SSTs with aggressive waste layers.

The work products from these two main efforts provide the basis for the phase two planning. If the margins identified aren't sufficient to ensure the integrity through the life of the mission, phase two would focus on activities to further enhance the understanding of tank integrity. Also coincident with any phase-two work would be the independent integrity assessment of the tanks, which would be complete in 2018. With delays in the completion of waste treatment facilities at Hanford, greater reliance on safe, continued storage of waste in the SSTs is increased in importance. The goal of integrity assessment would provide basis to continue SST activities until the end of the treatment mission.

INTRODUCTION

The mission of the River Protection Project (RPP) is to store, retrieve, treat, and dispose of the highly radioactive waste in Hanford Site tanks in an environmentally sound, safe, and cost-effective manner. The waste is stored in 28 active double-shell tanks and 149 single shell tanks. Although new waste additions stopped in 1980, the single-shell tanks (SSTs) continue to store over 30 million gallons of radioactive waste left over from decades of plutonium production for defense purposes. In 2004, the last pumpable liquid was removed from the SSTs, except for those tanks undergoing active waste retrieval.

BACKGROUND

The Hanford radioactive waste is contained in 149 SSTs and 28 double-shell tanks (DSTs). The SST tank farms were constructed over a 20-year period as needed to support the reprocessing of fuel. Construction of the first SST tank farm was started in late 1943 and completion of the last SST tank farm occurred in 1964. See Fig. 1 for typical construction photo. The first four farms consisted of four 208 cubic meter (55,000 gallon) tanks and twelve 2006 cubic meter (530,000 gallon) tanks. The other farms were built with three different capacities: 2006 cubic meters (530,000 gallons), 2839 cubic meters (750,000 gallons), and 3785 cubic meters (1,000,000 gallons). In total, 149 SSTs, in 12 farms, were built for the storage of radioactive wastes at the Hanford Site.

As previously stated, four different tank types were constructed (see Fig. 2). The first, Type I, have a 6 meter (20 foot) diameter, 11.6 meter (38 foot) height, and hold 208 cubic meters. The second, Type II, have a 22.9 meter (75 foot) diameter, 9.8 meter (32 foot) height, and hold 2006 cubic meters. The third, Type III, also have a 22.9 meter diameter, but had an 11.9 meter (39 foot) height, and hold 2839 cubic meters. The fourth, Type IV, was broken down into three sub-types. All three Type IV tanks – Types IVA, IVB, and IVC – had a 22.9 meter diameter and hold 3785 cubic meters, with heights ranging from 14 to 14.9 meters (46 feet to 48.75 feet). All tanks carry the prefix designation 241-, followed by the farm letter designation and then the individual tank number.

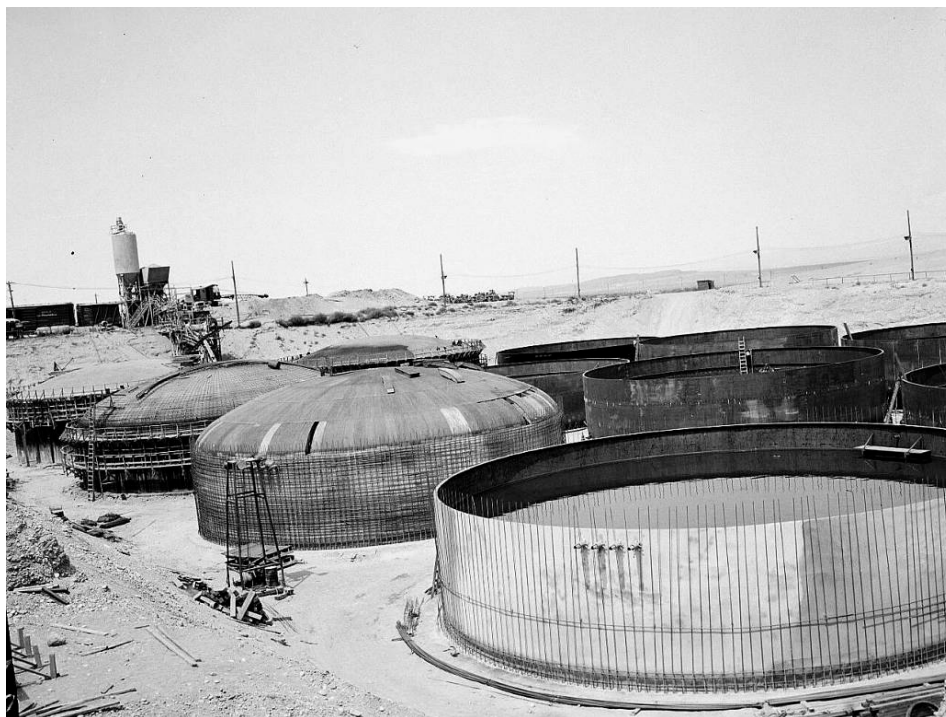


Fig. 1. 241-BX Tank Farm under Construction in 1947

In addition to the increasing volume of the tanks, other design features changed over the years. The Type I tanks have 38 cm (15-inch) thick flat slab tops and all other tank types have 38 cm (15-inch) thick concrete domes. The Type I and Type II tanks both have 30 cm (12-inch) thick reinforced concrete walls, and dished bottoms. The Type III tanks also have dished bottoms, but the walls were increased to 38 cm (15 inches). The lower portion of the tank wall on Type IV tanks was increased to 61 cm (24 inches) to accommodate the increased wall height. The Type IV tanks went to flatter bottom designs: a pan (or with a slight depression in the center) for the Type IVA tanks and flat for the other Type IV tanks. The bottom and the wall were welded with a fillet weld for the Type IVA and IVB tanks, but the Type IVC design has a 10 cm (4-inch) radius knuckle. To account for the increased heat loading in the Type IV tanks, the tanks were equipped with Air Lift Circulators; up to four in the Type IVA tanks, four in the Type IVB tanks, and 22 in the Type IVC tanks.

Early failures of SSTs, some potentially from stress corrosion cracking (SCC) of carbon steel liners, resulted in leakage of waste from the SSTs to the surrounding soil. This leakage led to a decision by the U.S. Atomic Energy Commission (predecessor to the U.S. Energy Research and Development Administration and subsequently the DOE) in the 1960s to initiate construction of DSTs with improved design, materials, and construction. The construction of the DSTs began in 1968 with the sixth farm being completed in 1986. All of the DSTs have a nominal million-gallon waste capacity. The free liquids from SSTs have been transferred to DSTs as part of the SST interim stabilization program, which was completed in fiscal year (FY) 2005. Eventually, the remaining solids (i.e., sludge and salt cake) and interstitial liquid in the SSTs will also be retrieved

and transferred to DSTs for subsequent processing and disposal; after that, the disposition of the SSTs will take place per the applicable requirements.

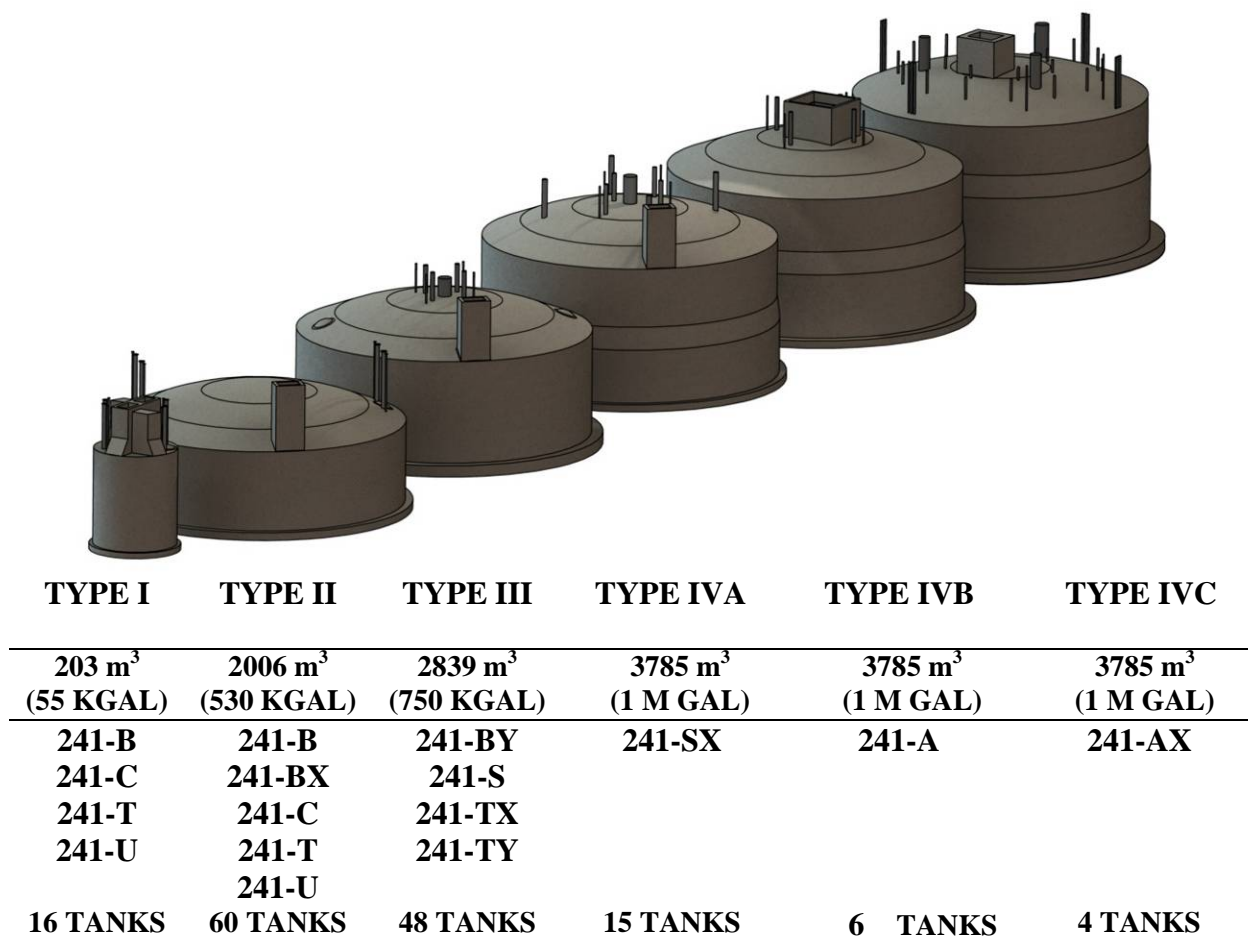


Fig. 2. Types and Nominal Volumes of the Single-Shell Tanks

At this point, the structural integrity program for SSTs is limited to ensuring that structural adequacy is maintained throughout SST waste retrieval and closure. However, since negotiations under the Tri-Party Agreement related to the schedule for waste treatment and vitrification have extended the use of the SSTs, the DOE established an extensive program for SST integrity.

Single-Shell Tank Operational History

The SSTs received alkaline waste from multiple nuclear fuel reprocessing operations, starting in 1944. The initial radioactive wastes were principally derived from three different chemical processing operations, each of which produced several different types of waste; the bismuth phosphate process, Reduction Oxidation (Redox) process, and Plutonium Uranium Extraction (PUREX) process. The bismuth phosphate process only recovered plutonium from irradiated reactor fuels. The Redox and PUREX processes recovered both plutonium and uranium from

the fuel. The bismuth phosphate wastes discharged to the tanks were later processed to recover uranium from the wastes by using the Tri-Butyl Phosphate (TBP) process. Potassium ferrocyanide was used to scavenge cesium ion from this waste. The oldest tanks (241-B, 241-BX, 241-BY, 241-C, 241-T, 241-TX, 241-TY, and 241-U farms) were constructed to receive waste from bismuth phosphate plants and received other wastes (e.g., low heat wastes from the Redox and PUREX plants and waste from uranium metal recovery). The Redox high heat wastes were stored in the 241-S and 241-SX farms. The PUREX high heat wastes were stored in 241-A, and 241-AX farms. The 241-SX, 241-A, and 241-AX designs allowed the storage of boiling wastes so water could be removed from the tanks to conserve space for the retention of radioactive materials. Tanks in the 241-A, -AX, and -SX Farms experienced high temperatures ranging from 200° F to 594° F. Other operations including the in-tank solidification (ITS) and tank farm evaporators were used to remove water and concentrate the wastes.

Waste additions to the SSTs ceased in 1980 and pumpable liquids have been transferred from the SSTs to the double-shell tanks (DSTs). Single-shell tank wastes are slated for retrieval and treatment in a Waste Treatment Plant and Immobilization (WTP) that is currently under construction. Technical issues have delayed the schedule for initiating operations of the WTP. The delays to the WTP will necessitate extended storage in the SSTs, most of which are beyond their design life even for the most recently built farm. Design life is based on steel liner corrosion rather than concrete degradation.

The Expert Panel and Genesis of and Single-Shell Tank Integrity Program

With the recognition that continued storage of waste in the SSTs would be required for decades into the future, it was essential to take steps to better understand the integrity of these aging structures. An expert panel on SST integrity, consisting of various subject matter experts in industry and academia, was created to provide recommendations supporting the development of the project. The expert panel was initially convened in 2009 and has met several times to address SST integrity concerns and to formulate recommendations as detailed in Table I. Although there has been some inevitable turnover, many of the key panel members have been participating since the panel inception. The current panel makeup is shown in Fig. 3.

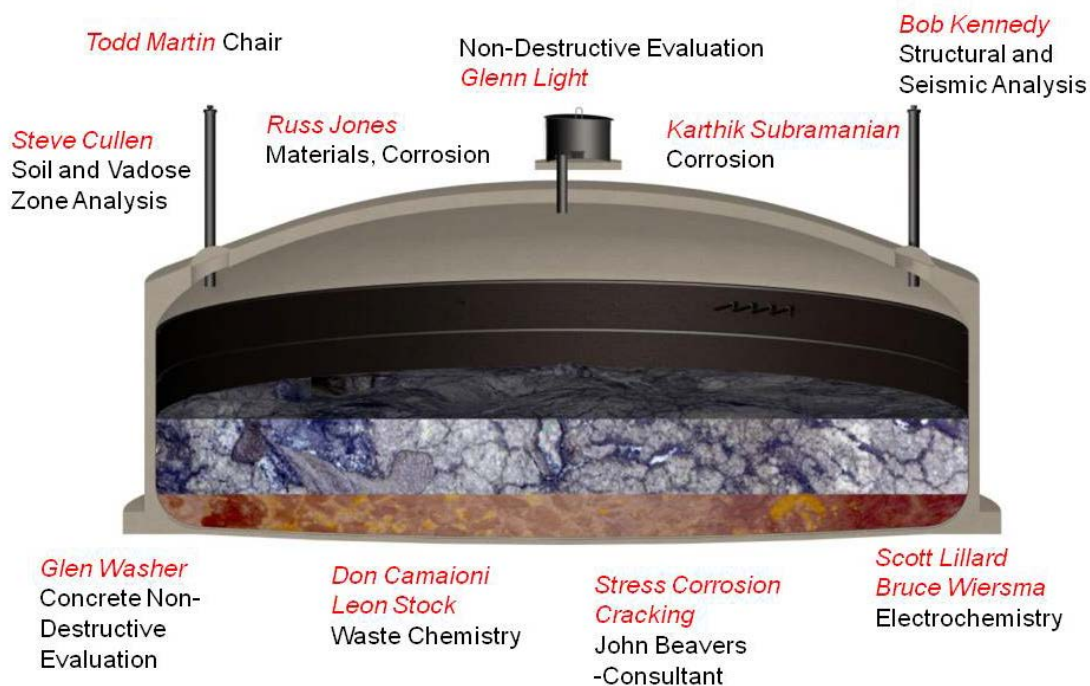


Fig. 3. Single-Shell Tanks Integrity Expert Panel - 2014

Table I. Single-Shell Tanks Integrity Expert Panel Meetings and Output

Meeting	Dates	Purpose	Documentation
First	January 26-28, 2009	Provide information to the Panel about SSTs.	WRPS-40656, <i>Summary of First Single-Shell Tank Integrity Expert Panel Workshop - January 2009 (1)</i>
Second	April 29-May 1, 2009	Respond to questions from Panel and for Panel members to present information based on assignments from the first meeting.	WRPS-42005, <i>Summary of Second Single-Shell Tank Integrity Expert Panel Workshop - April 2009</i> RPP-RPT-43116, <i>Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project (2)</i>
Third	January 20-21, 2010	New report to reflect new guidance.	RPP-RPT-45921, <i>Single-Shell Tank Integrity Expert Panel Report (3)</i>
Fourth	February 23-25, 2011	Review Progress, Refine Recommendations, Discuss Continued Panel Oversight	RPP-RPT-49272, <i>Fourth Single-Shell Tank Integrity Project Expert Panel Meeting (4)</i>
Fifth	August 28-29, 2014	Update the Panel on Findings from Implementation of Phase I Recommendations	RPP-RPT-59981, <i>Fifth Single-Shell Tank Integrity Panel Meeting</i>

The expert panel developed 33 recommendations in four main areas of interest: structural integrity (SI-X), liner degradation (LD-X), leak integrity and prevention (LIP-X), and mitigation

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of contamination migration (MCM-X) and documented their findings in RPP-RPT-43116, *Expert Panel Report for Hanford Site Single-Shell Tank Integrity Project* [5], for implementation of an enhanced SSTIP. In addition, the panel identified the key “top ten” primary recommendations that form the foundation of a robust SSTIP.

1. Recommendation SI-1, Perform Modern Structural Analyses or Analysis of Record (AOR)
2. Recommendation SI-2, Perform Dome Deflection Surveys
3. Recommendation SI-3, Obtain and Test Sidewall Core
4. Recommendation SI-4: Perform Non-Destructive Evaluation of Concrete
5. Recommendation LD-1, Expand Leak Assessment Reports
6. Recommendation LD-2, Avoid Inadvertent Addition of Water and Chloride to SSTs
7. Recommendation LIP-1, Continue Leak Detection Monitoring and Best Management Practices and Install Enhanced External SST Monitoring
8. Recommendation LIP-2, Avoid the Addition of Water-Insoluble Absorbents to SSTs
9. Recommendation LIP-3, Continue Use of High Resolution Resistivity
10. Recommendation MCM-1, Install Surface Barrier over SST Farms

WRPS produced implementing documentation in RPP-PLAN-45082, *Implementation Plan for the Single-Shell Tank Integrity Project* [6] that addresses these 10 primary recommendations as well as six additional secondary recommendations, identifying the scope, work plan, and work schedule to complete each recommendation.

In addition to the top 10 primary recommendations, the six secondary recommendations that WRPS recommended to pursue further are:

1. SI-5, Test Dome Concrete and Rebar
2. SI-6, Develop Engineering Mechanics Document
3. LD-3, Examine “non-compliant” wastes at 25°C
4. LD-5, Determine Ammonia Corrosion Control Concentration
5. LD-6, Assess SST Waste Compositional Variation
6. LIP-8, Assess the Feasibility of Testing for Ionic Conductivity Between Inside and Outside of SSTs

Regulator Acceptance

To provide regulatory framework for execution of the SSTIP, in late 2010, a series of working meetings were held with DOE/ORP, Ecology, and WRPS. These meetings were held to develop a consensus opinion of what elements of the 33 recommendations should be implemented near-term, with milestones and dates, and what recommendations were held for possible re-evaluation in 2015 or not to be implemented. A phased approach for implementation of the SSTIP was recommended with the goal of developing sufficient data to support a re-assessment of SST integrity by an Independent Qualified Registered Professional Engineer (IQRPE). Phase I activities were identified in a final change package with 8 enforceable interim milestones and 12 targets approved by DOE and the State at the start of calendar year (CY) 2011 (M-45-10-1 Change Package, for the Hanford Tri-Party Agreement).

The change package was organized into two principal areas, with two summary reporting activities collecting sub-ordinate tasks; a Summary Conclusions report on Leak Integrity (M-045-91F) and a Summary Conclusions report on Structural Integrity (M-045-91G). There is a major project assessment point that will occur in 2015 with the M-045-91H milestone and completion of Phase I activities. At this point, the Project, along with the regulators, will determine the effectiveness of the preceding Phase I actions and determine which Phase I activities should continue and if additional panel recommendations should become Phase II activities and milestones. The entire SSTIP leads to a culminating effort in 2018 (the M-045-91I milestone) with the IQRPE Certification of SST structural Integrity for the remainder of the mission (or such time as IQRPE believes is justified). The SSTIP milestone logic is shown in Fig. 4.

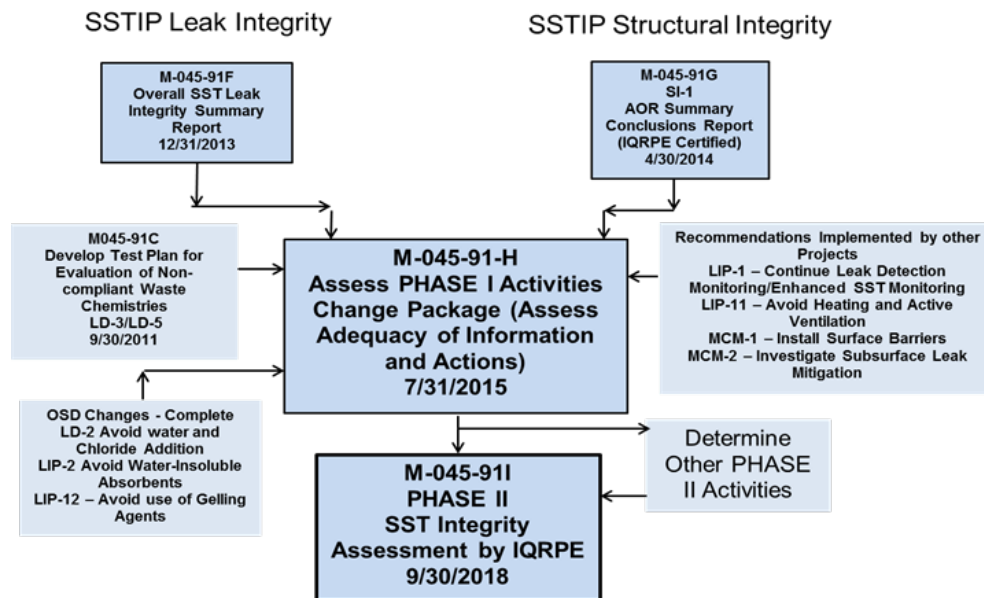


Fig. 4. Overall Milestone Logic for Single-Shell Tank Integrity Project

SUMMARY OF SSTIP PROGRESS TO DATE

Overall progress on SSTIP Activities was brisk and significant, but with periods of interruption. An effective organization structure was established and critical positions staffed. Special expertise was obtained through the use of contracts. The contractor, DOE, and regulator have met regularly to ensure smooth progress and acceptable completion. The project timeline is summarized below:

- The Expert Panel was formed and met in 2009.
- Recommendations were made to WRPS/ORP in 2010.
- Single-Shell Tank Integrity Project (SSTIP) work was initiated in FY 2011.
- The SSTIP was suspended in FY 2012 due to funding issues and priority.

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- Worked restarted but impacted by sequestration in FY 2013.
- 2014 saw the completion of major activities from Phase I of SSTIP in the areas of Structural Integrity and Leak Integrity.
- Planning for Phase II is a primary activity for FY 2015.

An overview of key activities from Phase I of the SSTIP are presented below; aligned with the originating Expert Panel Recommendation. All of the studies, analyses, and test reports produced by the SSTIP are available and have been approved for public release.

Recommendation SI-1, Perform Modern Structural Analyses

A modern structural analysis of record (AOR) was completed for all four SST tank types. The analyses show the SSTs are structurally sound, satisfying ACI Code and Structural stability evaluations. They include consideration of thermal and operating loads and a seismic analysis. Due to close tank spacing in some of the tank farms, a tank-to-tank interaction study was performed. All the analyses were performed by structural engineers from PNNL and BECHT Engineering and subject to review by independent, nationally recognized experts. Although primarily an analysis of past conditions, the models developed can also be used going forward as tanks are modified to support retrieval and tank loads potentially increased with retrieval equipment. Further detail on the structural analysis will be provided this session in paper #15526 by PNNL and BECHT Engineering titled “*A Summary of the Hanford Single-Shell Tank Structural Analysis of Record.*”

Recommendation SI-2, Perform Dome Deflection Surveys

Single-shell tank dome surveys provide a primary means of detecting concrete degradation. Excessive deflection would be indicative of incipient dome collapse. The dome survey program remains active and extensive repairs were made to benchmarks and monuments. All the SSTs are re-surveyed on 2-3 year frequency. All survey changes show minimal deflection, less than 0.6 cm (0.24-in).

Recommendation SI-3, Obtain and Test Sidewall Core

After extensive planning and demonstration of ability, the sidewall of tank 241-A-106 was cored and 11.6 meter (38 feet) of core was removed and tested for mechanical properties. Tank 241-A-106, a non-leaking tank, was selected because it experienced the most severe thermal history of any SST at Hanford. The core test results showed the concrete to be in very good condition and mechanical properties exceed those used in the structural analysis. See Fig. 5 for example core photo. Further detail on 241-A-106 sidewall core will be provided this session in paper #15548 by WRPS titled “*Hanford Single-Shell Tank Sidewall Coring Project.*”



Fig. 5. Example Concrete Core Photo from Tank 241-A-106 Sidewall (33 feet)

Recommendation SI-4, Perform Non-Destructive Evaluation of Concrete

Non-destructive examination of tank dome concrete is performed by visual inspection of the tank internals. A nominal number of 12 tanks are inspected each year with a goal of inspecting each of the SSTs every 10 years. The initial focus on structural integrity has been expanded to include detailed examination of the waste surface in response to concerns about water intrusion. No signs of structural distress have been found in the completed SST visual inspections.

SI-5, Test Dome Concrete and Rebar ‘Plugs’

Installation of retrieval equipment in tank 241-C-107 required the removal of large center dome plug measuring 55 inches in diameter. Several concrete cores and the top mat of rebar were successfully removed, shipped off-site and tested for mechanical properties. The material strength results were all higher than original tank design and higher than the properties assumed in the structural analysis. Petrographic examination of selected cores concluded that the concrete is in good condition and shows minimal carbonation after decades of ground contact.

LD-1, Expand Leak Assessment Reports to Leak Cause and Location

A methodology was developed using a cooperative process with site regulators for the determination of past SST liner leak cause and locations. This leak cause and locations analysis was completed and documented for 25 of the SSTs identified as having failed from liner leak. The evolution to identification of 25 SSTs with liner leak is shown in Fig. 6. This work challenges long-held assumptions and beliefs about past Hanford SST leaks. Further detail on this analysis will be provided this session in paper #15509 by WRPS titled “*Hanford Single-Shell Tanks Leak Causes and Locations.*”

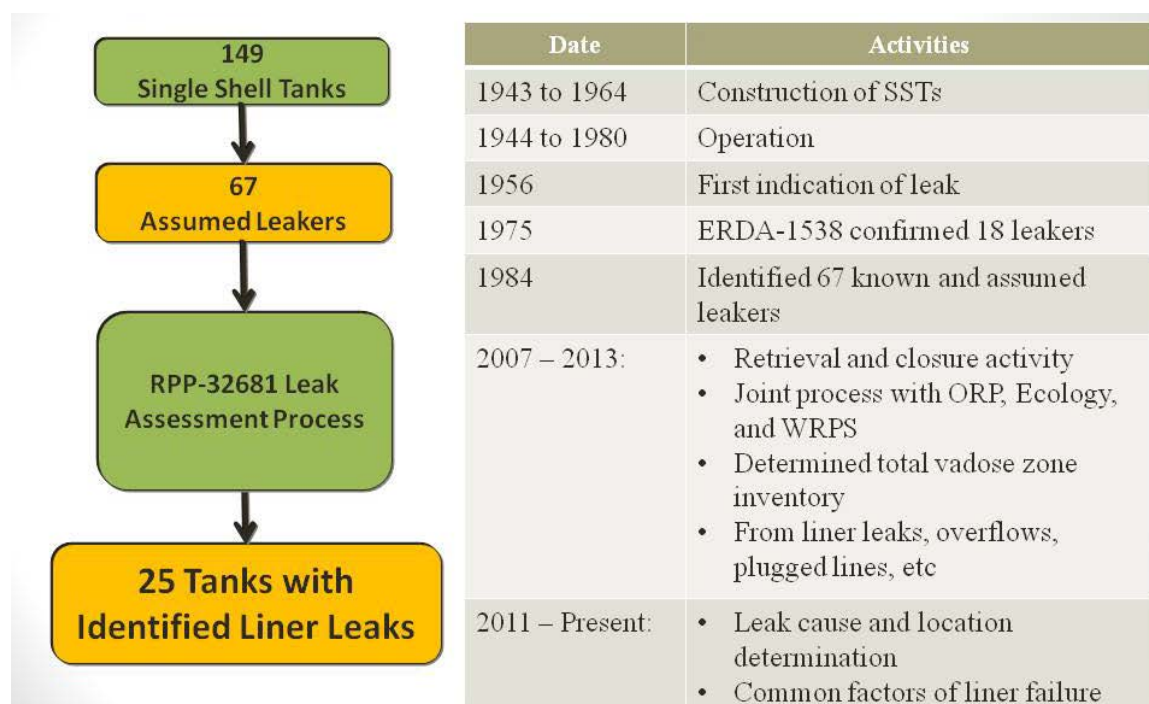


Fig. 6. Evolution of Identification of 25 SST with Liner Leaks

LIP-5, Evaluate Sludge and Salt-cake Leak Rates

In conjunction with the leak cause and location analysis described above, historical leak rates were estimated for the Hanford SSTs identified as having failed from liner leaks. The leak rates were estimated two ways: based on analysis of change in tank levels and based on the estimated leak volume divided by leak duration. The estimated leak rates varied from very large, 23,000 liters/day (6000 gal/day) to barely detectable, less than 23 liters/day (<6 gal/day). Tanks with high confidence determination of low leak rates could be candidate for less costly waste retrieval by modified sluicing.

LD-6, Assess SST Waste Compositional Variation

The recommendation was modified to examine factors that might be common to failure in the SSTs known to have a failed liner. A comprehensive failure analysis was performed, first identifying all potential failure mechanisms, dismissing some as not possible, and carrying potential factors forward for further evaluation. Based on review of historical information, and using standard statistical analysis techniques, the potential factors are binned to likely, unlikely or indeterminate in regard to their contribution to liner failure. High temperature operation, storage of aggressive waste types with chemistry associated with SCC, in tanks with steel of high yield strength and high residual stresses from non-stress relieved welds, and tank bottom designs without a curved lower knuckle were identified as likely contributing to liner failure. Although some factors are fixed, others are transient in nature and not expected to continue as the waste ages and cools.

LIP-8, Assess Feasibility of Ionic Conductivity

To improve DOE's ability to verify the integrity SST liners, WRPS contracted with Dr. Jerry Frankel of the Ohio State University to investigate the feasibility of using the presence of ions in the waste from a leak to detect the presence of ionic-conductive pathways in the tank liners. A small scale mockup demonstrated feasibility but the concept was shown to lack the sensitivity required for small leaks.

LD-3, Examine "Non-Compliant" wastes and LD-5, Determine Ammonia Corrosion Control Concentration

When the current DST corrosion prevention specifications are applied to the SST (based on best basis inventory compositions), 19 SSTs are identified as having potentially 'aggressive' waste layers. Corrosion testing of these aggressive waste layers using simulants has shown none exhibit potential for SCC. Six of the simulants do show propensity for pitting corrosion and this is continuing to be evaluated. Planned testing in 2015 includes determination of the effect of radiolytically generated ammonia, which is known to inhibit corrosion at some concentration.

CONCLUSIONS AND PATH FORWARD

The overall understanding of the structural integrity and leak integrity of Hanford SSTs has been improved by the actions of the SSTIP. Structural analysis, concrete material sampling and non-destructive examination indicates the SST structure remains robust. Leak integrity activities have captured valuable historical data and improved the understanding of past failure mechanisms and locations. The information will be useful in planning SST waste retrieval activities. Many factors believed responsible for past leaks are no longer active going forward.

As Phase II of the SSTIP is developed, some activity from Phase II will carry forward as part of ongoing integrity activity, such as SST dome deflection surveys and SST visual inspections. Corrosion testing will continue to understand the current threat to SST liners from potentially aggressive wastes. Other activities may be identified, of interest to DOE or the regulators that provide additional assurance of SST structural and leak integrity as the extended storage mission continues. All the SSTIP activities should be useful to the IQRPE when an integrity assessment is completed on the SSTs in 2018.

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