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Originator	Girardot, Crystal L	*Girardot, Crystal L*	07/19/2021
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RPP-7574
Revision 8

Double-Shell Tank Integrity Program Plan

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EXECUTIVE SUMMARY

The mission of the U.S. Department of Energy (DOE) River Protection Project (RPP) is to store, retrieve, treat, and dispose of the chemical and radioactive waste stored in the Hanford Site underground tanks in an environmentally sound, safe, and cost-effective manner. The waste is contained in 149 single-shell tanks (SST) and 27 double-shell tanks (DST). An additional DST that leaked waste to the tank annulus (Tank AY-102) has been emptied to the extent practicable and is no longer in service for waste storage. The DSTs are supported by ancillary systems and equipment, which allow movement of the waste into, within, and out of the tank system. The 242-A Evaporator facility, used for concentration of waste, is also a part of the Hanford tank farms waste processing and storage facilities.

The 28 DSTs, constructed from 1968 to 1986, are located in six tank farms. The DST design improved structural integrity and accessibility for inspection compared to prior SSTs. However, since some of the DSTs and ancillary equipment are expected to exceed their design life before the tank waste is removed and sent to the Waste Treatment and Immobilization Plant (WTP), the DST system must be maintained to ensure that the RPP mission goals can be met.

The broad requirements for tank integrity are defined in DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1*.[1] The DST Integrity Program (DSTIP) implements controls and inspections to ensure that DST system integrity is maintained throughout the RPP mission.

The DOE Office of River Protection (ORP) contractual agreement with the Tank Operations Contractor (Dowell 2011[2]) includes the original authorization agreement with a requirement to "maintain the tank structural integrity program as described in RPP-7574 as amended" (this report). The authorization agreement is updated annually, and the reference to RPP-7574 is maintained. This document (RPP-7574) is also included as an implementing requirement in the Tank Operations Contractor Management Plan, TFC-PLN-100, "Tank Operations Contractor Requirements Basis Document."[3]

This program plan is described in RPP-13033, *Tank Farm Documented Safety Analysis*,[4] as implementing environmental regulatory requirements concerning structural integrity assessments for DSTs and supporting the programmatic mission to maintain adequate DST storage space. The workscope covered under this DSTIP plan includes the following principal elements:

- DST integrity inspections (e.g., ultrasonic and video examinations) and documentation of results for use in periodic reinspections
- DST waste chemistry supernatant and core sampling and adjustments for corrosion mitigation to ensure compliance with corrosion control specifications

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[1] DOE G 435.1-1, 1999, *Implementation Guide for Use with DOE M 435.1-1,* U.S. Department of Energy, Washington, D.C.

[2] Dowell, J. A., 2011, "Contract No. DEAC27-08RV14800 – Approval of River Protection Project Authorization Agreement," (Letter 1100541 11-NSD-010 to C.G. Spencer, February 23), U.S. Department of Energy, Office of River Protection, Richland, Washington.

[3] TFC-PLN-100, 2020, "Tank Operations Contractor Requirements Basis Document," Rev. C-0, Washington River Protection Solutions, LLC, Richland, Washington.

[4] RPP-13033, 2021, *Tank Farm Documented Safety Assessment*, Rev. 7T, Washington River Protection Solutions, LLC, Richland, Washington.

- DST waste chemistry corrosion optimization studies to refine the waste chemistry parameters to minimize DST corrosion
- Development and installation of in-tank corrosion probes for DSTs to evaluate the corrosion potential of stored waste
- DST structural analysis and studies for thermal, operating, and seismic loads
- Periodic testing, evaluation, and certification of DST ancillary equipment (e.g., valve pits, transfer piping) that support the operation of the DST system.

In fiscal year (FY) 2016, the DSTIP completed the fieldwork and documented the integrity assessment of the DSTs and ancillary equipment as required by Title 40, *Code of Federal Regulations* (CFR) 265, Subpart J (40 CFR 265.191), "Assessment of Existing Tank System's Integrity,"[5] and *Washington Administrative Code* (WAC) 173-303-640(2), "Assessment of Existing Tank System's Integrity."[6] An Independent Qualified Registered Professional Engineer (IQRPE) certified this assessment and provided recommendations for future integrity work in RPP-RPT-58441, *Double-Shell Tank System Integrity Assessment Report (DSTAR).*[7] The next such assessment is due in FY 2026.

To ensure continued improvement of the technical bases, the DSTIP receives programmatic guidance and advice from the Tank Integrity Expert Panel (TIEP). The TIEP members have national and international reputations, and the members serve in positions in industry, national laboratories, and academia. As a comprehensive program to ensure the continued viability of the DSTs to support the Hanford mission, the DSTIP activities also include facilitating expert panel workshops on the technical aspects of DST use and life extension, providing guidance for the modeling of DST waste and operational characteristics.

[5] 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart J, "Tank Systems," *Code of Federal Regulations*, as amended.

[6] WAC 173-303-640, "Tank Systems," *Washington Administrative Code*, as amended.

[7] RPP-RPT-58441, 2016, *Double-Shell Tank System Integrity Assessment Report (DSTAR)*, Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington.

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FIGURES

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TERMS

Acronyms and Abbreviations

Ag/AgCl	silver/silver-chloride
AOR	analysis of record
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	ASTM International
BNL	Brookhaven National Laboratory
CFR	Code of Federal Regulations
CPP	cyclic potentiodynamic polarization
$Cu/CuSO_4$	copper/copper-sulfate
DFLAW	direct-feed low-activity waste
DNV GL	Det Norske Veritas–Germanischer Lloyd
DOE	U.S. Department of Energy
DOE-EM	U.S. Department of Energy, Office of Environmental Management
DST	double-shell tank
DSTAR	Double-Shell Tank System Integrity Assessment Report
DSTIP	Double-Shell Tank Integrity Program
Ecology	Washington State Department of Ecology
EMF	Effluent Management Facility
ER	electrical resistance
ETF	Effluent Treatment Facility
FEA	finite element analysis
FIC	Food Instrument Corporation
FY	fiscal year
HAZ	heat-affected zone
HD	high definition
HFFACO	Hanford Federal Facility Agreement and Consent Order
HIAP	High-Level Waste Integrity Assessment Team
IDRT	Integrity Data Review Team
IQRPE	Independent Qualified Registered Professional Engineer
LAI	liquid-air interface
LDP	leak detection pit
LERF	Liquid Effluent Retention Facility
MIC	microbiologically induced corrosion
MPCMS	multi-probe corrosion monitoring system
NACE	NACE International
NEI	Nuclear Energy Institute
ORP	Office of River Protection
OSD	operating specification document
P-scan	pulse-echo ultrasonic inspection
PASS	pit air supply system
PER	problem evaluation request
PF	pitting factor
PNNL	Pacific Northwest National Laboratory

qPCR	quantitative polymerase chain reaction
RCMP	retractable corrosion monitoring probe
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RPP	River Protection Project
SCC	stress corrosion cracking
SCE	saturated calomel electrode
SRNL	Savannah River National Laboratory
SST	single-shell tank
SWRT	secondary waste receiving tank
TAPI	Tank and Pipeline Integrity
THE	Tsujikawa-Hisamatsu electrochemical
TIEP	Tank Integrity Expert Panel
TMACS	tank monitor and control system
TOC	Tank Operations Contractor
TOLA	thermal and operating load analysis
TPA	Tri-Party Agreement
TSIP	Tank Structural Integrity Panel
UT	ultrasonic testing
VCI	vapor corrosion inhibitor
VSC	vapor space corrosion
WAC	Washington Administrative Code
WFD	waste feed delivery
WRPS	Washington River Protection Solutions, LLC
WTP	Waste Treatment and Immobilization Plant

Units

°C	degrees Celsius
°F	degrees Fahrenheit
ft	feet
ft^2	square feet
ft^3	cubic feet
gal	gallon
in.	inch
M	molar
mil	thousandth of an inch
min	minutes
mV	millivolt
w.g.	water gauge

1.0 INTRODUCTION

This document summarizes the requirements and scope of the Double-Shell Tank Integrity Program (DSTIP). Figure 1-1 shows the overall scope of the DSTIP. The U.S. Department of Energy (DOE) Office of River Protection (ORP) contractual agreement with the Tank Operations Contractor (Dowell 2011) includes a requirement to "maintain the tank structural integrity program as described in RPP-7574" (this report).

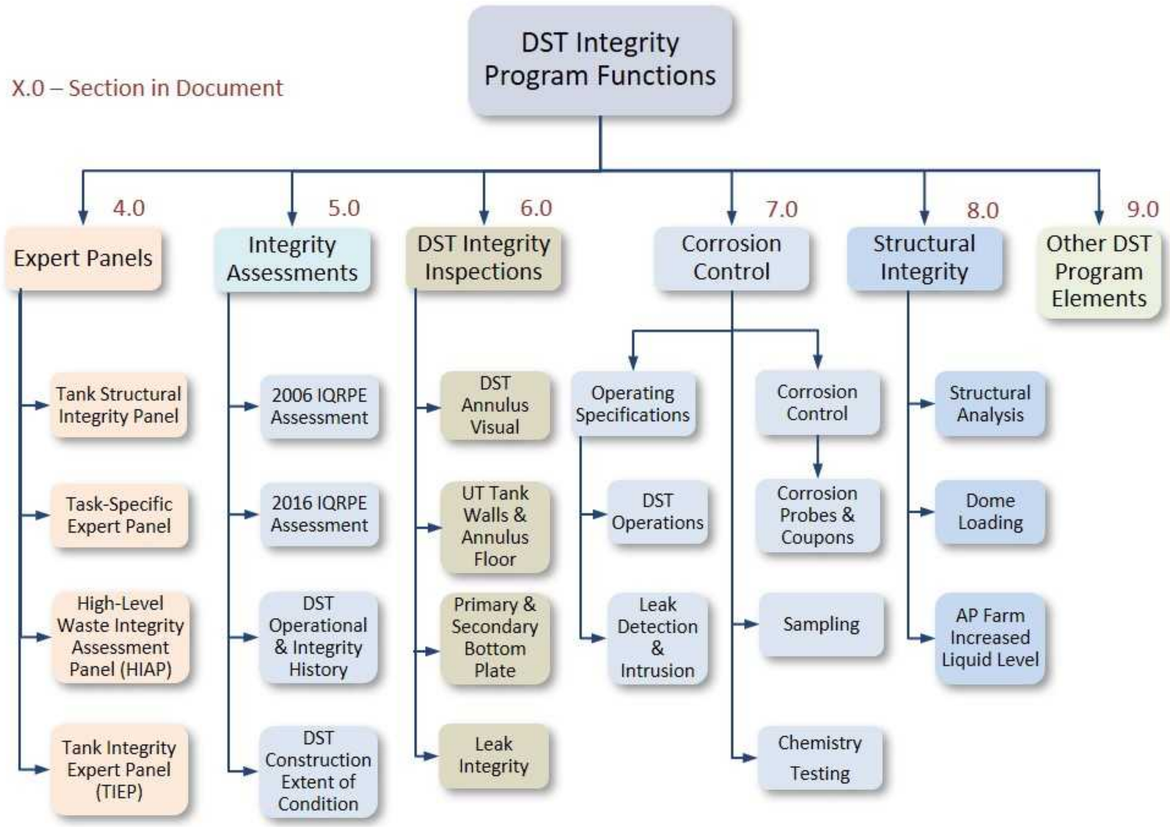


Figure 1-1. Overall Scope for the Double-Shell Tank Integrity Program.

The mission of the DOE River Protection Project (RPP) is to store, retrieve, treat, and dispose of the chemical and highly radioactive waste stored in the Hanford Site tanks in an environmentally sound, safe, and cost-effective manner. The waste is contained in 149 single-shell tanks (SST) and 27 double-shell tanks (DST). An additional DST that leaked waste to the tank annulus (Tank AY-102[8]) has been emptied to the extent practicable and is no longer in service for waste storage. The DSTs are supported by ancillary systems and equipment, which allow movement of the waste into, within, and out of the tank system. The 242-A Evaporator is an interface with the DST system that serves to concentrate the waste.

[8] Throughout this report, individual tanks and tank farms are referred to without the "241-" preceding the tank/tank farm designator (e.g., Tank 241-AY-102 is referred to as Tank AY-102, and 241-AY Tank Farm is referred to as AY Farm).

2.0 BACKGROUND

The 28 DSTs, constructed from 1968 to 1986, are located in six tank farms. The DST design improved structural integrity and accessibility for inspection. However, since some of the DSTs and ancillary equipment are expected to exceed their design life before the DST waste is removed and sent to the Waste Treatment and Immobilization Plant (WTP), the DST system must be maintained to ensure that the RPP mission goals can be met.

The DSTIP was established to meet the following DOE requirements:

- DOE O 435.1, *Radioactive Waste Management*
- DOE M 435.1-1, *Radioactive Waste Management Manual*
- DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1*
- BNL-52527/UC-406, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*
- *Washington Administrative Code* (WAC) 173-303-640, "Tank Systems"

A review for compliance with the requirements and guidelines is documented in RPP-ASMT-62082, *Implementation of DOE O 435.1 in the Double Shell Tank Integrity Program*. The requirements relevant to the DST integrity program scope can be summarized as the functions shown in Figure 2-1.

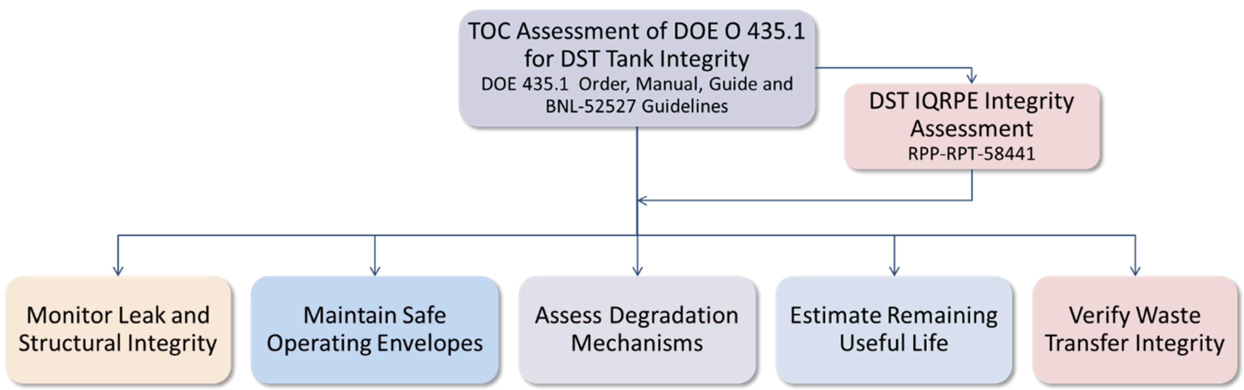


Figure 2-1. Integrity Program Functions

A detailed history of the DSTIP is provided in RPP-RPT-60782, *Double-Shell Tank Integrity Program History*. Appendix A of RPP-RPT-60782 identifies the functional areas of the program and the documents produced under each functional area.

2.1 DOUBLE-SHELL TANK SYSTEM

DOE constructed 28 DSTs, of which 27 tanks have maintained their integrity. Tank AY-102 has leaked from the primary tank onto the floor of the secondary liner and is not fit for use. These tanks are supported by ancillary equipment (e.g., transfer piping, valve pits, and one catch tank), which allow movement of the waste into, within, and out of the tank system.

The DST system has an interface with the 242-A Evaporator, which removes water from the waste to recover tank space consumed by retrieval and tank farm operations. The A-301 catch tank receives condensate from the high-heat AY and AZ Farm tanks, which is then transferred to Tanks AY-101, AZ-102, or the Effluent Treatment Facility (ETF).

Construction of the Double-Shell Tank Farms

The need for additional tank space and the need to support an increased radionuclide heat load led to a decision by the U.S. Atomic Energy Commission (predecessor to the U.S. Energy Research and Development Administration, and subsequently 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 DSTs design allows the detection of any potential primary tank leaks. Leaking waste would be held in the secondary containment, allowing for corrective action long before there could be a release of waste to the environment. Table 2-1 lists the construction dates, year of initial service, and the expected design life at the time of construction.

Table 2-1. Double-Shell Tank Construction and Age as of 2020

Tank farm	Number of tanks	Construction period	Construction project	Initial operation	Design life	Current age as of 2021
AY	2	1968 – 1970	IAP-614	1971	Undefined[a]	50
AZ	2	1970 – 1974	HAP-647	1976	Undefined[a]	45
SY	3	1974 – 1976	B-101	1977	50	44
AW	6	1976 – 1980	B-120	1980	50	41
AN	7	1980 – 1982	B-130, B-170	1981	50	40
AP	8	1982 – 1986	B-340	1986	50	35
Total	**28**					

[a] Design life is not addressed in either the functional design criteria or the design specifications.

The DSTs consist of a primary steel tank inside of a secondary steel liner (Figure 2-2). Both the primary tank and secondary liner are built of the same specification carbon steel. In each DST, the primary tank was post-weld heat treated to reduce residual stresses from fabrication and the propensity for stress corrosion cracking (SCC) failures.

The secondary steel liner is encased by a reinforced concrete shell. The primary tank rests on a refractory concrete slab used to thermally insulate it from the secondary liner and concrete foundation. This refractory slab also provides air circulation/leak detection channels under the primary tank bottom plate. An annular space of 2.5 ft exists between the secondary liners and primary tanks. This annular space also allows for visual surface and ultrasonic volumetric inspections of the primary tank walls and secondary liners.

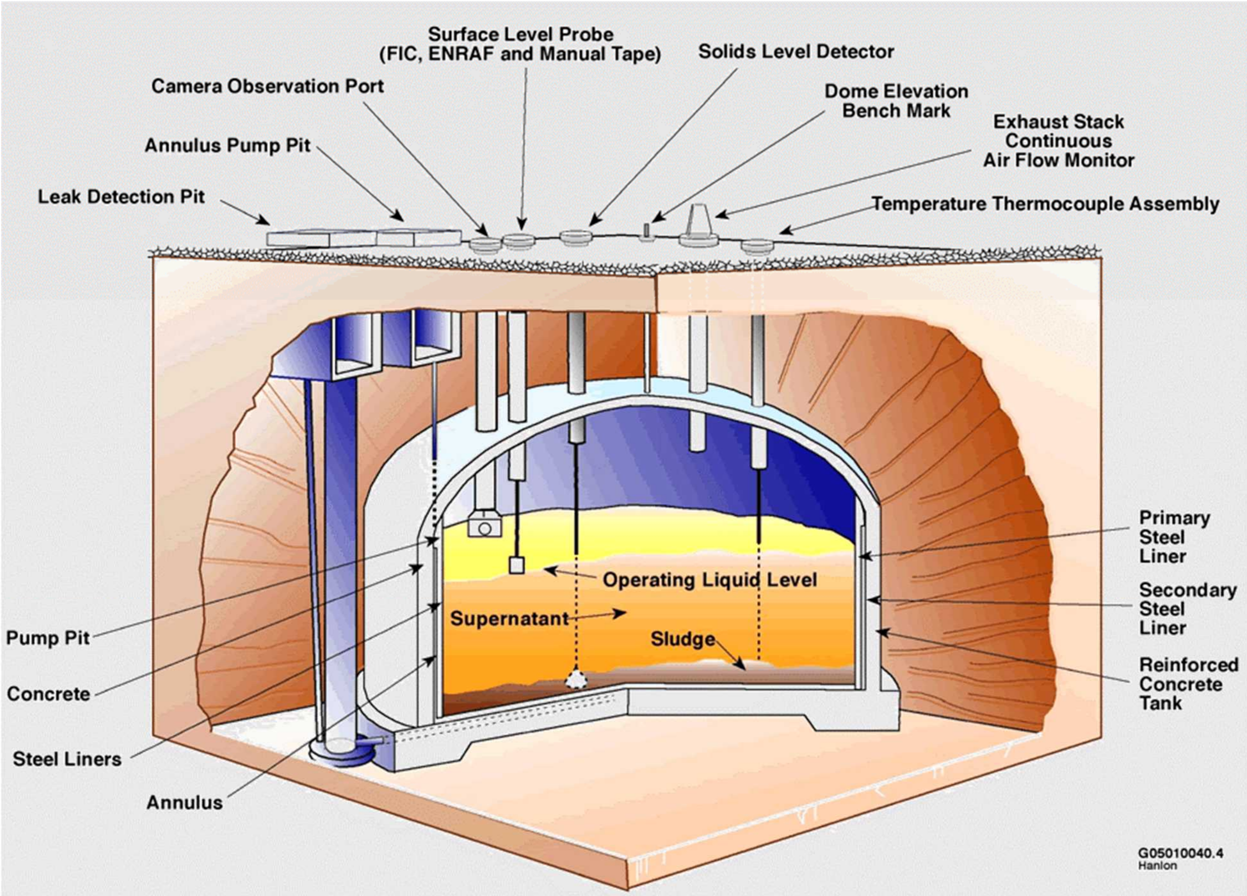


Figure 2-2. Typical Double-Shell Tank Configuration.

All DSTs are buried underground, with the top of the concrete dome being located approximately 7 to 8 ft below the surface of the ground. The amount of ground cover increases to more than 15 ft out at the edge of the dome.

2.2 ANCILLARY SYSTEMS

Waste transfer system – The waste transfer system consists of pipelines, pump and valve pits, pumps, jumpers, and valves. The transfer system is periodically reviewed by an Independent Qualified Registered Professional Engineer (IQRPE) and is described in RPP-RPT-58441, *Double-Shell Tank System Integrity Assessment Report (DSTAR)*. Integrity for the waste transfer system is maintained as described in RPP-PLAN-52788, *Waste Transfer System Fitness-for-Service Implementation Plan*.

Catch tank AZ-301 – The AZ-301 condensate receiver tank collects condensate from the primary tank exhaust system for the waste tanks in AZ and AY Farms. The tank is located in a containment vault. The condensate was previously routed to Tank AY-101 or AZ-102. The condensate is now pumped to an 8,000-gal tanker truck (AZ301TK-COND) for transport to the 200 East Area ETF.

3.0 INTEGRITY PROGRAM DEVELOPMENT

The DSTs are the primary assets of the DST system. While the other elements of the system are required for operation, the loss of DST space has a significant effect on the ability to meet RPP mission requirements. As such, the DSTIP focuses on ensuring the integrity of the 27 DSTs and the integrity of the DST system ancillary equipment (e.g., transfer system).

This program plan identifies the DSTIP activities. The workscope covered under this DSTIP Plan includes the following principal elements:

- DST integrity inspections (e.g., ultrasonic and video examinations) and documentation of results for use in periodic reinspections
- DST waste chemistry supernatant and core sampling, and adjustments for corrosion mitigation to ensure compliance with corrosion control specifications
- DST waste chemistry corrosion optimization studies to refine the waste chemistry parameters to minimize DST corrosion
- Development and installation of in-tank corrosion probes for DSTs to evaluate the corrosion potential of stored waste
- DST structural analysis and studies for thermal, operating, and seismic loads
- Periodic testing, evaluation, and certification of DST ancillary equipment (e.g., valve pits, transfer piping), which support the operation of the DST system.

The workscope discussed above reflects the strategy developed prior to the Tank AY-102 leak. A number of recommendations have been made for enhanced integrity inspections to address the concerns identified from the Tank AY-102 leak assessment. These recommendations primarily focus on the inspection of the tank bottom to assess the cause of the Tank AY-102 leak and to identify if other DSTs may have similar conditions.

3.1 STRATEGY DEVELOPMENT

The elements of this program came from a DOE-wide initiative pertaining to concerns related to the aging radioactive waste storage facilities throughout the DOE complex. These concerns led to Brookhaven National Laboratory (BNL) developing guidelines for structural integrity programs for tank systems (BNL-52527/UC-406). The committee of experts who developed these guidelines is commonly known as the Tank Structural Integrity Panel (TSIP).

Structural integrity is defined in the TSIP guidelines as including leak tightness (barriers to release of waste) and structural adequacy (strength against collapse or failure from normal and abnormal loads). The TSIP guidelines advocate a systematic ongoing approach to assessing structural integrity as a basis for identifying necessary management options to ensure leak tightness and structural adequacy over the life of the mission.

DOE has subsequently adopted the TSIP guidelines and, in accordance with DOE O 435.1, requires site operators to have a program consistent with the DOE guidelines provided in DOE M 435.1-1. The ORP contractual agreement with the Tank Operations Contractor (Dowell 2011) includes a requirement to "maintain the tank structural integrity program as described in RPP-7574."

In addition to being subject to the requirements of the DOE Order, the DSTs and ancillary equipment are regulated under:

- *Resource Conservation and Recovery Act of 1976* (RCRA) and associated regulations
- *Revised Code of Washington* (RCW) 70.105 et seq., "Hazardous Waste Management," and its implementing requirements
- Title 40, *Code of Federal Regulations* (CFR), Part 265 (40 CFR 265), "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart B, "General Facility Standards"
- WAC 173-303-640, "Tank Systems."

DOE and the Washington State Department of Ecology (Ecology) regulatory requirements have objectives similar to the structural integrity program advocated in the TSIP guidelines. Thus, a tank structural integrity program consistent with the TSIP guidelines supports compliance with the federal and state regulatory requirements for the DSTs and ancillary equipment. RPP-16922, *Environmental Specifications Requirements,* describes the major elements of the Hanford DSTIP and mechanisms for meeting the environmental requirements.

Tank integrity activities began in 1992 with the negotiation of the M-32 milestones as part of the *Hanford Federal Facility Agreement and Consent Order – Tri Party Agreement* (TPA) (Ecology et al. 1989). Ecology and ORP renegotiated these activities and agreed to a new series of actions under the M-48 milestones. These activities included visual inspection of the DSTs and development of ultrasonic testing (UT) systems. These milestones led to preparation and issuance of the DST integrity assessment report (RPP-28538, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14*) under the M-48-14 milestone. The project eventually included waste chemistry testing and the development of in-tank corrosion monitoring, along with the guidance from expert panels.

3.2 APPROACH FOR STRUCTURAL INTEGRITY VERIFICATION

Structural integrity verification is a two-step process consisting of data collection and data evaluation. The data required for verification of the structural integrity of a tank system includes loading, geometry, and material properties (BNL-52527/UC-406, Section 2.2, for tank structural integrity, and Section 7.2 for transfer piping).

To assess future structural integrity, estimates of changes in postulated loading conditions (e.g., waste-specific gravity), geometry (e.g., wall thinning caused by corrosion), and material properties (e.g., as affected by aging and degradation) are required. Therefore, evaluating structural integrity over the component mission life requires understanding of the historical data, past operating conditions, potential aging mechanisms, and degradation rates.

Additional elements of a comprehensive tank system structural integrity program that are needed to ensure structural integrity over time include the following (BNL-52527/UC-406, Sections 2.3 and 7.3 for tanks and transfer piping, respectively):

- Identifying aging mechanisms
- Quantifying the degree of degradation
- Evaluating the effect of degradation on tank system integrity

- Verifying structural adequacy
- Considering management options.

To ensure the continued structural and leak integrity of the DSTs, the DSTIP inspects the tanks to detect degradation of the system integrity, employs chemistry control to minimize the propensity for corrosion in the DSTs, and assesses structural integrity of the tanks.

3.3 DOUBLE-SHELL TANKS AGING MECHANISMS

As documented in BNL-52527/UC-406, Section 3, the possible degradation mechanisms for nuclear waste storage tanks are listed in Table 3-1 with the significance level. Each mechanism and significance level is discussed in detail in BNL-52527, Section 3.

Table 3-1. Possible Degradation Mechanisms for Nuclear Waste Storage Tanks

Component	Mechanism	Significance
Steel shell and liner (primary tank and secondary liner)	1. General corrosion (bulk, uniform)	A
	2. Pitting/crevice corrosion	A
	3. Stress corrosion cracking (SCC)	A
	4. Microbiologically induced corrosion (MIC)	A
	5. Concentration cell/waterline corrosion (LAI)	A
	6. Corrosion of external tank surfaces by in-leakage	A
	7. Thermal embrittlement	C
	8. Radiation embrittlement	C
	9. Creep and stress relaxation	C
	10. Fatigue	B
	11. Erosion and erosion-corrosion	B
	12. Wear	B
	13. Hydrogen embrittlement and attack	B
Concrete	1. Elevated temperature	A
	2. Freezing and thawing	A
	3. Leaching of calcium hydroxide or other soluble constituents	A
	4. Aggressive chemical/sulfate attack	A
	5. Corrosion of embedded steel	A
	6. Alkali-aggregate reactions	C
	7. Creep and shrinkage	C
	8. Abrasion and cavitation	C
	9. Irradiation	C
Refractory concrete	1. Elevated temperature	A
	2. Effects of chemicals	A

Source: BNL-52527/UC-406, 1997, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*, Brookhaven National Laboratory, Upton, New York.

Significance: A – Potentially significant; B – Potentially nonsignificant but may become significant under certain specific circumstances; C – Non-significant.

The TSIP guidelines identify a number of aging mechanisms that have the potential to cause degradation in tank systems. Their significance depends on tank-specific conditions and plausible failure modes. The TSIP guidelines recommend that "to produce a realistic and cost-effective program" only those aging mechanisms that would be expected to cause significant degradation for the tank-specific conditions and that affect the likely failure modes should be included in the tank structural integrity evaluation.

The mechanisms deemed most significant as identified by the DST life extension panel (PNNL-13571, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*) for the Hanford DSTs are discussed in the following sections.

3.3.1 Failure Mechanisms for Primary Tanks

The DST primary tanks have three main areas of vulnerability to corrosion: (1) interior surfaces of the tank exposed to the headspace air, (2) interior surface of the tank in contact with the waste, and (3) exterior surface of the tank exposed to the annulus air or water intrusion. These surfaces are subject to general corrosion, pitting corrosion, and SCC, and the tanks may also be vulnerable to other more specialized forms of attack as the tank ages.

The DST life extension panel (PNNL-13571) indicates that localized pitting and concentration cell corrosion caused by the formation of localized regions of aggressive species in the waste are the most threatening degradation mechanisms for the DST primary tanks.

Stress corrosion cracking (SCC) – SCC requires a susceptible material and the simultaneous presence of a sustained tensile stress and an aggressive environment. Carbon steel is susceptible to SCC in certain environments and temperatures. SCC has occurred in tanks at the Savannah River Site and in the older Hanford SSTs. Specifications to minimize SCC in DSTs are identified in RPP-RPT-47337, *Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*, and have been incorporated into the current operating specification document (OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks*). All primary tanks in the Hanford DSTs were stress-relieved during fabrication.

Liquid-air-interface (LAI) corrosion – Historically, LAI corrosion occurred when out-of-specification waste was left as a static top layer in the tank for years at a time. This LAI corrosion typically occurs high up on the tank wall, in an area of the tank that has low stress. As such, this corrosion does not present a challenge to structural integrity but could challenge the leak integrity of the tanks if preventive measures are not taken.

The TSIP guidelines identified concentration cell or waterline corrosion and corrosion of external tank surfaces by in-leakage as potentially significant failure mechanisms for steel tanks. The DSTs do not have stagnant water in contact with the external tank surface, although the tank interior waterline corrosion at the LAI remains a potential concern, primarily because the headspace is actively ventilated and carbon dioxide in air depletes hydroxide (which protects against corrosion) at the waste surface.

Condensate additions to Tanks AY-101 and AZ-102 have been correlated to corrosion observed at the LAI during UT inspections in 2018, as discussed in Section 6.2.1.1 (RPP-RPT-61005, *Investigation of Tank 241-AY-101 and 241-AZ-102 Liquid to Air Interfaces*). The water was added without proper mixing and without adequate inhibitors.

Water intrusion has also been observed through the top of the annuli in the AY Farm. The source of this water and its impact on the tanks was investigated. Though no clear source of water was found, the pathway into the annulus comes from a gap between the primary tank and the secondary liner. Where these two shells meet, the secondary liner lays on top of the primary tank. Though this space exists in all of the DSTs, the gap was intentionally formed in the AY Farm by use of ½-in. copper rods.

The impact to the tanks at this location is deemed small. Evidence of intrusion is being monitored. If an increase is noted or if water intrusion is detected in other tank annulus areas, measures will be taken to investigate it at that time. These measures could include increased visual inspection or sampling of the material to determine origin.

Pitting/crevice corrosion (primary tank bottom plate) – Based on the likely cause of the failure of Tank AY-102, primary bottom plate localized corrosion from contact with aggressive species in the waste may be of concern for the remaining DSTs. A study was performed to evaluate and identify DSTs with increased risk of corrosion of the tank bottom (RPP-RPT-60469, *Internal Tank Bottom Corrosion Study for Double Shell Tanks*) that help define and prioritize inspection and sampling.

In 2019, changes were made to the chemistry control limits in the DST operations specification document, OSD-T-151-00007, to incorporate extensive corrosion testing work that investigated SCC and pitting in the Hanford DSTs. Based on the likely failure mechanism of Tank AY-102 being halide-induced pitting corrosion, the updated OSD incorporated halides into the specification and increased the minimum concentration of nitrite, a chemical species shown to lower pitting corrosion and SCC susceptibility.

The current OSD also reflects historical limits for prevention of SCC. Localized corrosion was traditionally detected by inspection and prevented on a case-by-case basis. Current corrosion testing is focused on the prevention of all of the types of corrosion considered as critical in Table 3-1, leading to the pitting factor approach (discussed in Section 7.2).

3.3.2 Failure Mechanisms for the Secondary Liner

Under normal operation, the failure mechanisms for the secondary liner are the same as those for the exterior of the primary tank. During leak events from the primary tank to the secondary liner, the lower knuckle of the secondary liner would be the area of highest stress. The reinforced concrete backs the liner on the sidewall and base of the liner; at the lower knuckle, there is no concrete backing to the liner. Therefore, this portion of the secondary liner is load-bearing.

Background – After the Tank AY-102 primary tank breach, the condition of the secondary liner was investigated. On November 20, 2013, Washington River Protection Solutions, LLC (WRPS) inspected the 6-in. diameter drain line that collects liquid outside of Tank AY-102 secondary containment and routes the liquid to the leak detection pit (LDP) sump. The drain line was dry at the outer perimeter of the tank and wet near the center. The crawler, sediment, and water were contaminated; however, the source of contamination was not determined. The wetting suggested intrusion of water through a wall joint at the base pad (RPP-RPT-56464, *241-AY-102 Leak Detection Pit Drain Line Inspection Report*). This work also showed about 30 ft^3/min of airflow out of the drain line into the LDP.

In 2014, Tank AP-102 annulus floor UT inspections showed a 70 percent penetration (localized in one small pit from the outside) in the secondary liner. This finding highlighted the possible threat to the secondary liner in other DSTs from moisture accumulation in the foundation beneath the liner. Intrusion of this kind apparently resulted in significant wall thinning in the bottom of the secondary liner of Tank AP-102 and degradation of varying degrees of localized corrosion in essentially all other tanks that have been inspected.

This thinning appears to be caused by a continually wet environment from moisture intrusion into the tank foundation associated with the connection to the LDP system. Limited laboratory testing of carbon steel in LDP water, LDP simulants, and groundwater simulant by 222-S Laboratory, Savannah River National Laboratory (SRNL), and Det Norske Veritas–Germanischer Lloyd (DNV GL) showed general corrosion rates of 5–15 mils/year for a bounding case (RPP-RPT-60698, *FY2017 DST and SST Chemistry Testing Report*, and SRNL-STI-2014-00616, *Hanford Double Shell Waste Tank Corrosion Studies – Final Report FY2014*).

Additional testing was conducted in fiscal year (FY) 2019 and FY 2020, with longer exposure times to water obtained from the AY Farm LDP. The results showed localized pitting corrosion of up to 2 mils/year for a 6-month exposure and >27 mils/year pitting corrosion for a 28-month exposure (RPP-RPT-62996, *Tank Waste and Ground Water Effects on the Corrosion Susceptibility of the Secondary Liner of Double-Shell Tanks*). However, there was visual evidence that microbiologically influenced corrosion (MIC) had possibly accelerated the attack.

Many of the DST foundation pads have been subject to long-term water intrusion and accumulation in the LDPs. Two evaluations were performed by WRPS to investigate LDP intrusion and to recommend mitigation actions.

- RPP-RPT-55666, *Double-Shell Tank Tertiary Leak Detection System Evaluation*, indicates the primary source for water in the LDPs is most likely the annulus ventilation system drawing moisture (humidity or perched water) from soils near the tank base and into the LDP drain pipe through a joint between the concrete tank wall and the foundation slab. This intrusion pathway likely subjects portions of the bottom of the secondary liner to either continual water exposure or high ambient humidity, both of which increase the potential for corrosion of the secondary liner bottom plate from the underside.
- RPP-PLAN-60778, *Double-Shell Tank Tertiary Leak Detection System Investigation and Mitigation Plan*, reviewed the range of possible actions to mitigate water intrusion.

In December 2016, John Marra (DOE-EM Chief Engineer) reviewed the DST program as part of a DOE-chartered DST Integrity Programmatic Risk Review Team. His report recommended the following:

> *Moisture intrusion into the tertiary leak detection area of the DSTs is undesirable and is likely causing the observed annulus floor thinning. The LDP vents should be decoupled from DST annulus ventilation as soon as reasonably practical. Additionally, crawlers should be deployed in the cooling channels cut into the refractory base that separates the primary liner from the secondary liner to determine a 'baseline' reading for continued monitoring.*

In 2017, the Tank Integrity Expert Panel (TIEP) recommended the following in RPP-ASMT-61727, *Structural Considerations for Double-Shell Tank Vacuum Limits*.

> *The liquid detection pit (LDP) and associated lines are ventilated in an incidental and unmeasured manner through connections with the secondary liner. This incidental ventilation results in water intrusion that can expose the secondary liner to moisture. The Panel has expressed concerns about the potential for corrosive conditions due to this moisture intrusion (RPP-ASMT-61313 and RPP-ASMT-60833).*

Corrosion in Tank AY-102 from breach – Waste leakage into the Tank AY-102 annulus discovered in 2012 required consideration of potential corrosion on the annulus floor and associated long-term waste confinement capability. Measured temperatures of the steel floor, interior of the refractory, and concrete beneath the tank suggest that the wastes on the secondary steel liner in the annular region and directly beneath the tank are between 100 and 120°F. An evaluation of the propensity for corrosion due to leaked waste was initiated in FY 2013. After 3 years of testing varying leaked waste compositions, temperatures, steel heat treatments, and equilibrium reactions with the atmosphere, the test results show there is no propensity for corrosion of the secondary liner because of the current leaked waste compositions (RPP-RPT-57774, *Evaluation of Tank 241-AY-102 Secondary Containment System*, RPP-RPT-62996).

The water flush and inhibitor addition (of the primary tank with leakage into the annulus) to reduce the waste inventory in 2018 requires sampling in 2021 to verify that the residual liquid waste in the annulus is well inhibited to protect the secondary liner (RPP-ASMT-62047, *Tank Integrity Expert Panel Corrosion Subgroup Comments on Preparing Tank 241-AY-102 for Closure*).

Microbiologically influenced corrosion (MIC) – MIC becomes a potential concern in environments of near neutral pH, stagnant water, and moderate temperatures. The mechanisms of MIC can vary; however, MIC generally presents itself as biofilms on the steel surface that can produce chemical environments leading to pitting corrosion, increasing the potential for failure.

The environments that are characteristic of MIC mimic the LDP environment of many tanks and tank farms; therefore, the possibility of MIC requires further investigation. During the November 20, 2013, drain line inspection of Tank AY-102 (RPP-RPT-56464), sections of the drain line were observed to be moist, with portions of the wall containing tubercles. The presence of tubercles often indicates, but cannot confirm, MIC. The only way to confirm the presence of MIC is to sample the tubercle, analyze the material and microorganisms present, and evaluate the potential for corrosion. This can be done using a method known as quantitative polymerase chain reaction (qPCR), which determines the identity and amount of MIC communities present in the sample. Because MIC requires unique mitigation strategies, assessing for its presence is imperative.

Inspection results – As part of the improvements to the DSTIP, UT inspections of the annulus floors have been initiated (summarized in Table 3-2). These inspections have shown wall loss on the annulus floor, which requires further examination. As such, WRPS prepared a plan to investigate threats to the secondary liner. RPP-PLAN-60778 addresses recommended actions to assess the current integrity of the secondary liner and mitigate the threat from LDP moisture.

Table 3-2. Annulus Floor Ultrasonic Testing Results Summary

Tank	Examination date	Max % thinning	Area
AN-107	09/1998	10.0%	8 ft^2
AP-106	09/2014	2.2%	9.8 ft^2
AP-102	10/2014 08/2019	70.2% 71.6%	52 ft^2 100 ft^2
AN-103	04/2015	23.8%	65 ft^2
AN-104	09/2015	39.6%	69 ft^2
AW-103	05/2016	19.4%	66 ft^2
AN-105[a]	05/2016	29.8%	62 ft^2
AN-106	01/2017	9.6%	60 ft^2
SY-101	07/2017	23.2%	52 ft^2
SY-102	08/2017	13.6%	53 ft^2
SY-103	08/2017	17.6%	58 ft^2
AY-101	NA[b]	NA[b]	NA[b]
AZ-101	05/2018	11.0%	26 ft^2
AZ-102	07/2018	16.2%	51 ft^2
AP-107	10/2018	13%	64 ft^2
AP-108	12/2018	10.8%	51 ft^2
AN-102	05/2019	17.8%	50 ft^2
AP-106	07/2019	15.8%	53 ft^2
AW-102	11/2019	17.2%	50 ft^2
AW-101	01/2020	20.6%	56 ft^2
AW-106	FY 2021	17%	52 ft^2
AW-105	FY 2021	29%	55 ft^2
AW-104	FY 2021	20.2%	50 ft^2
AP-103	FY 2021	10%	50 ft^2

[a] Also scanned in 1999 (0.2%, 10 ft^2) and 2006 (3.6%, 10 ft^2); different areas were scanned.

[b] Tank AY-101 annulus floor covered in debris from previous wall cleaning efforts, and ultrasonic testing could not be performed.

FY = fiscal year.

The secondary liner is only accessible for inspection on the floor of the annulus. This annulus floor is the same thickness as the knuckle region, and the majority of the liner beneath the refractory is thinner, as shown in Table 3-3. Pitting measurements in the annulus inspections represent a greater degree of penetration in the bulk of the liner.

Table 3-3. Secondary Liner Thickness

Farm	Secondary bottom knuckle (annulus floor)	Secondary bottom (beneath refractory)
AY	1/4 in.	1/4 in.
AZ	1/2 in.	3/8 in.
SY	1/2 in.	3/8 in.
AW	1/2 in.	3/8 in.
AN	1/2 in.	3/8 in.
AP	9/16 in. (1/2 in.)	3/8 in.

The 70 percent pit in Tank AP-102 from 2019 is 350 mils where the liner thickness is ½ in. (500 mils). An equivalent depth pit in the ⅜-in. center portion of the tank would be an approximate 95 percent penetration (RPP-RPT-61896, *Ultrasonic Inspection and Air Slot Visual Inspection Results for 241-AP-102 – FY 2019*, Table 4-2). The Tank AP-102 annulus floor pit could be an anomaly (150 mils remaining thickness); however, there are two other pits at 155 and 159 mils remaining depth. All three pit depths are equivalent to a 90–95 percent penetration in ⅜-in. plate. The AP Farm tanks are the newest DSTs.

LDP Intrusion Mitigation – In FY 2020, the design and fabrication of a blower skid was completed but not installed in FY 2021. When funding becomes available, a process test will be conducted to introduce a positive pressure in Tank SY-102 and monitor the LDP liquid level to see if intrusion inflows are stopped. The test duration would be long enough to verify cessation of intrusion (3–6 months). Results of the test would formulate a basis for project application on the remaining tanks. The justification is to: (1) save the operating cost of pumping the LDP, and (2) eliminate intrusion and the resulting corrosion from wetting the secondary liner.

Corrosion Inhibitors – In FY 2019 and FY 2020, SRNL investigated corrosion control measures for the secondary liner using vapor corrosion inhibitors (VCI). Several studies were conducted by adding the corrosion inhibitors to the groundwater simulant solutions and showed that VCIs were able to mitigate corrosion on the weathered coupons when dosed at proper levels. In FY 2021, SRNL is testing the use of a dry nitrogen gas as a corrosion mitigation strategy in the LDP systems and secondary liners, which may be easier to deploy than the VCIs.

Secondary Bottom Liner Visual LDP Robot – Use of a robotic crawler to view the LDP drain pipe into the concrete foundation would give the clearest indication of liquid and the extent of corrosion in the environment below the secondary liner. The crawler was designed, fabricated, and delivered in FY 2020, but not funded for an inspection in FY 2021. Initial deployment should be performed in AW Farm due to unfavorable UT results and historical water intrusion in the LDP. Candidate tanks could be Tanks AW-106, AW-105, AW-104, or AW-103, whichever has the worst secondary liner UT data. Extending this work to other DSTs is discussed in Section 7.4.

3.3.3 Failure Mechanisms of the Reinforced Concrete

The reinforced concrete of the waste storage tanks account for the structural integrity, and the TSIP identified elevated temperature, freezing and thawing, leaching of calcium hydroxide, aggressive chemical attack, and corrosion of reinforcing steel as potentially significant failure mechanisms. The latter four mechanisms are not of concern because the reinforced-concrete structural elements of DSTs are belowground, above the water table, and not in contact with tank waste. In addition, based on data from older SST concrete and reinforcing steel samples, no significant degradation was identified on the concrete tank for one of the oldest Hanford waste storage tanks to date (RPP-RPT-50934, *Inspection and Test Report for the Removed 241-C-107 Dome Concrete*).

Temperature – Degradation effects of elevated temperature on structural properties of reinforced concrete were addressed in the finite element modeling discussed in RPP-RPT-28968, *Hanford Double-Shell Tank Thermal and Seismic Project – Summary of Combined Thermal and Operating Loads with Seismic Analysis*. All of the DST concrete temperatures to date are well within design limits and should have had no significant effect on degradation of material properties since initial operations. High temperatures in the four aging waste tanks (Tanks AY-101, AY-102, AZ-101, and AZ-102) were included in the integrity assessment reports for the "bounding DST" (i.e., worst-case DST), which used maximum operating conditions and cycles to predict the temperature effects on material properties and aging.

Degradation effects of elevated temperature on structural properties of reinforced concrete, along with the effects of increased waste levels used in the finite element modeling, are discussed in RPP-RPT-32237, *Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms*.

4.0 EXPERT PANELS

Over the course of the DSTIP, personnel have sought advice and direction from numerous panels comprising outside experts brought in to review the various aspects of DST integrity and operations and involving members from academia, industry, and national laboratories. The current advisory panel is the TIEP. The scope covered by this panel is defined in TFC-CHARTER-67, "Tank Integrity Expert Panel."

Tank Integrity Expert Panel – Established in 2015, the purpose of forming the TIEP is to consolidate all of the expert panel groups and create a single point-of-contact for expert advice on issues related to tank integrity. The panel is made up of experts from the fields of corrosion, chemistry, electrochemistry, structural analysis, materials, nondestructive examination, and policy execution.

Panel work occurs through subgroups, which are listed below. Each subgroup includes at least one panel member to facilitate communication back up to the panel from the subgroups. The subgroups are called on as needed. The Corrosion subgroup is the most active subgroup, holding bi-weekly conference calls and two meetings per year. The TIEP meets at least once per year to review recent integrity items and provides feedback. However, the TIEP is on contract throughout the year to provide expert advice on any emergent integrity issues that may arise.

Corrosion subgroup – The Corrosion subgroup oversees the corrosion testing conducted by three laboratories: DNV GL in Dublin, Ohio; SRNL in Aiken, South Carolina; and the 222-S Laboratory at Hanford.

Structural subgroup – The Structural subgroup provides input on topics related to structural analysis and control of loads. This subgroup was engaged in evaluating proposed plans for managing waste leaking into the Tank AY-102 annulus during retrieval. The Structural subgroup supports the level rise analyses for the DSTs. By raising the operating liquid level height in the DSTs, the waste storage capacity of the DST system is increased.

Materials subgroup – The Materials subgroup provides input on materials (including non-metallic) and degradation mechanisms other than corrosion.

Inspection subgroup – The Inspection subgroup provides input on identifying, developing, and deploying technologies used to assess tank conditions. New technologies are being investigated for tank bottom inspection. As the research phase continues, the Inspection subgroup will be called on to provide expert insight into the feasibility of proposed technologies.

Programmatic Execution subgroup – The Programmatic Execution subgroup provides input on the effectiveness and efficiency of the overall integrity program.

5.0 INDEPENDENT INTEGRITY ASSESSMENTS

Integrity assessments are required to ensure that the existing DST system is sound and fit for use. The DST system is considered a treatment, storage, and/or disposal unit under RCRA. Integrity assessments are required in accordance with 40 CFR 265.191 and WAC 173-303-640(2), "Assessment of Existing Tank System's Integrity." Certification of this integrity assessment by an IQRPE is required by 40 CFR 270.11(d), "Signatories to Permit Applications and Reports," and WAC 173-303-810(13)(a), "Certification."

The scope of the DST system in the 2016 IQRPE assessment included 27 DSTs and ancillary systems, including 92 pipelines, 40 pits, and other ancillary systems. With the primary tank previously determined to have been breached, Tank AY-102 is not fit for use and was not evaluated as part of this IQRPE assessment. However, Tank AY-102 was used for comparison to other tanks as part of the assessment.

Two integrity assessments have been conducted for the DST system. An initial assessment was completed in 2006 that provided an overall programmatic review of DST integrity. The second assessment, completed in 2016, assessed changes in the system and activities since completion of the initial assessment. The IQRPE recommended that the next assessment be conducted in 2026.

5.1 INITIAL INTEGRITY ASSESSMENT (2006)

Completion of the IQRPE integrity assessments in March 2006 for the DST system was considered by DOE and Ecology to have satisfied the TPA Milestone M-48-00, "Complete Identified Dangerous Waste Tank Corrective Actions, March 31, 2006." Final reports were issued in November 2008, as summarized in Table 5-1.

Table 5-1. Reports Prepared by the Independent Qualified Registered Professional Engineer

Document number[a]	Title	Contents
RPP-28538	*Volume 1: IQRPE DST Integrity Assessment Report HFFACO M-48-14*	Provides the overall integrity assessment and recommendations to improve tank integrity
RPP-27591	*Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity*	Provides the design and condition assessment of the transfer lines
RPP-25153	*Volume 3: IQRPE DST System Integrity Assessment – Waste Compatibility*	Assesses the compatibility of material in contact, or potentially in contact, with the tank farms hazardous wastes
RPP-25299	*Volume 4: IQRPE DST System Integrity Assessment – Cathodic Protection for DST Transfer Lines*	Assesses the cathodic protection systems in the tank farms
RPP-27097	*Volume 5: IQRPE DST System Integrity Assessment – Waste Transfer Line Encasement Integrity Technology Study*	Contains a study of the feasible methods of assessing buried transfer lines for the purposes of future assessments
RPP-22604	*Volume 6: IQRPE DST System Integrity Assessment – Evaluation and Documentation of DST Secondary Liner Issues*	Provides documentation of issues raised early in the assessment regarding the design of the secondary liners of the DSTs

Table 5-1. Reports Prepared by the Independent Qualified Registered Professional Engineer

Document number[a]	Title	Contents
RPP-20556	*Volume 7: IQRPE DST System Integrity Assessment – Evaluation of the Dome Load Program for Double Shell Tanks*	Documents the assessment of the tank farms dome load management program

[a] Full references are provided in Section 12.0.

DST = double-shell tank. IQRPE = Independent Qualified Registered Professional Engineer.

The IQRPE made a total of 78 recommendations on completion of the 2006 DST assessment. RPP-RPT-50440, *2006 Double-Shell Tank Integrity Assessment Recommendation Dispositions,* is a compilation of the actions taken to close the 78 recommendations. Most of the actions were completed and the recommendations closed. All outstanding actions were included in the scope of the 2016 assessment (discussed in Section 5.2).

The IQRPE assessments are conducted on an interval recommended by the prior assessment. In RPP-28538, the IQRPE recommended the next assessment be conducted in 10 years from the completion of last revision in December 2008.

5.2 DOUBLE-SHELL TANK INTEGRITY ASSESSMENT (2016)

The 2016 integrity assessment built on the work done in the initial assessment and evaluated the tank farms modifications completed since 2006. The IQRPE made 24 recommendations to improve DST integrity as part of the 2016 DST assessment (RPP-RPT-58441). The IQRPE recommended that the next assessment be conducted in 2026 when some of the tanks will be approaching their expected design life. Other recommendations were to continue UT and visual observations in the annulus of the tanks at a 10-year maximum cycle. Due to the breach in the Tank AY-102 primary tank bottom, another recommendation was to develop methods and perform measurements of tank thicknesses at the bottom of the DSTs. A complete list of recommendations identified by the IQRPE is provided in RPP-RPT-58441.

The 2016 IQRPE assessment determined that the 27 active DSTs are fit for use, and that the 92 pipelines, 40 pits, and other ancillary systems are also fit for use. There were no findings that the DST system was not operated or maintained per code, legal, or industry standard.

The 26 recommendations from the 2016 IQRPE assessment are provided in Section 3.3.3 of RPP-RPT-58441. The WRPS disposition of these recommendations is documented in RPP-RPT-60226, *2016 Double-Shell Tank Integrity Assessment Recommendation Dispositions*. Each recommendation was submitted through the problem evaluation request (PER) system. All of the associated PER items have been closed for the 2016 IQRPE assessment recommendations.

The IQRPE recommended the next assessment be conducted in 10 years (2026). This update is currently planned for in the life-cycle baseline.

6.0 DOUBLE-SHELL TANK INTEGRITY INSPECTIONS

DST integrity inspections include both visual and volumetric examination of the primary tank and secondary liner from the annulus space between them. Visual inspections are conducted to observe and trend any changes in physical appearance of the exterior surface of the material. Volumetric examinations use UT methods to examine through the material, evaluating thickness and the presence of any pitting or linear crack-like defects in the regions interrogated. Due to limited access and radiological hazards within the annulus space of the DSTs, these inspections have to be completed with remotely operated robotic equipment. Representative portions of the primary tank and secondary liner are examined periodically to establish an understanding of the overall condition of the equipment and its ability to meet the RPP mission demands to safely store the waste.

The primary objective of these programs is to monitor the condition of the valuable DST assets over time, evaluating any unanticipated changes in condition. The data obtained by these programs serves to inform future operational and inspection decisions. To date, discoveries of tank bottom corrosion in the Tank AY-102 primary tank, material loss from the foundation side of the secondary liner of several DSTs, and LAI corrosion in Tanks AY-101 and AZ-102 have prompted additional action to prolong the life of the DSTs and mitigate damage mechanisms when discovered. Discovery of these challenges early on is of critical value to the integrity program mission.

6.1 ANNULUS VISUAL INSPECTION

Visual inspections of tank surfaces are accomplished through the use of digital video camera and recording technology (RPP-PLAN-46847, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks*). The video camera, along with lighting, are lowered by tether into the annulus through risers. The pan and title angles, zoom, and lighting intensity are controlled remotely through a communication cable within the tether.

The video camera is lowered into the annulus and controlled as needed to view the condition of the visible tank surfaces, including the exterior of the primary tank wall and dome, the interior of the secondary liner wall and dome, the refractory, and the annulus floor.

Recordings of video inspections are reviewed to determine the general condition of the annulus surfaces and to identify areas of interest. Previously identified areas of interest are revisited with each new inspection until status as an area of interest is terminated. The findings of the visual integrity inspections are documented in revisions to reports maintained current for each tank farm.

- RPP-RPT-31599, *Double-Shell Tank Integrity Inspection Report for 241-AN Tank Farm*
- RPP-RPT-34310, *Double-Shell Tank Integrity Inspection Report for 241-AZ Tank Farm*
- RPP-RPT-34311, *Double-Shell Tank Integrity Inspection Report for 241-AY Tank Farm*
- RPP-RPT-38738, *Double-Shell Tank Integrity Inspection Report for 241-AP Tank Farm*
- RPP-RPT-42147, *Double-Shell Tank Integrity Inspection Report for 241-AW Tank Farm.*

General visual inspection of each DST annulus is conducted nominally every 3 years through a number of risers necessary for achieving 95 percent or more coverage of the annulus floor with each inspection. Directed visual inspection is conducted as needed to corroborate results of UT inspections or examinations.

6.2 ULTRASONIC TESTING INSPECTION

The DSTIP uses UT with remote robotic crawlers to examine the DSTs for thinning, pitting, and cracking. This type of inspection provides a volumetric examination of the metal. The examinations are performed using a magnetic crawler deployed via special trays through annulus risers from grade. The crawler delivers various ultrasonic transducers to conduct the examination.

The crawler used during most pulse-echo ultrasonic inspection (P-scan[9]) imaging is shown in Figure 6-1. The crawler, manufactured by FORCE Technology, is known as the AGS-2. The scanning bridge on the crawler, called a Y-arm, can be outfitted with various transducer configurations. Water is used as the couplant to facilitate sound transfer from the transducer to the metal and is continuously fed to the transducers at a rate needed to maintain an acceptable signal.

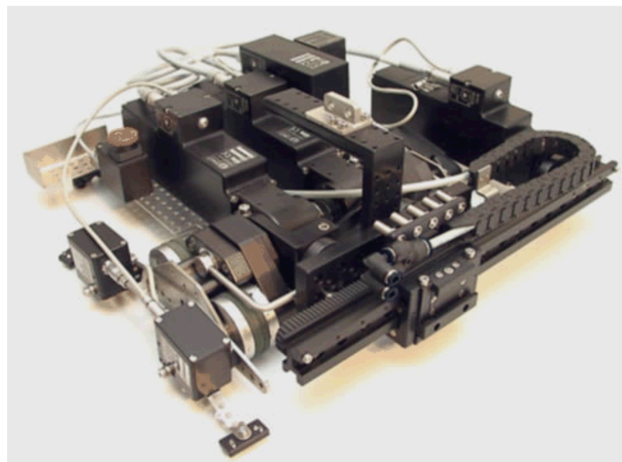


Figure 6-1. FORCE Technology AGS-2 Crawler

While typical inspection operations use two 24-in. annulus risers for inspection crawler deployment, several smaller crawlers are also available to allow inspection through 12-in. risers. This 12-in. riser inspection capability is used infrequently given the availability of the 24-in. risers and continuity of data acquired through those risers over the program's history.

6.2.1 Inspection Scope and Periodicity

Portions of the primary tank and secondary liner are examined within DSTs on a periodic basis. UT inspections are conducted on an 8- to 10-year periodicity for each tank. Given 27 DSTs within the program, this requires a pace of approximately three tanks per year, although the program allows flexibility to accelerate or delay tanks based on the judgment of the engineering integrity leads. Inspected areas are repeated in future occurrences for comparison, allowing long-term trending of the material condition and any onset of degradation. These areas are described below.

- Four 15-in. wide vertical scans of the primary tank wall full height are performed for all DSTs.
- A 20-ft length of circumferential weld joining the primary tank vertical wall to the lower knuckle is scanned, along with the adjacent heat-affected zone (HAZ) for all DSTs.

[9] P-scan is a trade name used by FORCE Technology, Brøndby, Denmark.

- A 20-ft length of the vertical weld joining shell plate courses of the primary tank is scanned, and extended as necessary to include at least 1 ft of vertical weld in the nominally thinnest wall plate and adjacent HAZs for all DSTs.
- A 20-ft long circumferential scan is performed at a location of the primary tank wall corresponding to a static LAI level for selected DSTs, extending at least 1 ft above that liquid/vapor interface. The selection of tanks to receive these scans relates to several factors:
  - Where a static level has existed for any 5-year period; this is evaluated by integrity engineers while planning the inspection
  - Where condensate is periodically added to the surface from the seal pot drain of the ventilation system; this includes the following:
    - Tank AY-101
    - Tank AZ-102
    - Tank SY-102
    - Tank AW-106
    - Tank AN-101
    - Tank AP-106
  - At the discretion of the integrity engineering lead
- Two 15-in. wide and 16-ft (minimum) length scans are performed of the secondary liner bottom via the annulus space for all DSTs. These scans are typically split, with one through each 24-in. riser. Access to the secondary liner bottom in the annulus for inspection can be challenging or impractical in several instances due to debris or equipment restrictions. These instances are evaluated on a case-by-case basis by the integrity engineering lead to determine a path and reduce coverage if data proves unattainable. Actions may include cleaning the annulus floor or deploying a smaller crawler instead through 12-in. riser penetrations.

Through the life of the inspection program, the scope for each tank has evolved. This is by design and allows the program to adapt to findings and use a targeted approach when making decisions to expand coverage. Prior to each new inspection, the results and scope of past inspections are reviewed. In most cases, inspections are completed in an identical fashion to provide long-term trending of the tank condition. In unique scenarios, the scope may be changed or increased based on the developing body of knowledge and learning nature of the program. Table 6-1 provides a summary of the typical scope completed for each DST.

Table 6-1. Typical Inspection Scope for All Double-Shell Tanks

Tank component	Primary tank					Secondary liner	
Inspection scope	*35 ft x 15 in. (x4)*	*20 ft*	*20 ft*	*20 ft*	*20 ft*	*20 ft x 15 in.*	*16 ft x 15 in. (x2)*
Inspection region	**Vertical strip**	**Horizontal welds**	**Vertical welds**	**Bottom knuckle**	**Liquid/air interface**	**Wall**	**Floor**
AN-101	✓	✓	✓		✓		✓
AN-102	✓	✓	✓		✓		✓
AN-103	✓	✓	✓	✓	✓		✓
AN-104	✓	✓	✓	✓	✓		✓
AN-105	✓	✓	✓		✓	✓	✓
AN-106	✓	✓	✓				✓
AN-107	✓	✓	✓	✓			✓
AP-101	✓	✓	✓	✓			✓
AP-102	✓	✓	✓				✓
AP-103	✓	✓	✓				✓
AP-104	✓	✓	✓				✓
AP-105	✓	✓	✓		✓		✓
AP-106	✓	✓	✓		✓		✓
AP-107	✓	✓	✓			✓	✓
AP-108	✓	✓	✓				✓
AW-101	✓	✓	✓		✓		✓
AW-102	✓	✓	✓		✓		✓
AW-103	✓	✓	✓			✓	✓
AW-104	✓	✓	✓		✓		✓
AW-105	✓	✓	✓				✓
AW-106	✓	✓	✓		✓		✓
AY-101	✓	✓	✓		✓	✓	✓
AZ-101	✓	✓	✓				✓
AZ-102	✓	✓	✓	✓	✓		✓
SY-101	✓	✓	✓	✓	✓		✓
SY-102	✓	✓	✓		✓		✓
SY-103	✓	✓	✓		✓	✓	✓

6.2.1.1 Tank AY-101 and AZ-102 Key Inspection Targets

During a routine UT inspection of Tank AY-101 in February 2018, wall thinning up to 33 percent of the nominal tank wall thickness was discovered at and above the LAI. Comparison to a previous UT inspection in 2010 indicated much of this degradation was new and had occurred within the last 8 years. Review of the tank operational history revealed that the receipt of uninhibited condensate from the AZ-301 condensate collection tank, which had occurred since 2006, was the most likely cause of the corrosion at the LAI.

Efforts to mitigate the uninhibited condensate additions by either adding caustic or recirculating the tank had not been performed for some time (RPP-RPT-61005).

Immediate actions taken upon discovery of thinning at the LAI included:

- February 2018: UT scans of the LAI on the opposite side of Tank AY-101 to confirm the pitting was not isolated
- March 2018: In-tank visual inspection, which identified localized corrosion at and above the current LAI
- March 2018: Tank sampling to confirm the presence of an uninhibited surface layer
- April 2018: Recirculation of one tank volume, to mix the uninhibited surface layer with the bulk supernatant liquid
- April/May 2018: Post-recirculation tank sampling to confirm the effectiveness of the recirculation.

Since Tank AZ-102 was also a periodic receiver of condensate, the actions were repeated and yielded similar results. Expanded UT of the LAI in Tank AZ-102 was performed in July 2018 and confirmed localized thinning from uninhibited condensate additions of up to 31 percent of the nominal wall thickness. Prior thinning of up to 20 percent had been observed during less extensive UT inspection in 2012.

The TIEP and TIEP Corrosion subgroup were consulted as part of the response actions and provided a recommended path forward. As a result of these recommendations, the actions described below were performed.

Limits were placed on the amount of condensate or raw water added to these tanks in a given time period. Condensate additions to Tanks AY-101 and AZ-102 were ceased entirely, and condensate was rerouted to the Liquid Effluent Retention Facility (LERF) via tanker truck, with a long-term solution of hard piping from AZ-301 directly to LERF being investigated. All 27 DSTs were evaluated for pitting propensity based on chemistry, and no immediate actions were deemed necessary. Chemistry limits for protection against pitting have been developed and were implemented in FY 2019.

The scope of UT inspections was expanded to include LAI scans for other condensate receiver tanks in addition to those tanks with static liquid levels. The LAI region in Tanks AY-101 and AZ-102 were reevaluated in FY 2021 to track the progression of the pitting found in FY 2018. No significant progression of the pitting was observed for Tanks AY-101 and AZ-102 (reports currently being drafted). These results will be shared with the TIEP at the annual meeting planned for August 2021 to determine if more frequent UT inspections are warranted.

6.2.1.2 AP-102 Key Inspection Targets

Scanning of the annulus floor was performed for the first time through Risers 30 and 31 during a routine UT inspection of Tank AP-102 in October 2014. Examination results indicated wall thinning up to 70.2 percent of the nominal tank thickness along the annulus floor through Riser 31. Results also indicated two areas of reportable wall thinning (thinning that exceeds 10 percent of the nominal wall thickness), no non-reportable pits (pitting greater than 10 percent but less than 25 percent of the nominal wall thickness), and multiple reportable indications of pitting (pitting greater than 25 percent of the nominal wall thickness).

Management and the expert panel at the time were consulted as part of the response actions and provided a recommended path forward. The conclusion and path forward determined included:

- No through-wall penetrations were identified
- Recommend completing enhanced visual inspection of Tank AP-102
- Recommend rescanning Tank AP-102 annulus in 5 years
- Continue planned annulus floor UT in other DSTs
- Cover a minimum length of 16 ft
- Inspect a region covering three concrete foundation drain slots
- No further compensatory actions required at this time.

The enhanced visual inspection of Tank AP-102 was completed in January 2015, and the results are documented in RPP-RPT-38738.

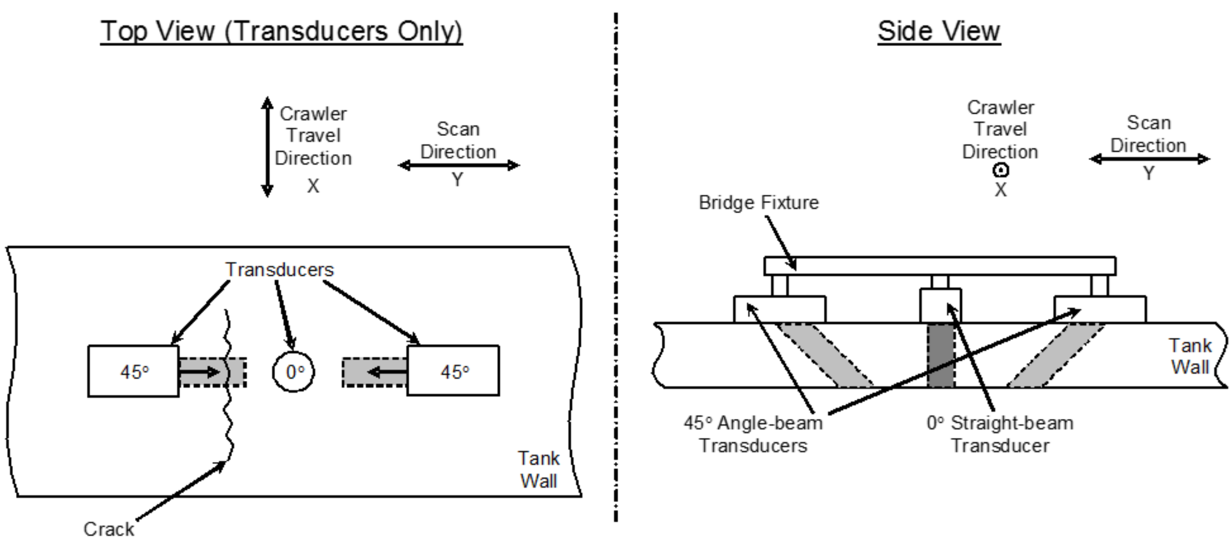
The DSTIP includes annulus floor UT scanning, which covers a minimum length scan of 16 ft, ensuring a region covering three concrete foundation drain slots is inspected.

Rescanning of the Tank AP-102 annulus floor was completed in FY 2019, 5 years after the initial finding. These repeat examination results are documented in RPP-RPT-61896. Overall, little change was observed between examinations, and additional off-normal examinations are not anticipated following the next 5-year duration, reverting to a 10-year frequency.

6.2.2 Inspection Methods

Examination of Plate and Knuckles

The P-scan crawler inspects the primary tank vertical walls using one dual-element, 0-degree transducer to detect wall thinning and corrosion pitting, and two 45-degree shear-wave transducers to detect cracking transverse to the scanning direction. This examination setup is illustrated in Figure 6-2.



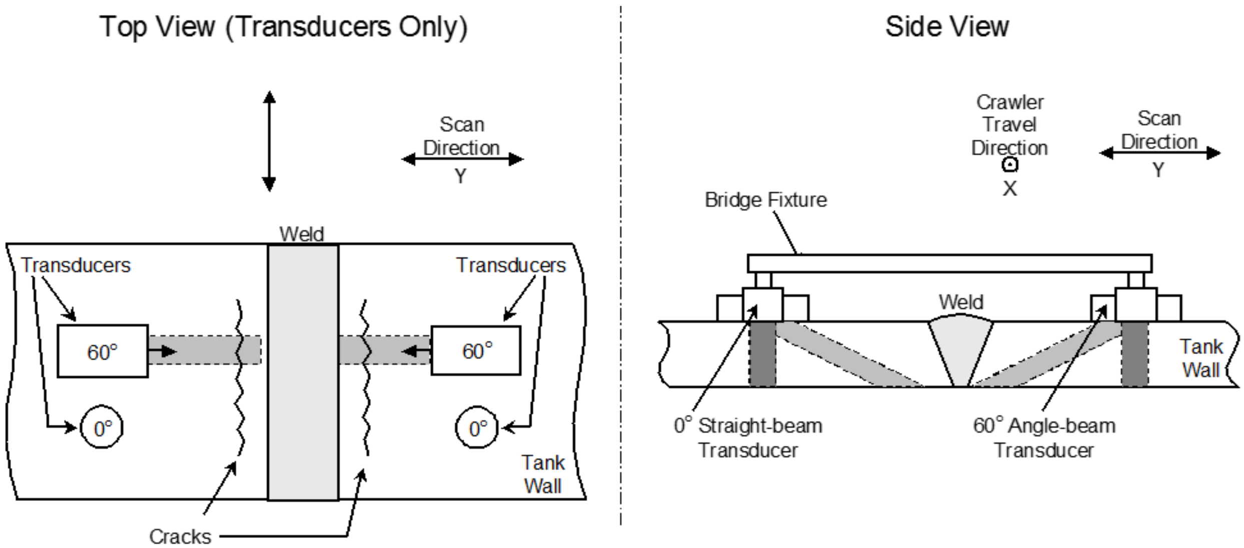
Vertical Wall Scan Inspection Setup – Uses two 45-degree transducers and one 0-degree transducer (inspect for wall thinning, pitting, and axial cracks)

Figure 6-2. Ultrasonic Testing Setup for Vertical Wall Scan Inspections

Examination of Welds

The examination of the welds and HAZ consists of angle beam examinations in the HAZ, since the physical weld bead configuration (weld bead contour or crown) does not permit transducer placement on the weld.

To detect cracks parallel to the weld, a 60-degree shear-wave transducer is directed toward the weld, and a dual-element, 0-degree transducer is also included to detect wall thinning and corrosion pitting (Figure 6-3). The examination of the HAZ using 60-degree angle beams does provide some coverage of the actual weld metal, through to the inside surface.



First Pass of Verticial and Horizontal Weld Inspection – Uses two 60-degree transducers and two 0-degree transducers (inspect for wall thinning, pitting, and HAZ cracks parallel to the weld)

Figure 6-3. Schematic of Ultrasonic Testing Setup for First Pass of Weld Inspections

To detect cracks oriented perpendicular to welds, two opposing 45-degree shear-wave transducers are directed parallel to the weld. Welds were examined from both sides of the weld crown (see Figure 6-2).

6.2.3 Data Evaluation

Data collected as part of the DSTIP requires review by one of the integrity leads or their designee prior to release. If the lead determines that the data needs further review, an Integrity Data Review Team (IDRT) is convened. The IDRT consists of the Chief Engineer, Manager of Tank and Pipeline Integrity, and responsible lead. The team can draw on other subject matter experts as necessary depending on the data under review (e.g., Quality Assurance, Tank Farm Project Manager, UT inspector). The results of the data review are documented by a technical evaluation, unless directed by the Chief Engineer to perform another type of documentation.

Data is evaluated against reportable and acceptance criteria as recommended by the TSIP and defined within the DSTIP. The TSIP guidelines provide criteria for thinning, pitting, and cracking. DSTIP reporting criteria are provided in Table 6-2.

Table 6-2. Ultrasonic Testing Evaluation Guidelines and Reportable Values

Parameter	TSIP acceptance criteria	DSTIP reportable value
Thinning	20% thickness	10% thickness
Pitting	50% thickness	25% thickness
Cracking	>12 in. 20% of thickness ≤12 in. 50% of thickness	Any linear indication > 6 in. in length and 0.1 in. in depth

DSTIP = Double-Shell Tank Integrity Program. TSIP = Tank Structural Integrity Panel.

6.3 PRIMARY TANK BOTTOM VISUAL INSPECTION

Each DST has two 24-in. diameter risers that are commonly used to deploy UT equipment as previously described. These risers are also used to deploy primary tank bottom visual inspection tools. These tools are displayed in Figure 6-4 and Figure 6-5. The first device leverages an existing fleet of FORCE AGS-2 robotic crawler equipment (which the program has used to perform UT on Hanford DSTs for several decades), with a new arm attachment. This arm attachment provides a means to deliver a camera via a rigid tether through a guide and into the under-tank air slot pattern, navigating from the outer edge to the very center.

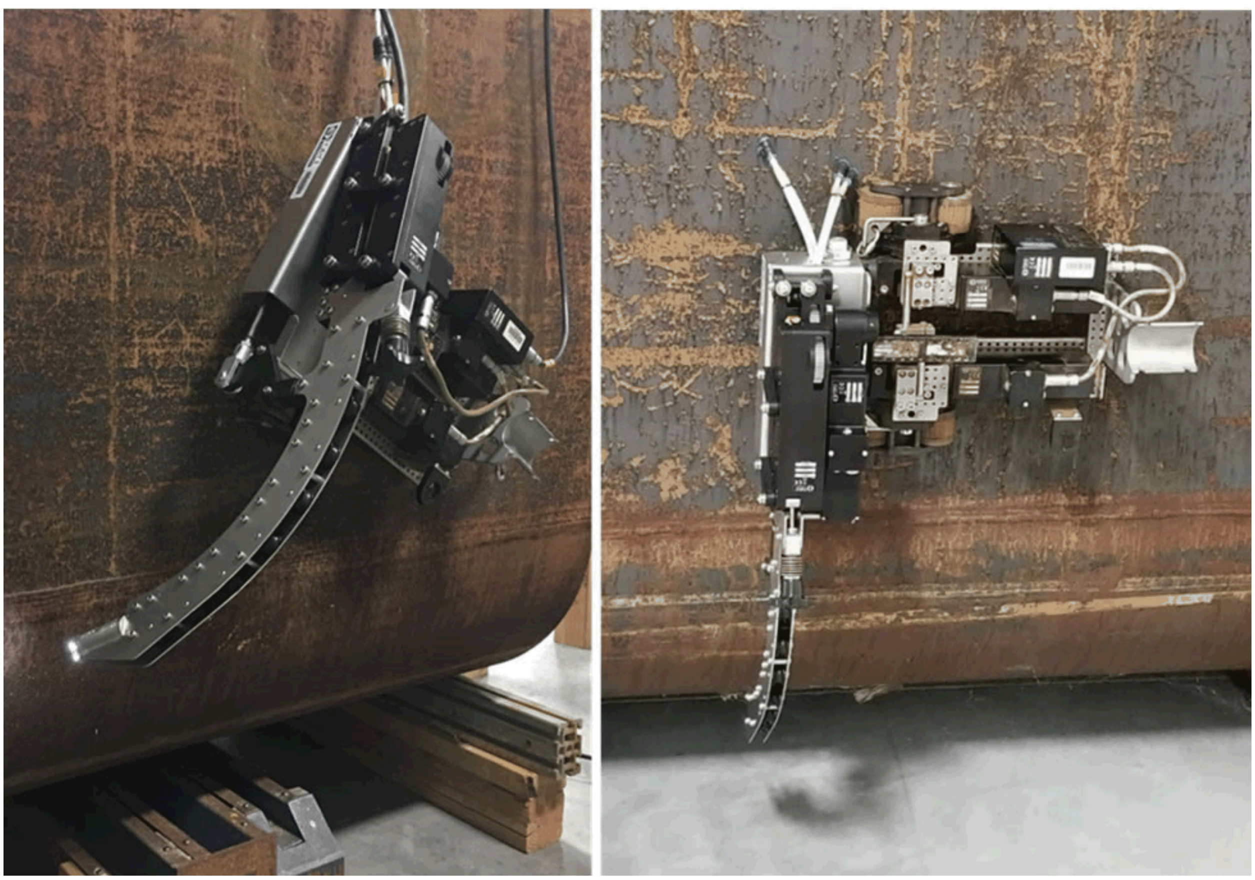


Figure 6-4. FORCE Technology AGS-2 Magnetic Crawler with CPP-1 Arm Attached

The second device, shown in Figure 6-5, is a custom-built Veolia/Inuktun crawler system. This tool consists of a larger magnetic wall crawler used to transport and deploy a smaller air slot inspection vehicle. The key difference in design for this system, in comparison to the FORCE crawler, is that the motive force to travel through the air slots is local to the air slot device. With front and rear cameras, a temperature sensor, and a radiation sensor built into the robotic platform, its capabilities are more ambitious than the simpler tool. The design of the air slot inspection device uses a traction wheel with a suspension system to provide downward force against the refractory pad, pressing the motorized tracks against the bottom of the primary tank surface. The design provides stable transport through the air slot environment and is adaptable to carry additional payloads such as sensors in the future.

Figure 6-5. Fabricated Veolia/Inuktun Tank Bottom Inspection System

Deployment through inspection risers requires considerable infrastructure and setup. This setup includes equipment tents, scaffolding with an I-beam to support a chain hoist over each riser, riser top hat extensions, operations trailer placement, generator placement, and all electrical power and signal cabling. By deploying through these risers with robotic inspection tools, access to various air slots in the refractory pad is achieved. Typical access to these air slots is depicted in Figure 6-6.

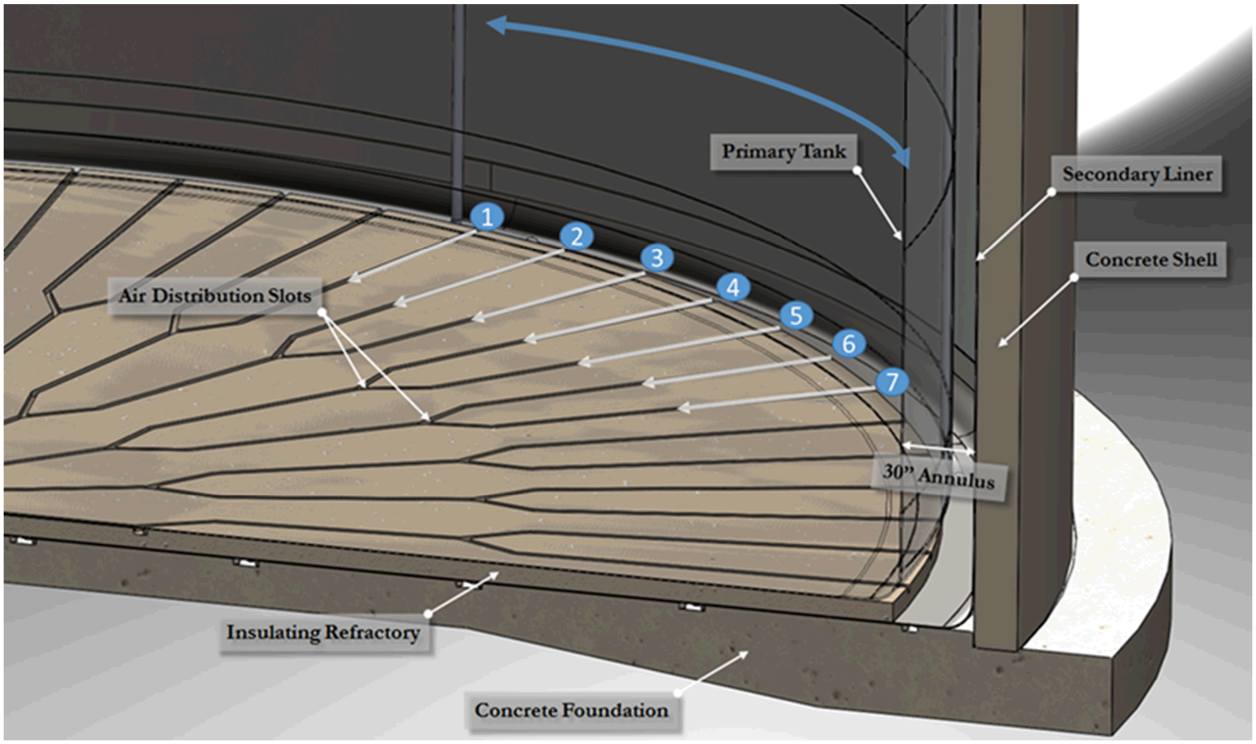


Figure 6-6. Typical Air Slot Access from 24-inch Riser Locations

To access these refractory air slots, tank bottom inspection devices are deployed along with supplementary hardware to guide annulus navigation. Tethered pan-tilt-zoom cameras with integrated lighting are deployed through adjacent riser openings. In addition, a magnetic crawler known as the Inuktun MaggHD can also be deployed to provide operational video feedback. The MaggHD features a full high definition (HD) camera with integrated spot and flood lighting and laser measurement capability. These operator vision devices are shown in Figure 6-7 and are all viewed and controlled from the inspection trailer located outside the tank farm fence line.

Figure 6-7. Pan-Tilt-Zoom and Magnetic Crawler Camera Hardware

Inspection tools are lowered into the annulus via a carbon steel deployment tray. These same trays are regularly used to deploy UT equipment. The tray uses leverage against the opposing wall to position the crawler to disembark. Once on the wall, overview cameras are used to guide movements and inspection performance. This process is shown in Figure 6-8 and Figure 6-9.

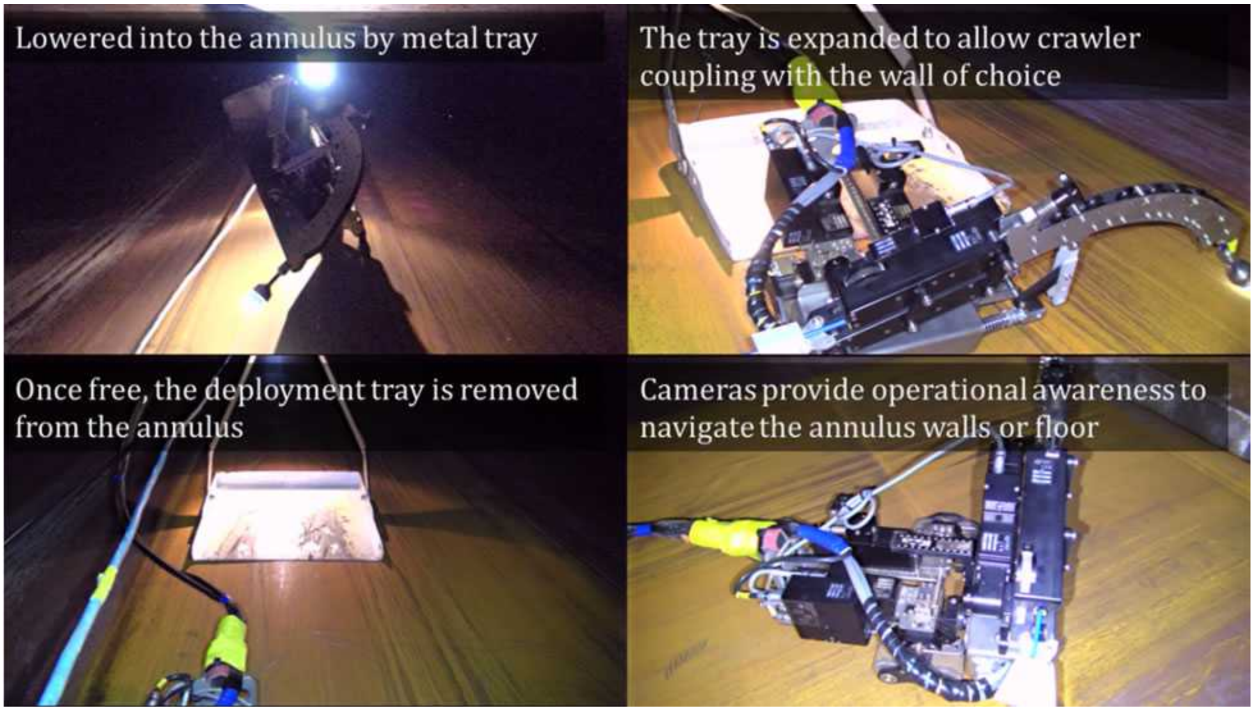


Figure 6-8. Inspection System Annulus Wall Deployment

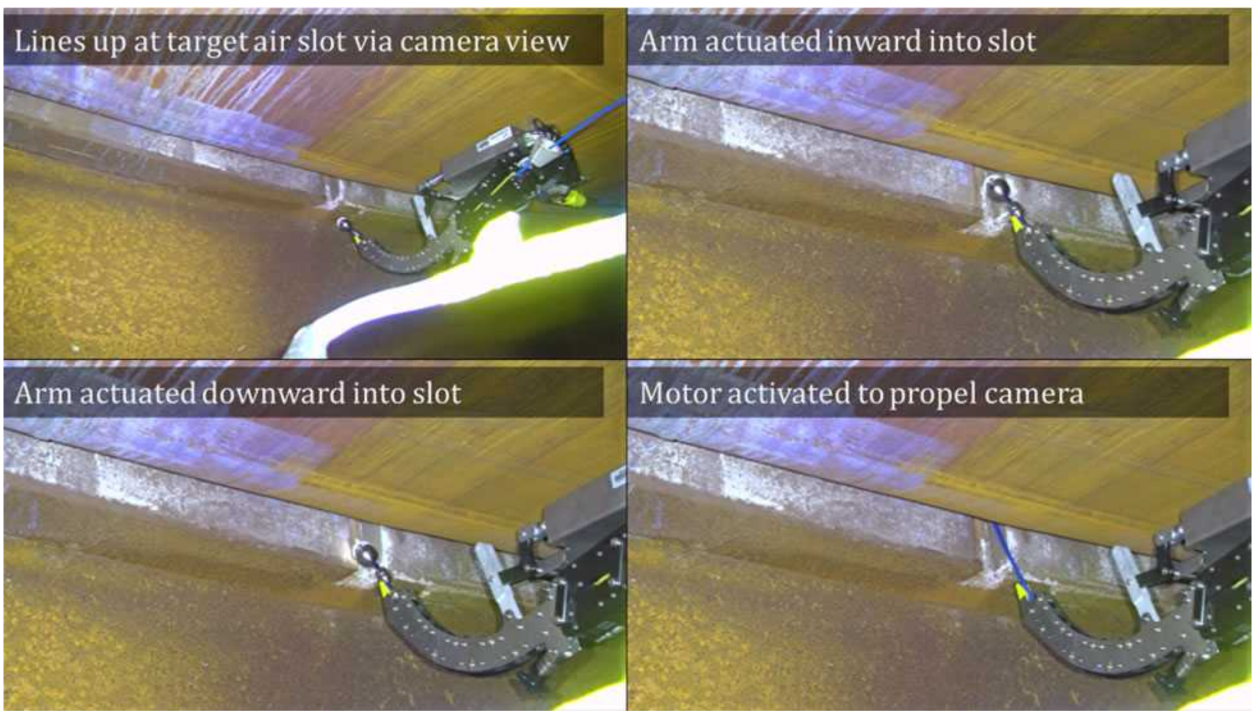


Figure 6-9. Inspection System Air Slot Delivery Logistics

Since developing these new inspection tools, periodic deployment is a regular practice alongside annulus UT operations to obtain more information about primary tank bottom conditions across the DST system. These inspections are conducted on an 8- to 10-year periodicity. An example of the tank bottom appearance through these air slots in Tank AP-107 is provided in Figure 6-10.

Figure 6-10. Tank AP-107 Air Slot 31-1 Image Examples

The tanks that have been inspected to date are listed in Table 6-3. Inspection results are discussed in respective UT reports.

Table 6-3. Tank Bottom Visual Inspection Deployments

Tank	Date	Technology
AP-107	8 /27/2018	Push Probe and Mini Crawler
AN-102	4/26/2019	Push Probe
AP-108	5/16/2019	Push Probe
AP-106	6/26/2019	Push Probe
AP-102	8/19/2019	Push Probe
AW-102	11/5/2019	Push Probe
AW-101	12/23/2019	Push Probe
AW-106	3/3/2020	Push Probe
AW-105	10/13/2020	Push Probe
AW-104	1/4/2021	Push Probe

7.0 CORROSION CONTROL

DOE G 435.1-1 (page II-166) contains corrosion control requirements that are addressed in RPP-ASMT-62082.

- Identify corrosion, fatigue, and other critical degradation modes
- Adjust the chemistry of tank waste and implement other necessary corrosion protective measures
- Identify additional controls necessary to maintain an acceptable operating envelope.

WRPS personnel control corrosion in the DSTs by ensuring there is a sufficient concentration of chemical species to inhibit the aggressive species present. OSD-T-151-00007 requires that the waste be maintained within specification for hydroxide and nitrite concentration for a given nitrate ion concentration. Corrosion control is accomplished with waste modeling, waste sampling, corrosion testing in laboratories with tank waste or simulants, and installation of corrosion probes in selected tanks.

7.1 WASTE SAMPLING

To ensure compliance with OSD-T-151-00007, the DSTs are recommended to be sampled in accordance with:

- RPP-7795, *Technical Basis for the Double-Shell Tank Chemistry Control Program*
- RPP-13639, *Caustic Limits Report-For Period Ending March 30, 2020*
- RPP-8532, *Double-Shell Tanks Chemistry Control Data Quality Objectives* (Figure 7-1).

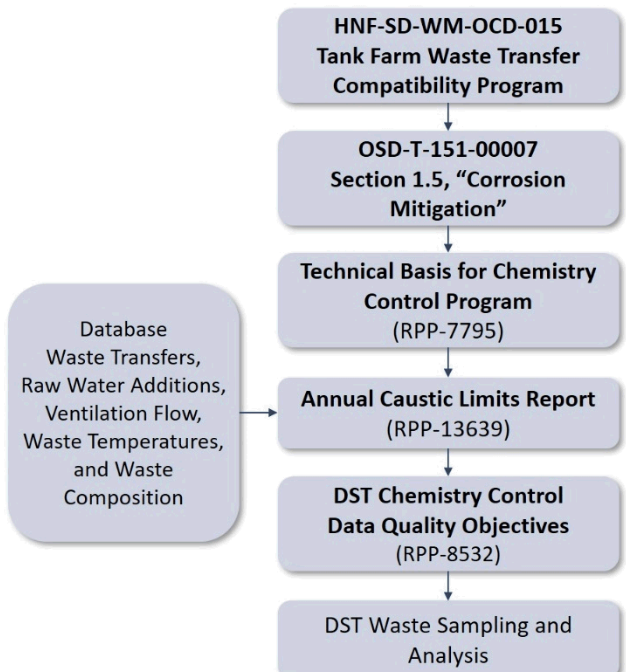


Figure 7-1. Corrosion Mitigation Logic Diagram

RPP-13639 identifies those tanks that are either out-of-specification or approaching specification boundaries. These documents require that all DSTs be sampled by need or on a semi-periodic basis, predominately dependent on the tank chemistry. Laboratory analysis of both actual waste and simulants is used to manage corrosion. The sampling of DSTs is negotiated with Tank Farm Projects and is limited by funding. Sample plans are documented in RPP-26781, *Tank Operations Contractor Sampling Projections for FY2021 through FY2025*, and updated yearly.

The following sampling priority needs are repeated from RPP-7795:

- The highest priority for chemistry control waste sampling is given to those tanks that are projected by the methods described in Section 3.0 (of RPP-7795) to either be below or to fall below the projected period corrosion control chemistry limits as determined by OSD-T-151-00007. Tanks predicted to go out of specification per the OSD during the waste composition projection period are to be prioritized for sampling 1 year prior to the projected out-of-specification date.
- In the absence of approval by the Expert Panel on Corrosion (or its successors), tanks that have not been sampled or lack analytical data from the preceding 15 years are to be prioritized for sampling and analysis within 1 year.
- The next highest priority is given to those tanks that are approaching the end of the sampling deferral extension granted by the appropriate expert advisory panel (having exceeded 15 years) or 20 years, whichever occurs first. DSTs in this category are to be prioritized for sampling within 1 year of their extension expiration date.
- Lowest priority is given to all remaining DSTs. DSTs not given a higher priority are listed in order of their last sample date, such that the oldest waste sample analysis are replaced before more recent waste analysis.

Other circumstances may warrant a specific DST receiving a higher or lower sampling priority. For example, if sufficient uncertainty exists regarding waste chemical composition (e.g., if the waste composition of a DST has changed and available sample data are deemed to no longer be representative), the Process and Integrity Engineering Manager may determine that a sample is required sooner than otherwise expected. Conversely, a special note should be made that core sampling of DSTs with less than 22 in. of solid wastes should either be given low sampling priority or deferred until sufficient solids are present. This restriction is due to the existing sampler stroke of 19 in. and a required solids sealing depth of +3 in. to separate supernatant solution from getting into the solids in the core sample.

Waste samples may also be required before, during, or after specific tank farms operations. For example, waste transfer planning between DSTs may require that samples be taken to mitigate uncertainty with regard to final waste compositions. Waste samples may also be required following chemical or water additions to specific DSTs. Lastly, SST retrieval operations can generally be expected to require sampling of the receipt DST at approximately 50 percent and 100 percent retrieval completion. The necessity of these samples will be directed by the relevant process control plans and recovery action plans.

These sampling events are to occur as described unless waived by the Process and Integrity Engineering Manager. If required sampling events are not conducted within the timeframes specified above, OSD-T-151-00007 will be consulted to ensure continued compliance with operating specifications.

In FY 2019, corrosion control limits in OSD-T-151-00007 were updated and improved to further protect DSTs from internal waste corrosion (see Section 7.2.2). As a result, a number of tanks were determined to be out of specification with the new limits, and recovery action plans were issued for Tanks AY-101, AN-102, AN-106, and AN-107:

- OSD-RAP-61917, *Recovery Action Plan for Out-of-Specification Waste Caused by Updated DST Waste Chemistry Requirements – AN-102*
- OSD-RAP-61918, *Recovery Action Plan for Out-of-Specification Waste Caused by Updated DST Waste Chemistry Requirements – AN-106*
- OSD-RAP-61919, *Recovery Action Plan for Out-of-Specification Waste Caused by Updated DST Waste Chemistry Requirements – AN-107*
- OSD-RAP-61920, *Recovery Action Plan for Out-of-Specification Waste Caused by Updated DST Waste Chemistry Requirements – AY-101*.

Recovery actions include prioritizing core sampling and corrosion testing in accordance with RPP-PLAN-64458, *Corrosion Evaluation Plan for Out of Specification Interstitial Liquid in Double-Shell Tanks*. Based on those results, plans will be updated and further actions will be identified, if needed.

7.2 CORROSION TESTING

Corrosion testing is a key element of the tank integrity program and helps ensure successful execution of the primary mission of safe and efficient management of tank waste. As the mission moves from SST retrieval and storage to processing and treatment, the tank system (tanks, piping, and 242-A Evaporator) will receive new streams with chemical compositions that have not been thoroughly tested as part of the current corrosion control program. Using existing control limits would lead to additional chemical additions to guarantee that conservative levels of inhibitors are present. The addition of sodium in these inhibitors directly equates to an increase in both operational and the overall life-cycle cost of the mission. Finally, the threat of external corrosion to the primary and secondary tanks have recently been identified, and possible inhibition techniques should be investigated.

Corrosion protection and mitigation is required or recommended by numerous regulations and guidelines:

1. Corrosion mitigation is required by DOE O 435.1. The implementation guide describes necessary integrity program elements such as identifying failure mechanisms, quantifying degradation, and evaluating tank integrity.
2. BNL-52527/UC-406 recommends measures to minimize corrosion, including adjustments to waste chemistry and verification of corrosion rates following such adjustments.
3. WAC 173-303-640(2) and 40 CFR 265 Subpart J require that the tank system integrity be assessed to determine if the tank system has sufficient structural strength and compatibility with the waste. Part of that determination includes assessing the corrosion protection measures.

The chemistry control limits are determined from testing conducted to investigate SCC and pitting corrosion. Work initially focused primarily on the influence of organics, the nature of LAI corrosion, SCC, and pitting propensity at temperatures below 50°C. Since 2012, work has focused more on understanding pitting corrosion in the DSTs, developing a protocol to allow a new specification to be implemented, and determining if these limits are effective at temperatures above 50°C.

This testing is shared by three separate laboratories: DNV GL, SRNL, and the 222-S Laboratory. Each facility provides unique capabilities (described further in Section 11.5.1). DNV GL are experts in material sciences and corrosion testing and perform the bulk of the electrochemical corrosion and stress corrosion cracking tests. SRNL has experience addressing plutonium production waste storage and remediation challenges, and provides consultation and investigative corrosion testing. The 222-S Laboratory has the unique capability to perform electrochemical tests on tank waste samples in hot cells – generating the most direct corrosion analysis of the waste, and corrosion forensic analysis on pipes and components used in the tank farms.

The types of corrosion testing these laboratories perform include cyclic potentiodynamic polarization (CPP) to test for localized corrosion susceptibility, Tsujikawa-Hisamatsu electrochemical (THE) technique to determine a practical propensity for pitting corrosion in a tested solution, slow strain rate tests to determine propensity for cracking corrosion, long-term coupon exposure tests, and additional set-up testing to mimic the tank environments.

The testing covers topics related to the DST primary liner, corrosion control specifications, SST steel liner corrosion, in-tank monitoring, refractory, secondary liner and LDP, vapor space corrosion, alternative alloys, the direct-feed low-activity waste (DFLAW) process, 242-A Evaporator, ETF, and inhibiting corrosion.

7.2.1 Stress Corrosion Cracking

Susceptibility to SCC has been studied for years, and more than 400 tests with waste simulants have been conducted. The compositions of the test simulants completely encompass the compositions of wastes in the DSTs. The results show that when the waste chemistries are held within the operating specifications, the risks for SCC are extremely low. Current SCC testing is focused on ensuring this low risk is maintained as SST retrieval and DFLAW processes add additional waste streams to the DST system and increase the temperature of the DST waste.

Specifications for the minimization of SCC in the DSTs are listed in Table 7-1 and are documented in RPP-RPT-47337. These controls were used in conjunction with a pitting corrosion testing study to create updated chemistry control limits that were implemented in 2019 (OSD-T-151-00007). Testing in FY 2020 and FY 2021 is determining if the bounding temperature of 50°C (Table 7-1), can be extended to the chemistry limit of 65°C in OSD-T-151-00007.

Table 7-1. Double-Shell Tank Specification Criteria

Specification criteria	Limit
Maximum temperature	50°C
Maximum concentration of nitrate ion	6.0 M
Maximum concentration of hydroxide ion	6.0 M
Minimum pH	11
Minimum concentration of nitrite ion	0.05 M
Minimum nitrite ion/nitrate ion ratio	0.15

7.2.2 Pitting Corrosion Testing

Pitting corrosion is initiated by aggressive species, such as chlorides and nitrates. To study the effect of these species and the pitting behavior of various waste types, electrochemical corrosion testing is used. The primary electrochemical test for corrosion control is CPP (ASTM G61-86e1, *Standard Test Method for Conducting Cyclic Potentiodynamic Polarization Measurements for Localized Corrosion Susceptibility of Iron-, Nickel-, or Cobalt-Based Alloys*). This test is used as a screening tool to determine if a waste type poses a pitting risk and if additional testing is necessary. Another electrochemical test used to determine corrosion risk is a THE test (ASTM G192-08, *Standard Test Method for Determining the Crevice Repassivation Potential of Corrosion-Resistant Alloys using a Potentiodynamic-Galvanostatic-Potentiostatic Technique*). The purpose of this test is to determine the electrochemical potential necessary to repassivate a growing pit.

In 2004 and 2005, a series of pitting corrosion tests for Hanford Site tanks was conducted in Argentina, as documented in NACE-06635, "Corrosion of Steel Tanks in Liquid Nuclear Wastes" (Carranza et al. 2006). Additional CPP testing was conducted in 2008 using simulants of the bounding waste types in DSTs, and the testing indicated that there was no evidence of pitting corrosion within the boundaries tested.

The CPP tests continued to be used to evaluate new compositions (RPP-RPT-37505, *Effects of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking in Hanford Double-Shell Tanks*). Work in FY 2013 and FY 2014 developed a pitting protocol to standardize the procedure for CPP testing across the multiple laboratories that conduct corrosion testing for Hanford (RPP-ASMT-56781, *Outcomes from the August 2013 Expert Panel Oversight Committee Meetings*), and now all CPP testing is completed using that protocol.

Testing in FY 2013 through FY 2015 investigated the propensity for pitting in the secondary liner of Tank AY-102 because of leaked waste on the annulus floor. A series of CPP and THE tests were conducted on simulants representing the leaked wastes and showed no propensity for pitting corrosion (RPP-RPT-57774).

Pitting corrosion tests are continually performed for new waste chemistries, sampled tank waste that is determined to be out of specification, and anticipated waste chemistries at a variety of temperatures. This testing is required to support returns from the DFLAW system, WTP, SST retrievals, and natural waste aging in the DSTs. These waste streams contain concentrations and ratios of both aggressive species and inhibitors not evaluated when the current operating specification limits were established.

Since 2016, DNV GL, SRNL, and the 222-S Laboratory have investigated pitting and LAI corrosion at current and anticipated DST chemistries, and SRNL undertook a statistically based investigation of the role of nitrate and halide ion-induced pitting corrosion. The objective was to develop a comprehensive waste chemistry envelope for the simultaneous minimization of the pitting and SCC risks caused by halide and nitrate ion (SRNL-STI-2019-00217, *Chemistry Envelope for Pitting Corrosion Mitigation*). A pitting factor (PF) equation was developed and implemented into the DST operating specifications to provide a criterion for pitting susceptibility.

The PF equation is a weighted ratio of the inhibitor species to the aggressive species, and the operating specification set to a conservatively, lower PF limit of 1.2.

$$\textbf{Pitting Factor} = \frac{\textbf{Inhibitor Species}}{\textbf{Aggressive Species}} = \frac{\mathbf{8.06\,[OH-] + 1.55\,[NO_2^-]}}{\mathbf{[NO3-] + 16.7[Cl-] + 5.7[F-]}}$$

The PF equation is valid for the species concentration ranges listed in Table 7-2.

For FY 2019, testing was performed at higher temperatures (50 to 75°C) to determine if there was a temperature dependence, as a few of the DSTs currently have waste temperatures above 50°C and some DST wastes have increased in temperature due to receiving SST waste. Additional testing is also ongoing to fill in some data gaps as identified by the TIEP Corrosion subgroup. Results will be incorporated into the pitting factor equation, as necessary, and the operating specification for corrosion control will be updated to incorporate protection against both pitting and SCC.

Table 7-2. Composition Ranges for Pitting Factor Statistical Tests

Species	Minimum	Maximum
Hydroxide (M)	0.0001	1.2
Nitrate (M)	0	5.5
Nitrite (M)	0	1.2
Chloride (M)	0	0.4
Fluoride (M)	0	0.3
Sulfate (M)	0	0.2
TIC (M)	-	0.1
Temperature (°C)	25	50

Source: SRNL-STI-2019-00217, 2019, *Chemistry Envelope for Pitting Corrosion Mitigation*, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina.

7.2.3 Vapor Space Corrosion Testing

Concern for DST vapor space corrosion (VSC) arose from notable VSC in several Savannah River Site tanks and apparent VSC wall thinning in some Hanford tanks. An expert panel workshop was held in July 2006 to discuss VSC and LAI corrosion of DSTs at the Hanford Site and Savannah River Site (RPP-RPT-31129, *Expert Panel Workshop on Double-Shell Tank Vapor Space Corrosion Testing*). The recommended approach to the investigation of the phenomenon started with a literature search, followed by thermodynamic modeling of species present in the vapors that deposit on the tank surface.

In FY 2007, Pacific Northwest National Laboratory (PNNL) conducted a literature review that became the basis for thermodynamic modeling of the chemical species in the tank vapor space. Subsequently, PNNL performed experiments to confirm the modeling results (PNNL-19767, *Chemical Species in the Vapor Phase of Hanford Double-Shell Tanks: Potential Impacts on Waste Tank Corrosion Processes*).

SRNL performed tank steel corrosion studies supporting the vapor space research (SRNL-STI-2010-00509, *Corrosion Testing in Simulated Tank Solutions*). The “principle gas-phase species likely to impact waste tank corrosion are carbon dioxide and anhydrous ammonia since these gases are present at much higher concentration than any other gases in the system.”

As such, VSC testing goals are to:

- Identify vapor components that are likely to be the main concern in causing or contributing to VSC (e.g., ammonium nitrate) and those that may inhibit such corrosion (e.g., ammonia)

- Explore the effects of waste chemistry changes (e.g., pH) on VSC and/or derive experimental or analytical methods to analyze the importance to VSC
- Explore any methods and approaches that might allow accelerated laboratory testing for VSC and LAI corrosion, such as is presently being accomplished for waste chemistry testing by slow strain rate tests (e.g., effect of present and changed tank waste chemistry).

7.2.4 Leak Detection Pit Testing

Liquid level increases in multiple LDPs raised concerns that the external surface of the secondary liners may be exposed to moisture. Over 10 LDPs have been subjected to water accumulations that exceeded the maximum authorized limit for extended periods of time. These LDP liquid heights indicate possible wetting of the secondary liner bottom, and this moisture increases the potential for corrosion on the external surface of the secondary liner. To assess the risk of moisture contacting the secondary liner, corrosion testing has been conducted at all three laboratories.

Total immersion testing, VSC testing, and LAI testing using LDP and groundwater simulants were performed (SRNL-STI-2014-00616). To coincide with the simulant testing, additional corrosion testing was conducted using actual LDP water samples (LAB-RPT-15-00002, *Final Report for the Corrosion Potential Investigation of Leak Detection Pit Water from Tank 241-AY-102*). Results showed there is a concern for pitting corrosion, and general corrosion rates could conservatively range from 5 to 10 mils/year. Additional testing was conducted in FY 2019 and FY 2020, with longer exposures times to water obtained from the AY Farm LDP. The results showed localized pitting corrosion of up to 2 mils/year for a 6-month exposure and >27 mils/year pitting corrosion for a 28-month exposure (RPP-RPT-62996); although there was visual evidence that MIC had possibly accelerated the attack. VCIs are currently being tested at SRNL to determine if deployment in the LDP systems could reduce corrosion.

Corrosion testing has shown that exterior corrosion because of constant moisture is the biggest threat to secondary liner integrity (see Section 3.3.2). To minimize secondary liner exposure to moisture, maximum authorized LDP levels are specified in OSD-T-151-00007, and the LDPs are pumped before the accumulation reaches those levels. The UT scans of the secondary liner will also continue to monitor wall loss of the secondary liners.

7.2.5 Waste Core Corrosion Testing

Testing actual waste samples is often more valuable than testing representative simulants. In FY 2002, a laboratory procedure was developed to perform consistent electrochemical corrosion testing on DST waste obtained from core samples. The test procedure is patterned after ASTM G5-94, *Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements*.

The test procedure is designed to evaluate the corrosion potential of the carbon steel at the tank bottom and wall in the knuckle-region of the DST where the sludge is in contact with steel. Sample collection, sample extrusion, and the electrochemical corrosion testing are performed while maintaining the waste under anaerobic conditions, like those found at the bottom of the tank. The tests are used to determine corrosion rates and assess whether carbon steel similar to that used in the DST construction is susceptible to aggressive corrosion mechanisms when in contact with the waste solids under tank storage conditions.

7.3 CORROSION PROBE MONITORING

In 1996, DOE launched an effort to improve corrosion monitoring in the DSTs. Proof-of-principle tests for new corrosion monitoring techniques were conducted at Oak Ridge National Laboratory and PNNL in 1996 (WHC-SD-WM-TI-772, *Technical Basis for Electrochemical Noise Based Corrosion Monitoring of Underground Nuclear Waste Storage Tanks*). Based on these studies, a three-channel prototype in-tank corrosion probe was designed, constructed, and deployed in Tank AZ-101 in August 1996. Based on the successful operation of the prototype system, six similar corrosion monitoring systems were installed in Hanford DSTs over the next 10 years. These systems provided valuable information on waste corrosivity and the challenges of developing corrosion monitoring systems for use in nuclear waste tanks, but ultimately proved to be too difficult to maintain and operate on a consistent basis in the tank farm environment. None of these original systems are still in service.

In 2007, the design of the DST corrosion monitoring systems was revised to address the maintenance and reliability issues observed in the original systems. The resulting instrument, known as the multi-probe corrosion monitoring system (MPCMS), shifted focus away from collecting in situ, real-time corrosion data, to facilitating the periodic collection of corrosion potential, corrosion rate, and coupon weight-loss data. The first MPCMS was installed in Tank AN-102 in 2008. Four additional DSTs were instrumented with MPCMSs by the end of 2010. Four of the five MPCMSs are still in operation, although several electrodes on them have failed since deployment. The MPCMS installed in Tank AY-102 is no longer operable, and the tank is out-of-service due to leakage. The MPCMSs have provided extensive data on waste corrosivity in the instrumented tanks; however, the design is expensive to fabricate and install. More importantly, the design does not facilitate troubleshooting, repair, or replacement of in-tank components on the probes when they fail.

In response to these challenges, a new corrosion monitoring system, known as the retractable corrosion monitoring probe (RCMP) was developed in 2012 (RPP-SPEC-49792, *Procurement Specification for 241-AW-105 Retractable Corrosion Monitoring Probe Assembly*). The mechanical design of the RCMP is significantly different than previous DST corrosion monitoring systems, using a cable reel and retractable probe head instead of a long, fixed probe to position a set of reference electrodes at various elevations in the tank.

System components for the RCMP are relatively inexpensive, commercially available, and designed to be replaceable in the event of failure. The primary purpose of the RCMP is to measure tank corrosion potential.

The MPCMS in-tank probes contain a variety of primary reference electrodes (e.g., saturated calomel electrode [SCE], silver/silver-chloride [Ag/AgCl] electrodes, copper/copper-sulfate [$Cu/CuSO_4$] electrodes) for use in making corrosion potential measurements. This mix of reference electrodes helped to identify the most robust electrode design for the in-tank environment (as per the original purpose of including multiple electrode types), but now complicate the comparison of corrosion potential data between the in-tank probes and laboratory measurements made using SCEs. Due to the pioneering work of the MPCMSs, all current RCMPs installations use only Ag/AgCl electrodes.

The MPCMSs contain an electrical resistance (ER) sensor in each region of the tank. Average corrosion rates have been calculated for each of the ER sensors by performing a regression analysis on recorded metal loss data from the date of installation through the latest day of data collected. Data collected from ER sensors and details of the data analysis are presented in the quarterly report for the corrosion probe monitoring systems (RPP-RPT-51766, *Corrosion Probe Monitoring Systems: July 2019 through September 2019 Quarterly Report*).

The RCMPs are designed to be installed only in the supernatant (or possibly into the top of the sludge layer) in the tank. The primary purpose of the RCMP is to measure tank corrosion potential for use in determining if the tank is at levels capable of inducing SCC. The RCMP assembly permanently mounts on a riser above a spray ring. The probe head is attached to a cable and reel, which enables the RCMP to be positioned at various elevations in the waste or fully retracted out of the waste to facilitate other in-tank operations.

Early RCMPs contained two primary reference electrodes: a Van London-pHoenix, Inc., Model 8604201 Ag/AgCl reference electrode, and a Refine [10] AG3 Ag/AgCl reference electrode. The Tank AW-105 RCMP also had a small secondary reference electrode comprising a graphite rod in addition to the two Ag/AgCl reference electrodes. The RCMP does not have ER sensors installed. Current RCMPs contain four Van London Ag/AgCl electrodes, although electrodes from different manufacturers are being explored that maybe more robust in the harsh tank waste environments.

Data from the MPCMSs and the RCMPs are used in conjunction with data generated for the Tank and Pipeline Integrity (TAPI) corrosion testing program to identify corrosion potentials in the various DST waste types capable of inducing pitting and SCC. The TAPI corrosion testing program is directed by the TIEP Corrosion subgroup. Corrosion potential data collected from the MPCMSs and RCMPs are compared with the results of laboratory testing to determine if a DST is at a corrosion potential capable of inducing pitting or SCC. The seven DSTs currently being monitored are shown in Table 7-3; only six of the corrosion probes are considered operable.

[10] Refine is a trademark of Cathodic Protection Co Limited, Venture Way, Grantham, Lincolnshire, NG31 7XS, United Kingdom.

Table 7-3. Corrosion Monitoring Systems Status Summary

Tank	MPCMS or RCMP	System install date	Data collection frequency	Average tank potential as of March 2021 (vs. SCE)	Threshold potential for onset of SCC (vs. SCE)	Corrosion rate (mil/year)	Disposition
AN-102	MPCMS	5/2008	Once every two weeks	-367 mV	200 mV	<< 1	System in reasonably good condition; continue operation
AN-107	MPCMS	6/2010	Once every two weeks	-404 mV	-100 mV	<< 1	System in reasonably good condition; continue operation
AW-104	MPCMS	7/2010	Once every two weeks	-379 mV	200 mV	<< 1	Replace system due to multiple electrode failures
AW-105	RCMP	8/2013	Once every two weeks	-379 mV	200 mV	N/A	Replace system due to multiple electrode failures
SY-101	RCMP	7/2014	Once every two weeks	-279 mV	200 mV	N/A	System in reasonably good condition; continue operation
AY-101	RCMP	9/2019	Once every two weeks	-29 mV	300 mV	N/A	System in good condition; continue operation
AP-102	RCMP	9/2020	Once per week	-181 mV	300 mV	N/A	System in good condition; continue operation
AZ-101	RCMP	10/2020	Once per week	-57 mV	0 mV	N/A	Difficulties during system installation, verifying performance

MPCMS = multi-probe corrosion monitoring system.
N/A = not applicable.
RCMP = retractable corrosion monitoring probe.
SCC = stress-corrosion cracking.
SCE = saturated calomel electrode.

These tanks were chosen to have corrosion probes installed because the tanks are representative of the different waste types described in Table 7-4. The waste type should be considered when prioritizing other tanks to have corrosion probes installed.

Table 7-4. Representative Waste Types

Waste type	Tank(s)
High nitrate	AN-102, AN-107
High carbonate	AY-102
Retrieved SST sludge	AY-101
Retrieved SST supernatant	SY-101
High fluoride	AW-105
High hydroxide	AW-104
Higher temperature	AZ-101

SST = single-shell tank.

To date, the corrosion potentials of all monitored tanks with active probes are below the threshold potentials associated with the onset of SCC, as shown in Table 7-3.

When the average potential for a tank gets within 50 mV of the threshold potential for onset of SCC (vs. SCE), the following actions should be taken:

- WRPS management will be notified via email within 2 weeks of discovery.
- WRPS will notify the TIEP within 2 weeks of being informed of the situation. WRPS will ask the TIEP to review the data and provide guidance on troubleshooting activities and/or possible corrosion testing that should be conducted. The TIEP will be requested to provide a formal response within 4 weeks of being notified.

- WRPS will plan on adding an additional probe to the tank in question within 1 fiscal year of the discovery of the issue. A recommendation is to have at least one spare RCMP head fabricated and ready for deployment. Having more than one spare available at a time is a fraction of the cost of having the spares fabricated one at a time. Testing of the electrodes in the spare RCMP would need to be conducted prior to installation.

7.4 SECONDARY LINER CORROSION INSPECTION AND MITIGATION

Many of the DST tertiary LDPs have been subject to long-term water intrusion and accumulation. Water accumulation underneath the tanks, as evidenced by historical LDP water accumulation, is suspected of causing corrosion on the bottom side of the secondary carbon steel liner. Recent laboratory studies have shown corrosion rates in excess of 10–15 mils/year, which could equate to an estimated 25-year life (the secondary liner could already be breached).

Pumping the LDPs and disposing of the accumulated water is also an operational expense that can be eliminated with this strategy.

Inspection – In FY 2020, a secondary liner bottom inspection robot was developed and fabricated for access through the LDP drain line. The crawler should be deployed so results can be used to assess the need for mitigation. AW and AN Farms have LDP drain designs that give direct access to the bottom of the secondary liner in a slot that spans the full diameter of the tank.

Mitigation – In FY 2020, process test equipment was fabricated but not installed to introduce a positive pressure in Tank SY-102 and monitor the LDP liquid level to see if intrusion inflows are stopped. The test duration is long enough to verify cessation of intrusion (3–6 months). Results of the test would formulate a basis for project application on the remaining tanks. The equipment is ready to deploy, and the installation and operation would not be cost prohibitive.

Intrusion will be stopped by removing the suspected motive force for the water migration (differential pressure between the tank foundation air space and the surrounding soil). This phase of the plan includes designing, installing, and operating a pit air supply system (PASS) to serve as a proof-of-concept, with the goals of assessing the ability to mitigate further water intrusion and helping define the required functional parameters of a future, permanent system.

The proof-of-concept system will be deployed at the Tank SY-102 LDP (SY-02C) and is expected to be operated for several months. Depending on the results at SY-02C, deployments at other LDPs may be performed. This process test is designed to operate over a range of flow rates and pressures. If the proof-of-concept system successfully prevents water intrusion, results can be used to size a permanent system that is optimized for long-term deployment, as shown in phase 4 of Figure 7-2. Results from the process test would determine viability of the concept and would allow design of the permanent system based on the following results from the test, laboratory work, and visual inspections:

- Airflow rate and positive pressure to mitigate intrusion in Tank SY-102
- Use of atmospheric air, dry air, or nitrogen based on ongoing laboratory work
- Prioritization of tanks or farms that have LDP intrusion or poor visual inspection results from the LDP drain line and foundation inspection.

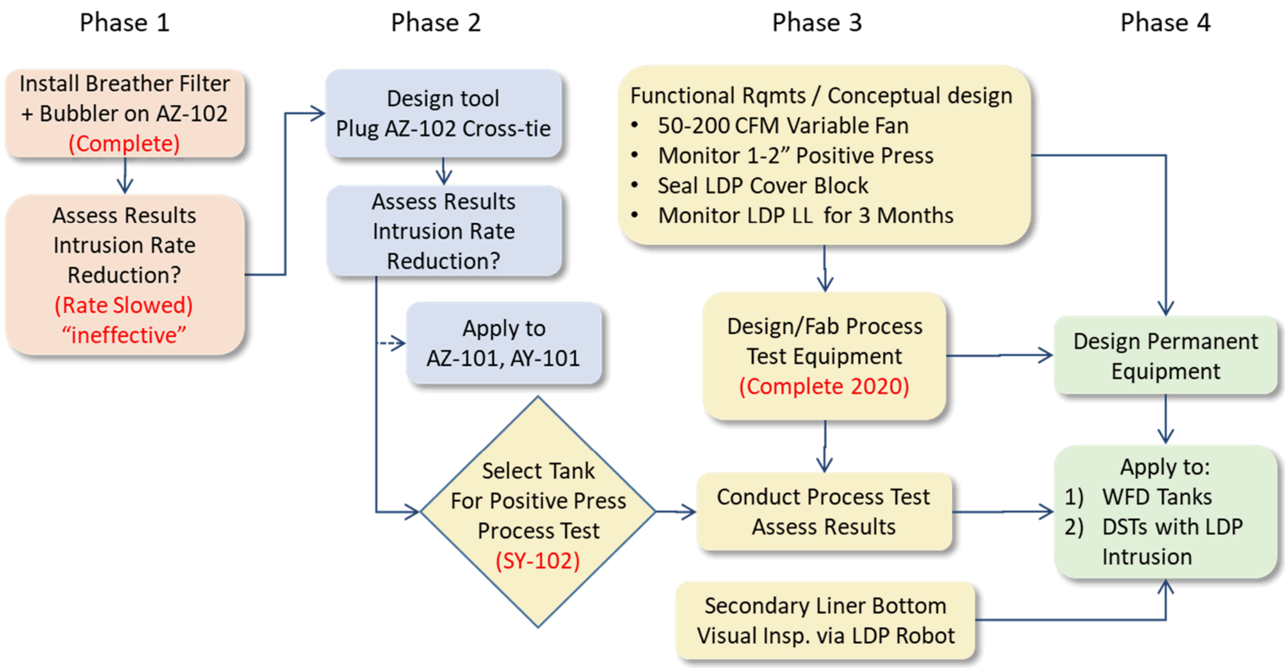


Figure 7-2. Leak Detection Pit Intrusion Process Test Phases

Phases 1 and 2 address the unvalved cross-ties that accelerate intrusion between the annulus and the LDP in the AY and AZ Farm tanks. The AY/AZ Farm cross-tie plugs need to be implemented but do not hold up proof-of-concept installation of the blower and video for the LDP drain line in Phases 3 and 4.

- The blower and robot video equipment have been procured and are ready to be installed.
- The installation and operation of the two pieces of equipment need to be funded for Phase 3 testing/operation.

Installation and operation of the above equipment/modifications should:

- Eventually remove the need to pump LDPs entirely
- Stop or significantly reduce the rate of corrosion of the secondary liner by removing water from the tank(s) connected to the LDP
- Lower risk of release to the environment in case of a leak in the primary tank.

After proof-of-concept test, blowers could be installed to protect the entire DST secondary tank system. In AY Farm, this would protect four tanks per blower.

Video equipment can be used to confirm intrusion has stopped and determine the status of the secondary liner in AN and AW Farm tanks.

7.5 LEAK INTEGRITY

In addition to visual inspection to monitor leak integrity, the DSTs are equipped with liquid level detecting instruments. The DST liquid levels in the primary tank are monitored daily using Enraf[11] surface level gauges. The primary tank surface level Enraf and the three annulus leak detector Enraf gauges make up the Ecology-approved leak system (Consent Decree 2010).

The Enraf leak detectors are able to detect 0.25 in. or less of liquid from the bottom of the tank and are read to the nearest 0.01 in. All of the DST leak detectors and level detectors are checked by Operations during both daily and nightly rounds. The local reading is recorded and compared to upper and lower limits. If the reading is outside those limits, further action is taken by Operations. These leak detectors also transmit alarms to the tank monitor and control system (TMACS), including an instrument "trouble" alarm.

Leak detection monitoring for the DSTs is specified in OSD-T-151-00031, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection*.

[11] Enraf is a registered trademark of Enraf B.V., Delft, Netherlands.

8.0 STRUCTURAL INTEGRITY

WRPS uses two elements to assess the structural integrity of the DSTs: the dome load program and structural analysis. The dome load program measures the tank dome elevations to monitor any changes. The structural analysis assesses the structural integrity of the DSTs using a modern finite analysis. This assessment evaluated the integrity of the tanks through 2028.

8.1 DOME LOADING

The established basis and protocol for the DST Dome Survey Program are documented in RPP-25782, *DST Dome Survey Program*. The goal of this program is to monitor the elevation of the tank and tank dome deflection to determine if settlement or excess deflection of the tank dome is occurring. Dome collapse relative to overloading or material degradation would be preceded by excessive downward deflection; therefore, the civil surveying of benchmarks on and relative to the tank domes is a key defense-in-depth feature.

The DST operating specification, OSD-T-151-00007, requires dome load controls. The procedural requirement for the dome load controls is TFC-ENG-FACSUP-C-10, "Control of Dome Loading and SSC Load Control," with the basis for the dome load limits from RPP-20473, *Design and Dome Load Criteria for Hanford Waste Storage Tanks*. Since deflection is a key indicator of structural integrity, monitoring of the tank dome by survey is required. Table 8-1 lists the dome load record reports that fulfill the requirements of the DST Dome Survey Program. Dome loading requirements for DSTs are a protection feature against excessive concentrated loads and potential dome collapse.

Table 8-1. Historic Dome Load Record Data Reports for Double-Shell Tanks

Document no.[a]	Dome load record reports
RPP-20257	*241-AN Tank Farm Historic Dome Load Record Data*
RPP-20258	*241-AP Tank Farm Historic Dome Load Record Data*
RPP-20259	*241-AW Tank Farm Historic Dome Load Record Data*
RPP-20260	*241-AY Tank Farm Historic Dome Load Record Data*
RPP-20261	*241-AZ Tank Farm Historic Dome Load Record Data*
RPP-20262	*241-SY Tank Farm Historic Dome Load Record Data*

[a] Full references are provided in Section 12.0.

TFC-OPS-OPER-C-10, "Vehicle and Dome Load Control in Tank Farm Facilities," includes requirements for dome load controls, vehicle access, vehicle restrictions, and movement of vehicles or equipment in the tank farms hazardous facilities. The procedure identifies the requirements for (1) compliance with vehicle or related equipment dome load impacts in tank farms hazardous facilities, (2) bringing a vehicle or equipment affecting dome loads into tank farms facilities, and (3) personnel responsibilities associated with vehicle movement or dome loads.

The surveys are performed on a frequency of no more than 3 years or as requested by Engineering, whichever is more restrictive. All survey data are reviewed by the responsible engineer and evaluated for tank settlement and dome deflection. Measurable deflections greater than 0.02 ft (0.24 in.) are investigated. Tank dome deflection of up to approximately 0.5 in. is within acceptable dome load limits per RPP-RPT-25608, *Hanford Double-Shell Tank Thermal and Seismic Project—Increased Concentrated Load Analysis*.

8.2 STRUCTURAL ANALYSES

The DSTs were designed and constructed to maintain structural stability under a variety of load conditions. These loads include dead loads, hydrostatic pressure, soil pressure, soil overburden, equipment loads, thermal loads, positive and negative differential pressure loads, live loads, and earthquake loads. These calculations were originally done in support of the design and construction of the DSTs; DOE has since updated the seismic guidelines for existing tanks to ensure compliance with current requirements. DOE employed BNL to develop a methodology for performing structural analysis of existing tanks, which is documented in BNL-52361, *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Tanks and Appurtenances*.

These guidelines provided recommendations for a structural analysis methodology and were used in developing the Hanford Site structural evaluation criteria that specify the loads required for verification of the structural adequacy of tanks. The site-specific evaluation criteria are provided in WHC-SD-WM-DGS-003, *Structural Acceptance Criteria for the Evaluation of Existing Double-Shell Waste Storage Tanks Located at the Hanford Site, Richland, Washington*, and specify many load combinations and the allowable stresses for each load combination that must be considered.

Finite element analysis (FEA) models are used to represent the reinforced concrete and steel-plate structural components of the DSTs, perform structural analyses, and determine resulting stresses at representative locations. The resulting stresses are compared to American Society of Mechanical Engineers (ASME) and American Concrete Institute code allowable limits, depending on the material of construction. Additional limit analyses are performed to determine ultimate capacities of the DST structures. These models incorporate the effects of soil-structure interactions, concrete degradation and creep, and simulated worst-case operational cycling, to provide the DSTIP with the ability to verify structural adequacy either for purposes of controlling loads on tanks or to estimate tank life expectancy as affected by degraded geometry (i.e., wall thinning).

The analysis of record for the DSTs is performed with two FEA models. A static FEA model represents the operational aspects of the tank and is referred to as the thermal and operating load analysis (TOLA). The TOLA considers fill/drain cycles of the tank with operating pressures and temperatures. The dynamic FEA model represents the entire tank structure and the surrounding soil, modeled with dynamic soil properties. The dynamic model incorporates the effects of soil structure interaction resulting from the modeled site-specific seismic event. The DST structural analysis of record for the thermal and operating loads and seismic loads is documented in RPP-RPT-28968, which included updated seismic data derived from the latest WTP earthquake ground motion. A bounding AY Farm tank design is used to represent a bounding case for all DST structures. The analysis also provides the technical bases for current operational limits, such as a maximum waste temperature of 350°F, as specified in OSD-T-151-00007.

The AW/AN Farm tanks level rise analysis also considers the effects of a large magnitude, distant Cascadia Subduction Zone event. The Nuclear Energy Institute (NEI) white paper, "Consistent Site Response/Soil-Structure Interaction Analysis and Evaluation," (NEI 2009) recommended a revised seismic input approach, which has been accepted by the U.S. Nuclear Regulatory Commission and is now specified in American Society of Civil Engineers (ASCE) 4-16, *Seismic Analysis of Safety-Related Nuclear Structures*.

Requirements for increased tank capacities resulted in further use of the DSTIP expert panel and additional structural analyses. The recommended criteria for considering the structural effects of waste level increase are documented in RPP-19438, *Report of Expert Panel Workshop for Hanford Site Double-Shell Tank Waste Level Increase*. The analysis of record for TOLA and seismic loads considering the increased waste level in AP Farm tanks is documented in RPP-RPT-32237.

8.3 MINIMUM WALL THICKNESS

The DST minimum wall thickness is analyzed in RPP-RPT-32238, *Hanford Double-Shell Tank Thermal and Seismic Project – Primary Tank Minimum Wall Thickness Analysis*. This analysis determined the minimum required thickness of each plate course on the DSTs. This analysis defines the minimum primary tank wall thickness of the Hanford Site DSTs that will ensure structural integrity. Figure 8-1 provides a graphical representation of the minimum wall analysis compared to the nominal, reportable, and action thicknesses.

The limiting structural criterion for the primary tank wall thickness for all of the families of DSTs was the buckling criterion assessed in RPP-RPT-28967, *Hanford Double-Shell Tank Thermal and Seismic Project – Buckling Evaluation Methods and Results for the Primary Tanks*. The buckling criterion is a function of waste temperature, depth, specific gravity, and the vacuum limit. Both elastic and plastic buckling analyses were performed for the DST primary tanks. The elastic buckling evaluation provides a method for evaluating the allowable vacuum limits for the DST primary tanks. Plastic deformations (permanent) or elastic deformations (temporary) represent a failure for the analysis, but not a failure of the primary liner. The level of the tank with smallest corrosion allowance is on the 0.50-in. plate on Course 2 near the transition from the thicker Course 1, which is 12 ft above the bottom of the tank, as shown in Figure 8-1. The maximum corrosion allowance varies with the maximum allowable vacuum. The structural analysis shows that for a maximum vacuum of 6-in. w.g., the corrosion allowance is 0.120 in. (120 mils) for all of the tanks. The AP Farm was analyzed for a maximum fill height of 460 in. (RPP-RPT-32237). The AW and AN Farm tanks will be reassessed in the future to raise the fill height.

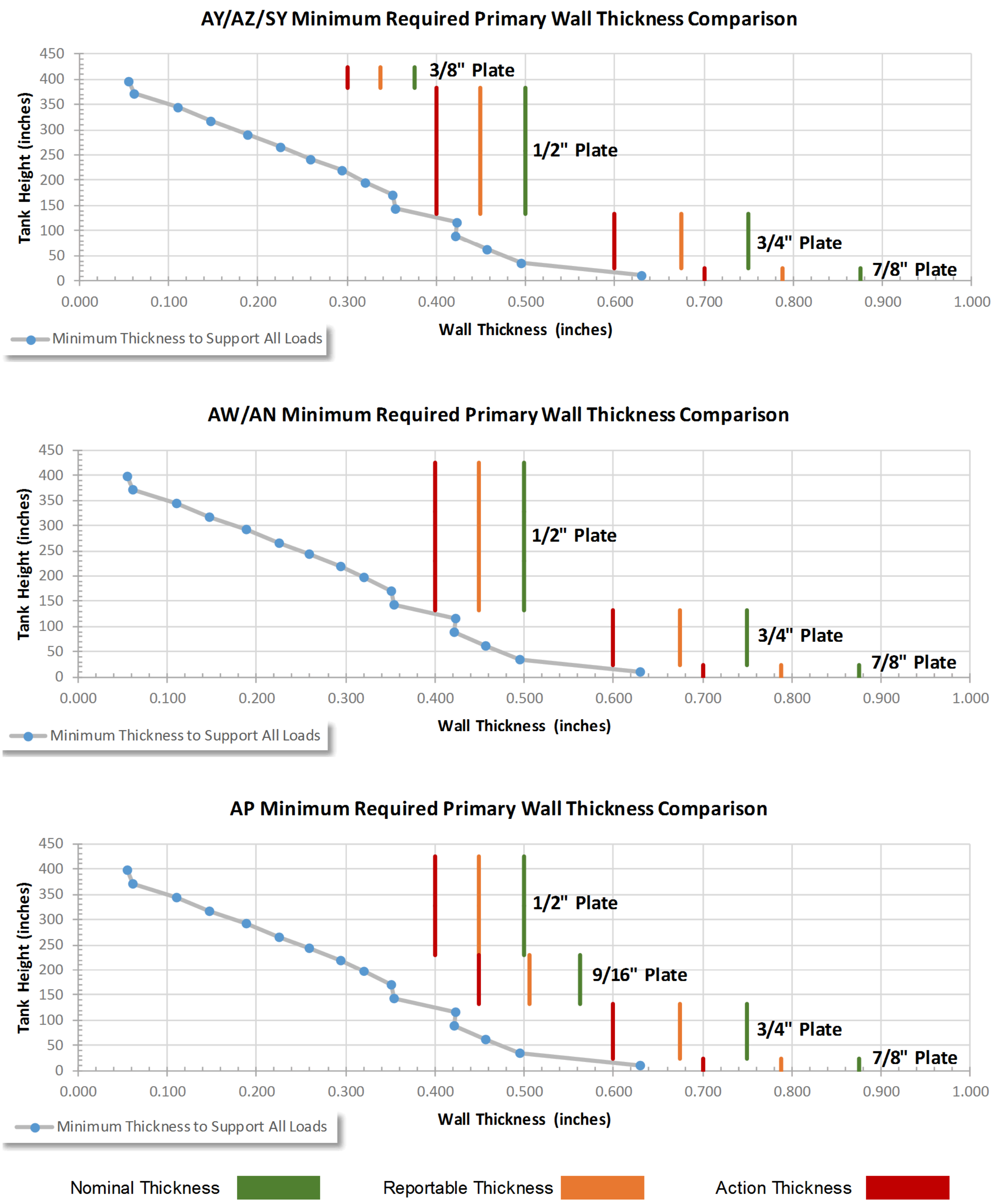


Figure 8-1. Analysis of Minimum Wall Thickness for Structural Integrity

8.4 INSPECTION DATA REVIEW

Data collected as part of the DSTIP requires review by one of the integrity leads or their designee prior to release. If the lead determines that the data needs further review, the IDRT is convened. The IDRT consists of the Chief Engineer, Manager of Tank and Pipeline Integrity, and responsible lead. The team can draw on other subject matter experts as necessary depending on the data under review (e.g., Quality Assurance, Tank Farm Project Manager, UT inspector). The results of the data review are documented by a technical evaluation, unless directed by the Chief Engineer to perform another type of documentation.

9.0 OTHER DOUBLE-SHELL TANK PROGRAM ELEMENTS

Document Tank Chemistry History

The TIEP recommended in RPP-ASMT-57582, *Second Workshop of the High Level Waste Integrity Assessment Panel: Extent of Condition and Balance of Program*:

> *The investigation into the Tank AY-102 leak revealed a much more complex history of waste transfers, chemistry, and in-tank waste mixing than was previously appreciated. Based on the aforementioned risk ranking, the program should investigate the detailed history of tanks with a higher potential for leaks. In addition to potentially identifying previously overlooked troublesome chemistries in the tanks, such analysis will also allow for a better understanding of the uncertainty associated with a tank's chemistry history.*

The task involves collaboration with the TIEP member experienced in Hanford tank waste chemistry to assess the corrosion risk over the storage of different waste types present in the tank. Ongoing efforts will continue to issue nominally two reports per year until complete and prioritized with the DST risk ranking.

The reports completed to date include:

- RPP-RPT-59351, *2016 Tank 241-AY-101 Annulus Contamination Investigation*
- RPP-RPT-60150, *2017 Tank 241-AZ-101 Operational and Integrity History*
- RPP-RPT-60957, Rev. 0, *Tank 241-AZ-102 Operational and Integrity History*
- RPP-RPT-61006, Rev. 0, *Tank 241-AN-107 Operational and Integrity History*
- RPP-RPT-62179, Rev. 0, *Tank 241-AN-102 Operational and Integrity History*
- RPP-RPT-62805, Rev. 0, *Tank 241-AW-105 Operational and Integrity History*
- RPP-RPT-63111, Rev. 0, *Tank 241-AW-104 Operational and Integrity History*

10.0 MANAGEMENT APPROACH

Management options addressed in BNL-52527/UC-406 are generally premised on: (1) maintaining safe operating envelopes to minimize corrosion, (2) assessing degradation mechanisms, and (3) estimating the remaining useful life based on thickness measurements. The specific options available to address corrosion of the tanks are both preventive and recovery from breaches. As listed in Section 8.2 of BNL-52527, the options are:

- Corrosion control
  - Chemistry control, including use of inhibitors
  - Electrochemical techniques
- Retrieval of waste
  - Partial removal of liquid
  - Maximum liquid removal
  - Total retrieval
- Repair
- Add new barriers or build new tanks.

Key elements of the management approach include the following.

Organizational structure – The DSTIP is an element of the Tank Farm Projects organization. Project responsibility rests with the project manager for the DSTIP.

Roles and responsibilities – Production Operations is responsible for day-to-day operations of the DST system, which include waste storage, waste transfer, surveillance, and maintenance to ensure compliance with DOE Orders and federal, state, and local laws and regulations. Activities of the DSTIP are integrated and carried out with the support of Production Operations, in accordance with applicable procedures and work control processes.

Project integration – Business operations include those activities necessary to establish and maintain the technical, cost, and schedule baseline; to manage activities in accordance with those baselines; and to adjust to change as necessary. The processes are covered in TFC-PLN-84, "Tank Operations Contractor Project Execution Management Plan."

Training – In addition to required technical qualifications, the project staff require knowledge in the areas of structural integrity (e.g., corrosion, structural integrity, inspection). Though the specialty may change depending on job assignments, some staff members should have NACE International (NACE) certification as a corrosion technologist, with the goal of becoming a senior corrosion technologist.

Quality assurance – The DSTIP will operate under TFC-PLN-02, "Quality Assurance Program Description." The project tailors its approach to quality with the vast majority of the work performed under enhanced quality controls. Enhanced quality applies to such tasks as chemistry control testing, visual inspections, and UT inspections.

Baseline – Work is performed as part of the project baseline in accordance with the earned value management system (RPP-7725, *Washington River Protection Solutions LLC Project Control System Description*).

11.0 SUMMARY PROGRAM ACTIVITIES

The components or functions within the DST Program are shown in Figure 11-1. Some sampling and inspection tasks are ongoing and routine; the remainder are unique. The cost and schedule to implement these activities are addressed in RPP-PLAN-62817, *Tank and Pipeline Integrity Program Improvement Plan*, and funding is managed by the WRPS program office.

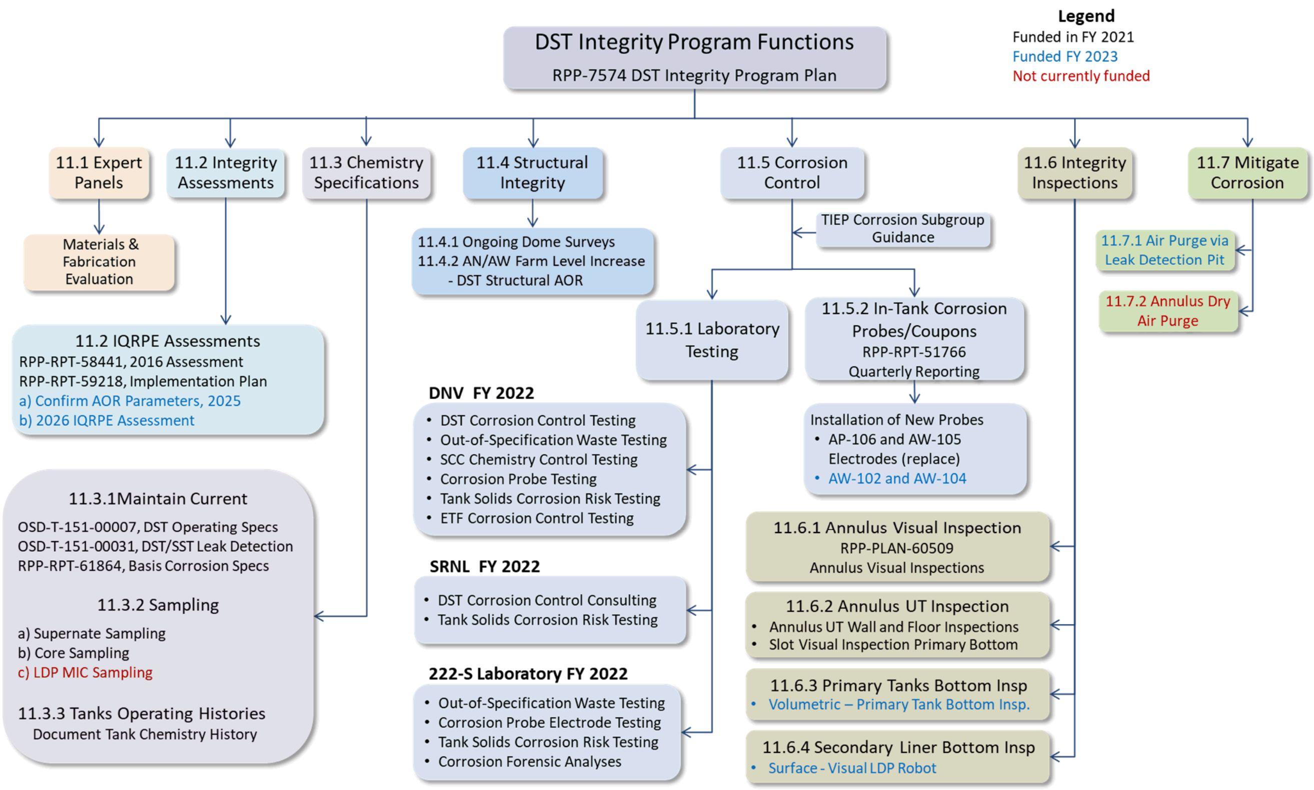


Figure 11-1. Program Functions

11.1 EXPERT PANELS

The TIEP panel consists of experts from the fields of corrosion, chemistry, electrochemistry, structural analysis, materials, nondestructive examination, and policy execution (TFC-CHARTER-67). The TIEP will meet annually to review the DSTIP activities. The TIEP Corrosion subgroup participates in biweekly calls and two meetings per year.

11.2 INTEGRITY ASSESSMENTS

Two integrity assessments have been conducted for the DST system. An initial assessment was completed in 2006 that provided an overall programmatic review of DST integrity. The second assessment, completed in 2016, assessed changes in the system and activities since completion of the initial assessment and concluded that 27 DSTs are fit for use (RPP-RPT-58441).

The next IQRPE assessment is due in 2026.

11.3 CHEMISTRY SPECIFICATIONS

11.3.1 Operating Specifications

OSD-T-151-00007, DST Operating Specifications – The operating specifications in this document cover storage operations for the DST farms (AN, AP, AW, AY, AZ, and SY Farms). Limits are provided for liquid levels, hydrostatic load, primary and annulus vapor space, tank and waste temperatures, corrosion mitigation, dome loading, tank bumping, and separable organics. The Detection/Control section describes the methods used to comply with the specification limits. The Recovery Action section describes the steps to be taken when a DST does not comply with an operating specification. The Technical Bases for the specification limits are located in Appendix A.

This document is maintained current with revisions as necessary.

OSD-T-151-00031, DST/SST Leak Detection – This operating specification document (OSD) provides a summary of leak detection and liquid level monitoring in the primary tank and annulus of the DST. Specification Limits and Recovery Actions are given. Recovery Actions describe the steps required when a Specification Limit is not met. Section 5.0 describes the Detection and Control methods that are used to meet the Specification Limits for each type of tank. Lastly, Appendix A includes both the Technical Bases that help to justify the reasoning behind the Specification Limits, and the regulatory agreements concerning intrusion and leak detection monitoring.

This document is maintained current with revisions as necessary.

RPP-RPT-61864, Chemistry Envelope for Pitting and Stress Corrosion Cracking Mitigation –SRNL, with input from the TIEP Corrosion subgroup, performed a statistically based investigation of nitrate and halide ion-induced pitting corrosion. The investigation developed a comprehensive waste chemistry envelope that minimizes the risk of both SCC and pitting caused by halide and nitrate ions. The waste chemistry envelope was designed to be robust enough to address future waste retrieval and process changes that could significantly change the waste composition of the DSTs.

This document was used as the technical basis for updating the chemistry control specifications in OSD-T-151-0007.

11.3.2 Sampling

Supernate sampling – The DST supernate is sampled to determine composition, allow corrosion testing of the sampled supernate, provide necessary chemical information to create complex simulants for off-site corrosion testing, and provide benchmarking of the models predicting compositions out tens of years. RPP-26781 provides recommendations for the sampling of DSTs for the next 5 years.

Core sampling – Core samples are required to determine composition of solids and interstitial liquid in the DST waste. With the failure of the primary tank in Tank AY-102 and the likely cause being service-induced internal pitting corrosion due to the historical waste composition and operating conditions, sampling the other tanks especially near the tank bottom is important to ensure that the waste is compliant with current corrosion control specifications.

Many of the DSTs have not had a core sample taken for many years. Therefore, there is a backlog of samples needed to verify waste conditions near the tank bottom are compliant with the pitting factor specification.

The next tanks to be sampled in FY 2022 are Tanks AN-102 and AW-105. In FY 2023, TAPI prioritizes Tanks AW-104 and AW-103 for core sampling.

Tank AY-102 annulus samples – The TIEP recommended Tank AY-102 annulus sampling in RPP-ASMT-62047: "Since the timing of final closure is uncertain, samples should be collected from the tank and annulus in 3 years to ensure that the solution remains sufficiently inhibited." The sample helps ensure that corrosion rates of the secondary liner remain within projections based on stable waste chemistry. Sampling is planned for late FY 2021.

Tank AY-102 breech site forensic inspection – To complete the forensic analysis of Tank AY-102, a sample of the corroded bottom plate needs to be obtained and analyzed. To obtain a sample, a magnetic crawler equipped with a remote cutting tool would be lowered into the tank. This process could be achieved with one robotic crawler or possibly using two, one for cutting and one to retrieve the plate sample.

Analyses would provide insight to the other sound DSTs and to understand the estimated remaining useful life of the DSTs. This analysis would also enable DOE to make appropriate risk-based decisions in support of the long-term RPP mission.

This work has been deferred to optimize the potential for repair and reuse development work that is ongoing in the Chief Technology Office.

11.3.3 Tank Operating Histories

Compiling the tank operating histories involves collaboration with the TIEP member experienced in Hanford tank waste chemistry to assess the corrosion risk over the storage of different waste types present in the tank. Ongoing efforts will continue to issue nominally two reports per year until complete and prioritized with the DST risk ranking.

The reports that have been completed to date are discussed in Section 9.0. For FY 2022, Tank AN-106 and an update to RPP-RPT-61006 is planned. The Tank AN-101 history will also be documented if resources are available.

11.4 STRUCTURAL INTEGRITY

11.4.1 Dome Elevation Surveys

The established basis and protocol for the DST Dome Survey Program are documented in RPP-25782. The goal of this program is to monitor the elevation of the tank and tank dome deflection to determine if settlement or excess deflection of the tank dome is occurring.

The surveys are performed on a frequency of no more than 3 years or as requested by Engineering, whichever is more restrictive. All survey data are reviewed by the responsible engineer and evaluated for tank settlement and dome deflection. Measurable deflections greater than 0.02 ft (0.24 in.) are investigated. Tank dome deflection of up to approximately 0.5 in. is within acceptable dome load limits per RPP-RPT-25608.

11.4.2 Level Rise Assessments

The AP Farm was analyzed for a maximum fill height of 460 in. (RPP-RPT-32237). The AW and AN Farms have been reassessed to raise the fill height and will be documented in RPP-RPT-60175.

The AW/AN Farm tanks level rise analysis also considers the effects of a large magnitude, distant Cascadia Subduction Zone event. NEI (2009) recommended a revised seismic input approach, which has been accepted by the U.S. Nuclear Regulatory Commission and is now specified in ASCE 4-16.

11.5 CORROSION CONTROL

11.5.1 Laboratory Testing

DOE O 435.1, *Radioactive Waste Management* – Requires testing to verify the basis for the waste chemistry to remain within safe operating envelopes.

RPP-ASMT-62082, *Implementation of DOE O 435.1 in the Double-Shell Tank Integrity Program* – Determines if the DST Integrity Program fully implements DOE O 435.1 in terms of demonstrated actual performance.

11.5.1.1 Det Norske Veritas–Germanischer Lloyd (DNV GL)

DNV GL are experts in material sciences and corrosion testing and perform the bulk of the electrochemical corrosion and SCC tests and mechanistic modeling. They develop and use waste simulants in their testing to help determine corrosion risks from the waste chemistry, providing valuable information to TAPI/Tank Monitoring and the expert panel to ensure corrosion is controlled in the Hanford waste tanks.

DNV GL Testing Tasks in FY 2022

- **Out-of-specification waste testing** – Test waste simulants in support of 222-S Laboratory work, as needed.
- **SCC chemistry control testing** – SCC testing of tank waste chemistries at tank temperatures >50°C in FY 2021 indicated that our current DST chemistry limits may not be protective for SCC above 50°C. Due to revising the limits to protect against SCC in the warmer tanks, Tanks AZ-102, (add other tanks as necessary) may be considered out of specification and will need to be tested to determine the SCC corrosion risks.
- **Corrosion probe testing** – This work will develop better electrodes for the RCMPs that have prolonged lifetimes and provide improved data quality. In addition, the RCMPs can be used to shuttle other corrosion testing methods into the DSTs for better real-time corrosion monitoring.
- **Tank solids corrosion risk testing** – Recent core sampling of Tanks AY-101, AN-107, and AN-106 has resulted in the identification of out-of-specification waste layers in the solids; however, the effects that solids have on corrosion risks to these tanks are not well defined or understood, and associated corrosion risks could be underreported. In addition, core samples from Tank AN-106 had lower than typical interstitial liquid content; how limited interstitial liquid in the waste solids affects the corrosion risk is not well

understood, especially in waste that is near or out of specification of the DST chemistry limits.

- **Effluent Treatment Facility (ETF) corrosion control testing** – The concentrate tanks and secondary waste receiving tanks (SWRT) contain wastes that are at higher concentrations and temperatures than the majority of the ETF processing vessels – making them more susceptible to corrosion. This work will determine if an explicit chemistry control specification is warranted, and if the current operating envelope can be expanded. The ETF is slated to receive a waste stream from the Effluent Management Facility (EMF). The EMF return stream composition is currently based on flowsheet projections that are periodically updated. This task determines the corrosion risk of the projections or actual sample data. SWRT B has experienced pitting corrosion along the roof of the tank. This testing will identify the cause of the in-tank condition and potentially identify methods for preventing future degradation.

11.5.1.2 Savannah River National Laboratory (SRNL)

SRNL provides plutonium production waste storage and remediation analyses, statistical modeling, and consultation and investigative corrosion testing. Their work explores the fundamental causes and corrosion mitigation strategies for the waste chemistries ensuring they remain with a safe operating envelop.

Savannah River National Laboratory Testing Tasks in FY 2022

- **DST corrosion control consulting** – SRNL expertise includes plutonium production waste storage and remediation, statistical modeling, and investigative corrosion testing. SRNL experts provide consultation to WRPS and the TIEP.
- **Tank solids corrosion risk testing** – Recent core sampling of Tanks AY-101, AN-107, and AN-106 has resulted in the identification of out-of-specification waste layers in the solids; however, the effects that solids have on corrosion risks to these tanks are not well defined or understood, and associated corrosion risks could be underreported. In addition, core samples from Tank AN-106 had lower than typical interstitial liquid content; how limited interstitial liquid in the waste solids affects the corrosion risk is not well understood, especially in waste that are near or out of specification of the DST chemistry limits.

11.5.1.3 222-S Laboratory

The 222-S Laboratory has the unique capability to perform electrochemical tests on tank waste samples in hot cells – generating the most direct corrosion analysis of the waste, and to conduct corrosion forensic analysis on pipes and components used in the tank farms. The ability to test samples from areas in the tank that are near or outside the DST waste chemistry limits forms the basis of determining the current corrosion risks in the tanks.

222-S Laboratory Testing Tasks in FY 2022

- **Out-of-specification waste testing** – Tanks AN-102 and AW-105 will be core sampled in FY 2022, samples of the solids will be specifically obtained for corrosion testing. In addition, corrosion testing is needed for the core samples already obtained from

Tank AN-101 to complete the corrosion risk assessments for these tanks. Other grab samples in FY 2022 that are nearly or fully out of specification will also be tested in the scope of this work to obtain the corrosion risks to the DSTs.

- **Corrosion probe electrode testing** – Testing of archived samples in support of DNV GL work will be performed, as needed. Forensic analysis of selected failed electrodes will also be conducted.
- **Tank solids corrosion risk testing** – Testing of archived solids samples in support of SRNL/DNV work will be performed, as needed.
- **Corrosion forensic analyses** – The 222-S Laboratory has received the jumper from the AY Farm. For the purpose of post-use forensic analysis, this jumper had the wall thickness measured at critical locations by UT before deployment. The same locations will be remeasured and a forensic analysis conducted to determine the level of corrosion and erosion corrosion.

11.5.2 Corrosion Probes

RCMPs monitor the tank potentials in selected DSTs, ensuring the potentials do not enter in the critical pitting and cracking zones. The current RCMP assembly permanently mounts on a riser above a spray ring. The probe head is attached to a cable and reel, which enables the RCMP to be positioned at various elevations in the waste or fully retracted out of the waste to facilitate other in-tank operations.

For FY 2022, a corrosion probe will be fabricated and installed in Tank AP-106, and the module for Tank AW-105 will be replaced. In FY 2023, corrosion probes will be fabricated and installed in Tanks AW-102 and AW-104.

11.6 INTEGRITY INSPECTIONS

11.6.1 Annulus Visual Inspections

General visual inspection of each DST annulus is conducted nominally every 3 years through a number of risers necessary for achieving 95 percent or more coverage of the annulus floor with each inspection. Directed visual inspection is conducted as needed to corroborate results of UT inspections or examinations.

For FY 2022, tanks in AN and AZ Farm will be inspected. In FY 2023, tanks in AW and SY Farm will be inspected.

11.6.2 Annulus Ultrasonic Testing Inspections

UT inspections are performed with remote robotic crawlers to examine the DSTs for thinning, pitting, and cracking. This type of inspection provides a volumetric examination of the metal. The examinations are performed using a magnetic crawler deployed via special trays through annulus risers from grade. The crawler delivers various ultrasonic transducers to conduct the examination. Portions of the primary tank and secondary liner are examined within DSTs on an 8- to 10-year periodicity for each tank.

Full UT scans will be performed in Tanks AN-107, AN-101, AP Farm, and Tank SY-101 in FY 2022. Full UT scans will be performed in Tanks SY-103, SY-102, and AP-101 for FY 2023.

11.6.3 Primary Tank Bottom Inspection Systems

Currently tanks with solids have no recent sample data or thickness measurements at the tank bottom (failure point for AY-102). Estimated remaining useful life and overall health of the DSTs cannot be effectively understood without thickness measurements of the tank bottom. Improved monitoring of the DST tank bottom condition through development of a new technology will reduce risk of operational failures and the associated impact to mission continuity. Three systems have been in development to solve this issue (SWRI, Eddyfi/Guidedwave, and Force Technologies/ITIVS). Performance demonstration tests are needed for these systems prior to deployment, which are planned to begin starting in FY 2023.

11.6.4 Secondary Liner Bottom Inspections

In FY 2020, a secondary liner bottom inspection robot was developed and fabricated for access through the LDP drain line. The crawler was delivered in FY 2021 and is currently in storage. The crawler should be deployed so results can be used to assess the need for mitigation. AW and AN Farms have LDP drain designs that give direct access to the bottom of the secondary liner in a slot that spans the full diameter of the tank.

Initial deployment is planned for FY 2023.

11.7 MITIGATE SECONDARY LINER CORROSION

11.7.1 Air Purge via Leak Detection Pit

Design and fabrication of a test unit for Tank SY-102 is complete and the skid is in storage. The next step is to install and operate the LDP at a slight positive pressure and monitor the intrusion rate in Tank SY-102. Initial deployment is planned for FY 2023.

After completion of the Tank SY-102 test, relocating the test unit to a second tank (Tank AZ-102 is a candidate) will be considered. Pending results, a permanent system could be designed and installed in multiple tanks.

11.7.2 Annulus Dry Air Ventilation

An engineering evaluation should be conducted to determine the scope of a ventilation concept to use dry air in the DST annular space. Funding is not available in FY 2022 for this scope.

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