RPP-7574, Rev. 4

Double-Shell Tank Integrity Project Plan

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Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

EDT/ECN: DCRF UC:
Cost Center: Charge Code:
B&R Code: Total Pages: 186
TM 06/01/16

Key Words: double-shell tanks, structural integrity, DSTIP, corrosion mitigation, integrity assessment, ultrasonic testing, Administrative Order, chemical limits, 242-A Evaporator, leak tightness, aging mechanisms, chemistry control, TSR, visual examination, electrochemical noise, electrical resistance, linear polarization resistance, waste corrosion, electrochemical corrosion

Abstract: This document describes the strategy, plans, and techincal basis for verifying double-shell tank system integrity. It includes references to the documents produced in support of the program.

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APPROVED
By Julia Raymer at 7:19 am, Jun 01, 2016

Release Approval Date

DATE:
Jun 01, 2016
HANFORD RELEASE

Release Stamp

Approved For Public Release

RPP-7574
Revision 4

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Date Published
April 4, 2016

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

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EXECUTIVE SUMMARY

The mission of the U.S. Department of Energy's (DOE) River Protection Project (RPP) is to store, retrieve, treat, and dispose of the 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), 27 double-shell tanks (DST), and one DST that has leaked to the tank annulus. The DSTs are supported by ancillary systems and equipment, which allow the movement of the waste into, within, and out of the tank system. The 242-A Waste Evaporator facility, 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. However, since 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), means must be taken to ensure that the DST System can meet the RPP mission goals.

The DOE requires a program for the structural integrity of high-level waste storage tanks. These requirements are defined in DOE G 435.1-1, *Implementation Guide for use with DOE M 435.1-1*[1]. For the Washington River Protection *Solutions*, LLC (WRPS), the DST Integrity Project (DSTIP) implements controls and inspections that ensure DST System integrity is maintained throughout the RPP mission.

This project plan identifies the DSTIP activities. The work scope covered under this DSTIP Plan includes the following principal elements:

- DST and 242-A Evaporator integrity inspections (e.g., ultrasonic and video examinations) and documentation of results for use in periodic re-inspections;
- DST waste chemistry 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; and
- Periodic testing and integrity assessment of the DST's 242-A Evaporator Facility.

In fiscal year (FY) 2006, the DSTIP completed the field work and documented the integrity assessment of the DSTs and ancillary equipment as the *Hanford Federal Facility Agreement and*

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

Consent Order – Tri-Party Agreement (Ecology et. al 1989)[2] Milestone 48-14. An Independent Qualified Registered Professional Engineer (IQRPE) certified this assessment and provided recommendations for future integrity work in RPP-28538, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14.*[3] The second such assessment is due in FY 2016.

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 modeling of DST waste and operational characteristics. To ensure continued improvement of the technical bases, the DSTIP receives programmatic steering and advice from the Tank Integrity Expert Panel (TIEP). The TIEP members have national and international reputations and the members have positions in industry, national laboratories, and academia.

[2] Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement,* 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

[3] RPP-28538, 2008, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14,* Revision 5, CH2M HILL Hanford Group, Inc., Richland, Washington.

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TERMS

Acronyms and Abbreviations

ASME®	American Society of Mechanical Engineers
ASTM®	American Society for Testing and Materials
BNL	Brookhaven National Laboratory
CFR	*Code of Federal Regulations*
CPP	cyclic potentiodynamic polarization
DOE	U.S. Department of Energy
DST	double-shell tank
DSTIP	Double-Shell Tank Integrity Project
DVI	double-valve isolation
Ecology	Washington State Department of Ecology
E_{corr}	free corrosion potential
EMAT	Electromagnetic Acoustic Transducer
EPOC	Expert Panel Oversight Committee
FEA	finite element analysis
FY	fiscal year
HAZ	heat-affected zone
HIAP	High-Level Waste Integrity Assessment Panel
IDRT	Integrity Data Review Team
IQRPE	Independent Qualified Registered Professional Engineer
LAI	liquid-air interface
LAWPS	Low-Activity Waste Pretreatment System
LDP	leak detection pit
MPCMS	Multi-Probe Corrosion Monitoring System
NACE	National Association of Corrosion Engineers
NDE	nondestructive examination
OCP	open circuit potential
ORP	Office of River Protection
OSD	operating specification document
PBM	Pittsburgh Brass Manufacturing
P-scan	pulse-echo ultrasonic inspection
PAUT	Phased-Array Ultrasonic Testing
PNNL	Pacific Northwest National Laboratory
PUREX	plutonium-uranium extraction
RCMP	retractable corrosion monitoring probe
RCRA	*Resource Conservation and Recovery Act of 1976*
RPP	River Protection Project
SCC	stress-corrosion cracking
SCE	saturated calomel electrode
SRS	Savannah River Site
SST	single-shell tank
T-SAFT	Tandem-Synthetic Aperture Focusing Technique
TAPI	Tank and Pipeline Integrity
THE	Tsujikawa Hisamatsu Electrochemical

TIEP	Tank Integrity Expert Panel
TIIG	Tank Integrity Inspection Guide
TOLA	thermal and operating load analysis
TPA	Tri-Party Agreement
TSIP	Tank Structural Integrity Panel
UHMWPE	ultra-high molecular weight polyethylene
UT	ultrasonic testing
VSC	vapor space corrosion
WAC	*Washington Administrative Code*
WRPS	Washington River Protection *Solutions*, LLC
WTP	Waste Treatment and Immobilization Plant

Units

°C	degrees Celsius
°F	degrees Fahrenheit
ft	feet
gal	gallon
in.	inch
M	molar
mil	thousandth of an inch
min	minutes
mm	millimeter
mV	millivolt
µm	micrometer
yr	year

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1.0 INTRODUCTION AND BACKGROUND

The mission of the U.S. Department of Energy's (DOE) River Protection Project (RPP) is to store, retrieve, treat, and dispose of the highly radioactive waste in Hanford Site tanks in an environmentally sound, safe, and cost-effective manner. Accomplishing the RPP mission requires providing and maintaining adequate tank capacity for waste storage and waste feed delivery. Thus, functional waste storage and transfer facilities are key assets for the RPP and the integrity of these systems is vital to the mission.

Washington River Protection *Solutions*, LLC (WRPS) manages the tanks for the DOE Office of River Protection (ORP). WRPS Production Operations manages the day-to-day activities for the tanks. WRPS Tank Farm Projects has responsibility to conduct inspections and assessments of the tanks along with any adjustments to the tank chemistry. Tank Farm Projects conducts its activities through the Double-Shell Tank Integrity Project (DSTIP), which provides for visual inspection of the annulus and primary tank, ultrasonic testing (UT) of the primary tank wall, and waste chemistry corrosion mitigation and monitoring.

1.1 INTRODUCTION

The structural integrity of the double-shell tanks (DSTs) include the analysis of record and the dome load program. The DST assessments include visual inspection of the annulus and primary tank, UT of the primary tank wall, and waste chemistry corrosion mitigation and monitoring, along with inspection of ancillary equipment that supports the DSTs.

1.2 DOUBLE-SHELL TANK SYSTEM

DOE constructed 28 DSTs of which 27 tanks have maintained their integrity. Tank AY-102[4] has leaked from the primary tank into the floor of the secondary liner and as such is not fit for use. These tanks are supported by ancillary equipment (e.g., transfer piping, valve pits, and one catch tank), which allow the movement of the waste into, within, and out of the tank system. Additional details on DST construction and the status of Tank AY-102 are provided in Appendix A and Appendix B, respectively.

In addition to the DST System, the DSTIP also conducts assessments of the 242-A Evaporator and Tank AZ-301. The evaporator removes water from the waste to recover tank space consumed by retrieval and tank farm operations. The miscellaneous tank receives condensate from high-heat tanks, which is then transferred to the Effluent Treatment Facility.

1.3 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 the DOE) in the 1960s to initiate construction of DSTs with improved design, materials, and construction. The construction of the

[4] 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).

DSTs began in 1968 with the sixth farm being completed in 1986. All of the DSTs have a nominal million-gallon waste capacity, with design lives of 20 to 50 years.

The DSTs design allows the detection of any potential leaks. Leaking waste would be held in the secondary containment, allowing for corrective action long before there could be any release of waste to the environment. Table 1-1 covers the construction dates, year of initial service, and the expected design life at time of construction.

Table 1-1. Double-Shell Tank Construction and Age as of 2016.

Tank farm	Number of tanks	Construction period	Construction project	Initial operation	Design life	Current age
AY	2	1968 – 1970	IAP-614	1971	40	46
AZ	2	1970 – 1974	HAP-647	1976	20	42
SY	3	1974 – 1976	B-101	1977	50	40
AW	6	1976 – 1979	B-120	1980	50	37
AN	7	1977 – 1980	B-130, B-170	1981	50	36
AP	8	1982 – 1986	B-340	1986	50	30
Total	**28**					

DSTs consist of a primary steel tank inside of a secondary steel liner (Figure 1-1). 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.

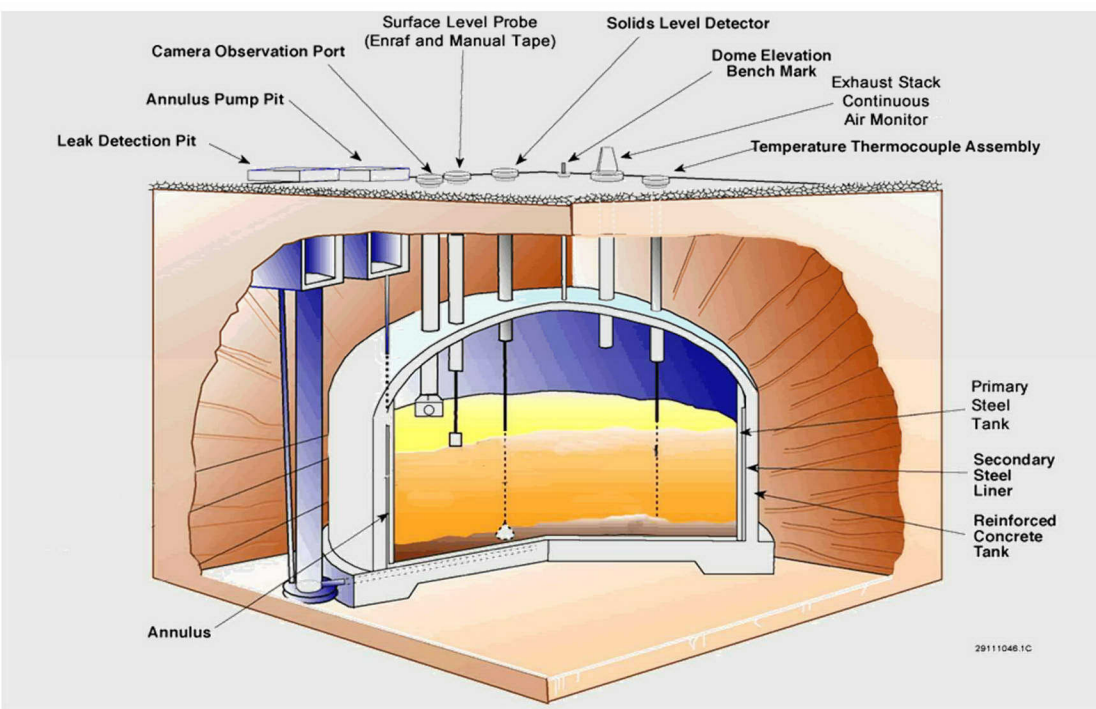

Figure 1-1. Double-Shell Tank Construction.

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.

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.

1.4 242-A EVAPORATOR

The 242-A Evaporator was built in 1976 and began operation in 1977. The facility was based on the 242-S Evaporator and incorporated lessons learned from the earlier facility to improve design and operation. The evaporator, shown in Figure 1-2, is located north of the AW Farm. The 242-A Evaporator receives feed from DST AW-102, reduces the water content of the waste, and then transfers the more highly concentrated waste to a number of receiving DSTs.

Figure 1-2. 242-A Evaporator.

1.5 WASTE TRANSFER SYSTEM

The Waste Transfer System consists of pipelines, pump and valve pits, pumps, jumpers, and valves. The transfer system was reviewed by an Independent Qualified Registered Professional Engineer (IQRPE) and is described in RPP-27591, *Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity*. Integrity for the waste transfer system is maintained as described in RPP-PLAN-52788, *Waste Transfer System Fitness-for-Service Implementation Plan*.

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2.0 PROJECT STRATEGY

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 mission requirements. As such, the DSTIP focuses on ensuring the integrity of the 27 DSTs, but also ensures the integrity of the DST System ancillary equipment (e.g., transfer system). The timeline for integrity activities is shown in Figure 2-1.

This project plan identifies the DSTIP activities. The work scope covered under this DSTIP Plan includes the following principal elements:

- DST and 242-A Evaporator integrity inspections (e.g., ultrasonic and video examinations) and documentation of results for use in periodic re-inspections;
- DST waste chemistry 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; and
- Periodic testing and integrity assessment of the DST's 242-A Evaporator Facility.

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

2.1 STRATEGY DEVELOPMENT

The elements of this program came from a DOE wide initiative. The DOE had concerns related to 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, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*). 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.

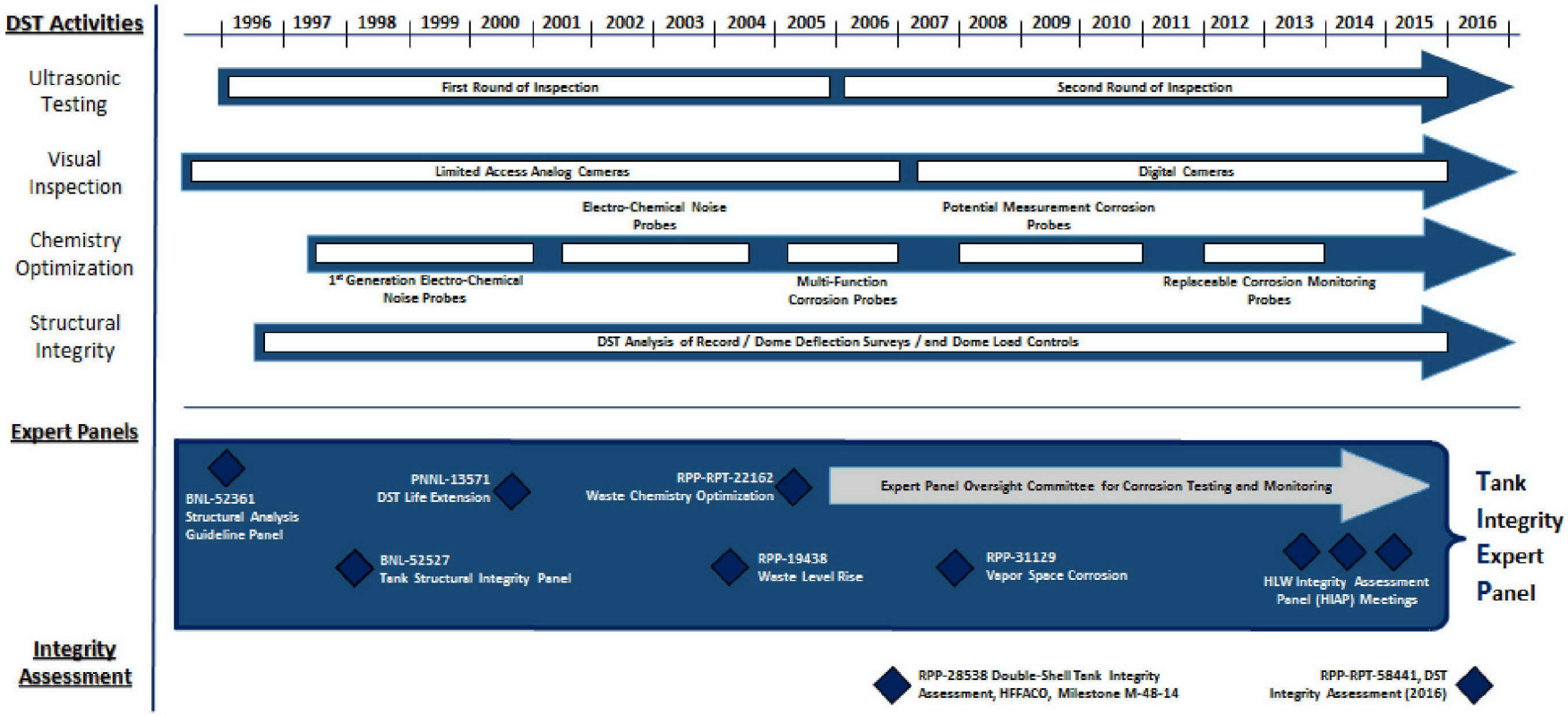

Figure 2-1. History of Double-Shell Tank Integrity Project.

The DOE has subsequently adopted these guidelines and requires site operators to have a program consistent with them (DOE M 435.1, *Radioactive Waste Management Manual*). The ORP contractual agreement with the Tank Operations Contractor (Dowell 2011, "Contract No. DEAC27-08RV14800 – Approval of River Protection Project Authorization Agreement") includes a requirement to "maintain the tank structural integrity program as described in RPP-7574" (this report).

In addition to the DOE Order, the DSTs and ancillary equipment are considered active facilities under regulations stemming from the 1976 designations of the *Resource Conservation and Recovery Act of 1976* (RCRA) requirements. This law led to promulgation of regulations to specify the configuration and operation of hazardous waste treatment, storage, and disposal facilities under Title 40, *Code of Federal Regulations* (CFR), Part 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart J, "Tank Systems." The state of Washington is not authorized to regulate such "interim status" facilities, but does have authorization for "final status" facilities once a permit is issued for the DSTs. As such, the DST System must comply with federal regulation and align with Washington's dangerous waste regulations (*Washington Administrative Code* [WAC] 173-303-640, "Tank Systems"). The management of tank systems under DOE Orders is described in DOE O 435.1, *Radioactive Waste Management*.

The DOE and the Washington State Department of Ecology (Ecology) regulatory requirements have similar objectives as the structural integrity program advocated in the TSIP guidelines. Thus, a tank structural integrity program consistent with the TSIP guidelines supports compliance with the regulatory requirements for the DSTs and ancillary equipment. The TSIP guidelines and comparison to the Hanford DSTIP are shown in Appendix C, and environmental requirements are documented in RPP-16922, *Environmental Specifications 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 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 chemistry testing and the development of in-corrosion monitoring along with the guidance from expert panels.

2.2 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, and
- 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. In addition, the project ensures inspection and maintenance of the waste transfer system, along with periodic inspection of the 242-A Evaporator. Figure 2-2 shows the overall scope of the DSTIP. Appendix D shows the functional areas of the program, the documents produced under each functional area, and the future activities proposed for each functional area.

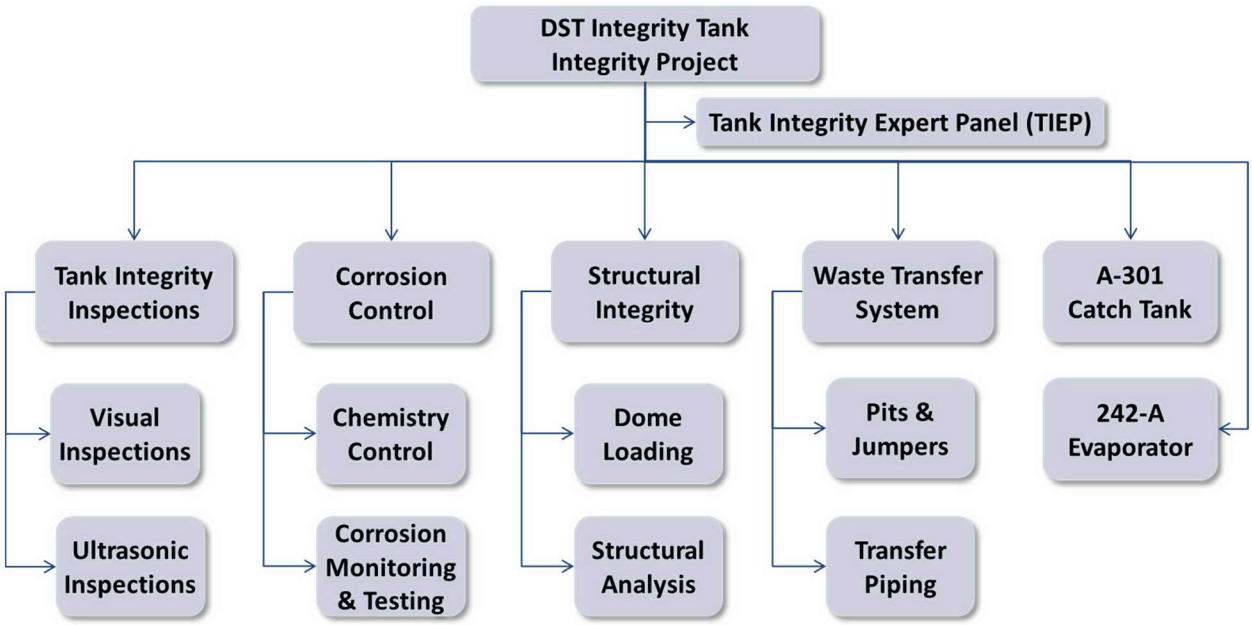

Figure 2-2. Overall Scope for the Double-Shell Tank Integrity Project.

2.3 TANK INTEGRITY INSPECTIONS

The DSTIP conducts nondestructive examination (NDE) of the primary tanks and the secondary liners to detect degradation that may be occurring. The two techniques employed are visual inspection of surfaces and UT, which provides a volumetric examination of the metal. The visual inspections occur on a three-year cycle. The UT inspections occur on an eight- to ten-year cycle.

2.4 CHEMISTRY CONTROL

The chemistry control uses favorable ratios between inhibiting compounds (e.g., hydroxide and nitrite) and aggressive species (e.g., nitrate). For waste in the DSTs, the DSTIP chemistry controls reduce the propensity for general corrosion, local corrosion (pitting), or SCC to occur.

The DSTIP is performing chemistry optimization testing, along with corrosion monitoring, to fully understand and improve corrosion mitigation in the DSTs. Chemistry optimization studies have built on years of testing at the Savannah River Site (SRS) and the Hanford Site to further identify the chemical composition ranges that minimize the propensity for localized corrosion. In-tank corrosion monitoring looks for indications of incipient corrosion from in-tank sensors and provides for data to confirm laboratory testing parameters are representative of actual tank chemistry environments.

2.5 STRUCTURAL INTEGRITY ASSESSMENT

During DST design and construction, steps taken to prevent SCC included material selection, tank wall thickness, and post-weld heat treatment. Hanford Site personnel selected higher strength steels to build the DSTs as compared to that used for single-shell tank (SST) construction. The thicknesses of the primary tank walls were increased over the steel plate used in previous construction, to minimize operational stresses. To reduce residual weld stresses from construction (e.g., stresses in the heat-affected zone [HAZ]), the tanks were post-weld heat treated up to 1,100 °F.

The TSIP followed previous work at BNL, which dealt with seismic analysis of the DOE's high-level waste tanks (BNL-52361, *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Tanks and Appurtenances*). The DOE incorporated these guidelines into DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, and the supporting technical documents for this standard. The Hanford Site developed site-specific guidelines based on this work 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*. This guidance was used to update the analysis of record for the DSTs in RPP-RPT-28968, *Hanford Double-Shell Tank Thermal and Seismic Project – Summary of Combined Thermal and Operating Loads with Seismic Analysis.*

2.6 INDEPENDENT INTEGRITY ASSESSMENT

Under RCRA, the DSTs contain mixed waste, which contains both hazardous (dangerous by the State of Washington definition) and radioactive waste. As such, the operation of the DSTs are also regulated by 40 CFR 265 and WAC 173-303, "Dangerous Waste Regulations." These regulations require integrity assessments of tank systems that store hazardous waste and determination by an IQRPE as to whether the tank system is fit for use.

Two integrity assessments have been conducted for the DST system. An initial assessment was completed in 2006, which provide an overall programmatic review of the DST integrity. The second assessment was completed in 2016, which assessed changes in the system and activities since completion of the initial assessment.

2.6.1 Initial Integrity Assessment

Completion of the IQRPE integrity assessments (Table 2-1) for the DST system is considered by DOE and Ecology to have satisfied the TPA Milestone M-48-00, "Complete Identified Dangerous Waste Tank Corrective Actions, March 31, 2006."

The assessment of the DST System was completed in March 2006 (RPP-28538). In conducting this evaluation, the IQRPE reviewed the DSTIP documentation pertaining to DST integrity and prepared several supplemental reports to document this evaluation. Table 2-1 lists the other supplemental reports prepared by the IQRPE to support the RPP-28538 DST System integrity assessment.

The IQRPE made a total of 78 recommendations on completion of the 2006 DST assessment. RPP-RPT-50440, *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. However, 15 of the closed recommendations have follow-up activities that are included in this report. A summary of the 15 dispositions and their locations in this report is provided in Appendix E.

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 ten years from the completion of last revision in December 2008. However, since the integrity assessment was used as a basis for the *Tank Farm Documented Safety Analysis* (RPP-13033), an additional requirement for the completion of the follow-on assessment was completed in March, 2016.

The 2016 integrity assessment built on the work done in the initial assessment and evaluated the tank farm modifications completed since 2006. The IQRPE made a total of 24 recommendations to improve DST integrity as part of the 2016 DST assessment. A report to the disposition these recommendations has been drafted (RPP-RPT-59218, *2016 Double-Shell tank Integrity assessment Recommendation Dispositions*). The dispositions will show the actions taken to close the recommendations, those recommendation still pending, and those recommendations that don't have a disposition.

In RPP-RPT-58441, the IQRPE recommended the next assessment be conducted in ten years (2028). This update is currently planned for in the life cycle baseline.

Table 2-1. Supplemental Reports Prepared by the Independent Qualified Registered Professional Engineer.

Document Number[a]	Title	Contents
RPP-27591	*Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity*	Contains 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 dangerous 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

Table 2-1. Supplemental Reports Prepared by the Independent Qualified Registered Professional Engineer.

Document Number[a]	Title	Contents
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
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 11.0.

DST = double-shell tank.

2.7 EXPERT ADVICE

Over the course of the DSTIP, advice and direction has been sought from numerous panels of outside experts brought in to review the various aspects of DST integrity and operations (Table 2-2). These panels date back to the BNL panel on seismic analysis for the high-level waste tanks and have involved members from academia, industry, and national laboratories. These panels have conducted both specific needs for DOE and programmatic assessment of integrity.

An example of a specific need panel was the Expert Panel for Chemistry Optimization, which was convened in 2004 to deal with the need to establish control limits below 50 °C to minimize the propensity for SCC. The results from their workshop led to the seating of Expert Panel Oversight Committee (EPOC) for Corrosion Testing and Monitoring, which evaluated the progress on SCC testing and provided programmatic guidance to the DST program in other areas of tank integrity (e.g., develop of protocol for pitting corrosion and sampling on tanks).

Table 2-2. Listing of Tank Integrity Expert Panels.

Expert panel	Reference[a]	Comments
Tank Structural Analysis Panel	BNL-52361, *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Tanks and Appurtenances*	Panel provided the basis for structural analysis of high-level waste (HLW) storage tanks.
Tank Structural Integrity Panel (TSIP)	BNL-52527/UC-406, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*	Panel provided the basis for structural integrity programs as provided for in DOE O 435.1, *Radioactive Waste Management* for HLW storage tanks.

Table 2-2. Listing of Tank Integrity Expert Panels.

Expert panel	Reference[a]	Comments
Expert Panel for Double-Shell Tank Life Extension	PNNL-13571, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*	Panel provided the basis for three degradation mechanisms: • General corrosion, • Pitting corrosion, and • Stress corrosion cracking.
Expert Panel Double-Shell Tank Level Increase	RPP-19438, *Report of Expert Panel Workshop for Hanford Site Double-Shell Tank Waste Level Increase*	Panel provided the basis for liquid level increase up to 460 in. in the 241-AP Farm along with guidance for other the level increases
Expert Panel for Tank Chemistry Optimization	RPP-RPT-22126, *Expert Panel Workshop on Tank Chemistry Optimization – Status of Oxygen Generation and Depletion Modeling*	Provided the basis for tank chemistry optimization corrosion testing.
Expert Panel Oversight Committee (EPOC)	This committee over saw implementation of the Chemistry Optimization and Vapor Space Corrosion Expert Panels. In this capacity they wrote advice between 2005 and 2015.	The committee now serves as the corrosion sub-group for the TIEP.
Expert Panel for Vapor Space Corrosion	RPP-RPT-31129, *Expert Panel Workshop on Double-Shell Tank Vapor Space Corrosion Testing*	Panel provided the basis for vapor space corrosion testing.
High-Level Waste Integrity Assessment Panel (HIAP)	RPP-ASMT-57582, *Second Workshop of the High Level Waste Integrity Assessment Panel: Extent of Condition and Balance of Program*	Panel provided recommendations to improve the DST integrity program in response to Tank AY-102 leak.
Tank Integrity Expert Panel (TIEP)	RPP-ASTM-60518, *Tank Integrity Expert Panel 2015 Meeting Outcomes*	Panel integrates HIAP, EPOC, and Single-Shell Tank Integrity Panel. The TIEP has accepted recommendations from the HIAP along with the corrosion testing recommendations of the EPOC.

[a] Full references are provided in Section 11.0.

In 2013, WRPS formed the High-Level Waste Integrity Assessment Panel (HIAP) to assess why the leak in Tank AY-102 was not detected and the threat was not known in advance. The measurement of high decay rates on the equipment used to sample the leak detection pit (LDP) for Tank AY-102 led to the formation of this panel, along with other actions. The panel met three times and developed recommendations for the improvement of the integrity project (e.g., inspection of the tank bottoms and secondary liners) and recommended forensic examination methods for Tank AY-102.

From the second meeting of the HIAP, the Tank and Pipeline Integrity (TAPI) group developed an implementation plan for improvements. The WRPS has prioritized these activities based on current tank integrity work and by potential payback of the tasks. A complete discussion of the

plan is provided in RPP-PLAN-57352, *Double-Shell Tank Integrity Improvement Plan*. Figure 2-3 shows that the tasks were prioritized into groups to allow a phased implementation of the work. The initial phase was further subdivided with the end purpose in mind.

To integrate all ongoing tank integrity work, WRPS established the Tank Integrity Expert Panel (TIEP) in 2015. In their first meeting, the panel reviewed the implementation plan developed by WRPS and agreed to the approach identified, which is shown in Figure 2-3. The EPOC was guiding work on chemistry optimization and vapor space corrosion, but is now a sub-group to the TIEP. The TIEP has reaffirmed the HIAP emphasis that tank inspection focus should move from the walls to the tank bottoms and continue the chemistry testing proposed by the EPOC through the newly established Corrosion Sub-Group.

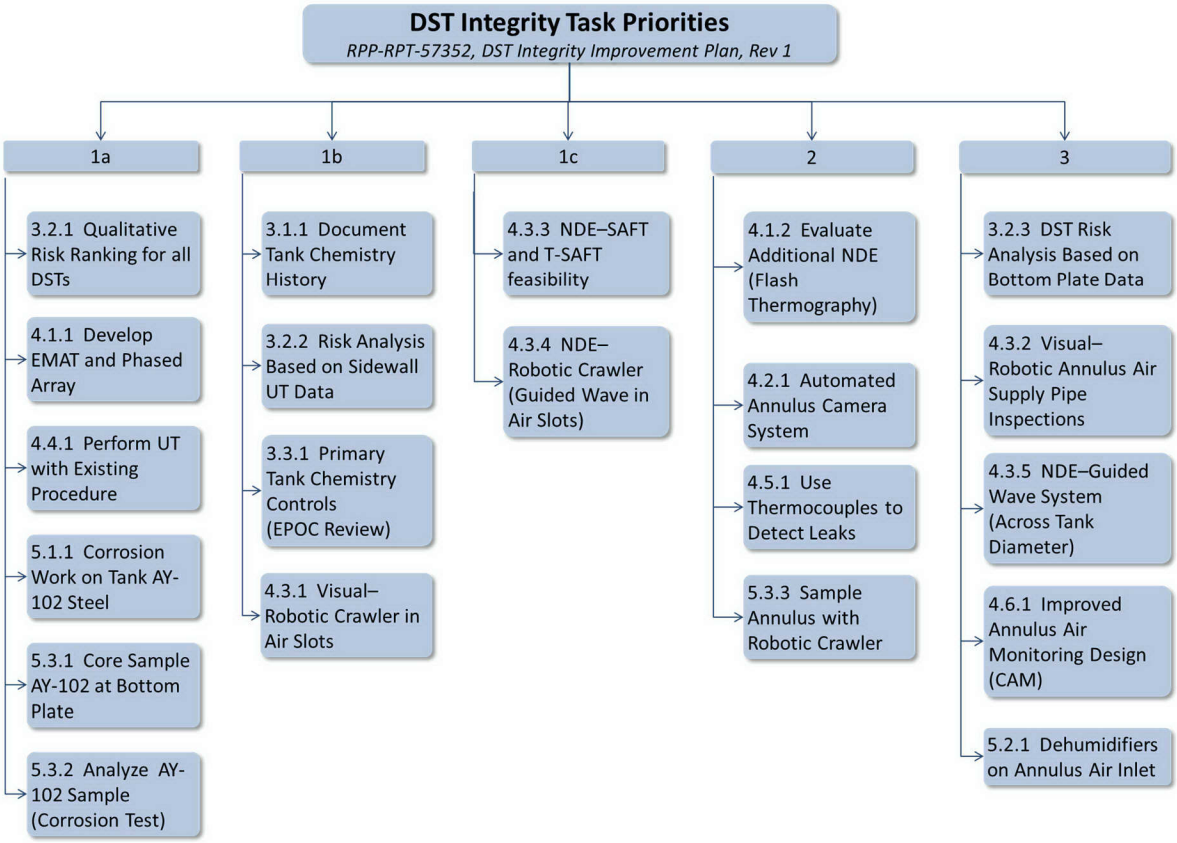

Figure 2-3. Tank Integrity Improvement Plan.

3.0 DOUBLE-SHELL TANKS AGING MECHANISMS

Numerous methods of degradation can reduce the integrity of carbon steel and concrete structures. For the primary tank and secondary liners, the primary types of degradation that can occur include the following:

- Thinning of the walls by general corrosion could lead to structural failure,
- Pitting of the walls could lead to through-wall leaks,
- SCC could lead to through-wall leaks,
- Liquid-air interface (LAI) corrosion could lead to accelerated thinning and pitting of the tank wall at an existing or previous waste surface, and
- Vapor space corrosion could occur above the LAI.

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.

3.1 AGING MECHANISMS FOR PRIMARY TANKS

The tanks have three main areas of vulnerability to corrosion: (1) interior surfaces of the primary tank exposed to the headspace air, (2) interior surface of the primary tank wall in contact with the waste, and (3) exterior surface of the primary tank wall exposed to the annulus air or water intrusion. These surfaces are subject to corrosion from general chemical attack, pitting, and SCC, and 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 waste are the most threatening degradation mechanisms for the DST primary tanks. A summary of UT measurement findings and updates from investigations is included in Appendix F.

The most significant form of corrosion found to date in the DST System is LAI corrosion. The LAI corrosion occurred when out-of-specification waste was left at a static level in the tank for years at a time. Fortunately, this LAI corrosion usually 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.

The TSIP guidelines identified concentration cell or waterline corrosion and corrosion of external tank surfaces by in-leakage as potentially significant mechanisms for steel tanks. The DSTs do not have stagnant water in contact with the external tank surface; this is not considered a problem area. Tank interior waterline corrosion at the LAI remains a matter of concern, particularly because a reaction with the carbon dioxide in the dome air space depletes hydroxide at the waste surface.

Water intrusion has been also 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 the gap exists in all of the DSTs, it was intentionally formed in the AY Farm by use of 1/2-in. copper rods.

The impact to the tanks at the current location is deemed small. The condition should be monitored. If an increase is noted, additional measures should be taken to investigate it at that time. These measures could include increase visual inspection or sampling of the material that appears to be a carbonate.

A new degradation mechanism may be present in the DSTs. As noted in RPP-ASMT-57582, the leak mechanism for Tank AY-102 has not been identified. The current plans to investigate the failure mechanism include both post-retrieval forensic examination and NDE of the tank bottom through the air channels. These investigations are necessary to determine whether the failure of AY-102 was cause by a construction flaw or by a degradation mechanism that may be present in other DSTs.

3.2 AGING MECHANISMS FOR THE SECONDARY LINER

Under normal operation, the aging 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 side wall and base of the liner, but at the lower knuckle, there is no concrete backing to the liner. Therefore, this portion of the secondary liner is load-bearing.

Waste leakage into the Tank AY-102 annulus discovered in 2012 also raised the issue of corrosion on the annulus floor and its 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 fiscal year (FY) 2013. After three 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*).

Liquid level increase in the Tank AY-102 LDP also raised the issue of corrosion of the exterior of the secondary liner because of moisture. Tank AY-102 LDP liquid levels have exceeded the maximum authorized limit in the past, which indicates possible wetting of the secondary liner exterior. An investigation of the corrosion threat because of LDP moisture began in FY 2014. Two different laboratories conducted long-term testing using groundwater and LDP water simulants and samples. The results indicated corrosion rates of 5 to 10 mil/yr were possible (RPP-RPT-57774). The corrosion results are conservative, as the duration of testing was only four months, and samples that showed the largest corrosion rates were fully immersed.

As part of the improvements to the DSTIP, UT inspections of the annulus floors have been conducted. These inspections have shown wall loss on the annulus floor, which requires further examination. As such, WRPS is preparing a plan to investigate threats to the secondary liner. RPP-RPT-55666, *Double-Shell Tank Tertiary Leak Detection System Evaluation*, will address the actions that WRPS is taking to assess the current integrity of the secondary liner and mitigate the threat because of LDP moisture.

3.3 AGING MECHANISMS OF THE REINFORCED CONCRETE

For the reinforced-concrete portions of waste storage tanks, the TSIP identified elevated temperature, freezing and thawing, leaching of calcium hydroxide, aggressive chemical attack, and corrosion of reinforcing steel as potentially significant aging 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. However, the effects of periods of elevated temperature caused by heat-generating waste needed to be modeled.

Degradation effects of elevated temperature on structural properties of reinforced concrete were addressed in the finite element modeling used for the RPP-RPT-28968. While 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 with high temperatures in the four aging waste tanks (Tanks AY-101, AY-102, AZ-101, and AZ-102) indicated possible significant structural effects, the integrity assessment reports for the "bounding DST" (i.e., worst-case DST) 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 were addressed along with the effects of increased waste level in the finite element modeling used for RPP-RPT-32237, *Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms*.

Another concern is the level of liquid in the LDPs. A maximum authorized limit has been established in Table 1.1.3 of OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks*, which prohibits liquid from filling the drain lines that lead from the refractory concrete to the tertiary LDPs. If the level in these wells is too high, the concrete collection slots underneath the secondary liner would have water in contact with concrete and metal in the secondary liner. Corrosion testing conducted in support of the Tank AY-102 Administrative Order Action Item 8 showed corrosion rates as high as 10 mil/yr for water in contact with the secondary liner (RPP-57774).

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4.0 INTEGRITY INSPECTIONS

The DSTIP inspects the DSTs visually to examine the surface of the tanks and with UT to examine volume of metal. These inspections have to be conducted remotely because of the hazardous conditions and limited access into the tanks. The remote nature of the inspections lead to the use of unique equipment and techniques.

4.1 VISUAL EXAMINATION

The Hanford Site DSTs are examined with remote cameras to assess the condition of the annulus surfaces of the primary tank and secondary liner. Annulus visual inspections were first performed in 1992 through a limited number of risers (typically two) and eventually evolved to using four risers for periodic annulus inspections. Prior to 2012, annulus visual inspections were either performed, as much as possible, in conjunction with periodic schedule ultrasonic testing or approximately every five years (not to exceed seven years between inspections).

The DSTs are examined visually (RPP-PLAN-46847, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks*) for conditions indicating structural and leak integrity deterioration on the annulus surfaces of the primary tank and secondary liner, using remote video equipment. Visual examinations will be performed every three years.

The visual inspection of the DST annulus is performed using a General Electric PTZ-70 color video camera (Figure 4-1). The annulus is accessed via 10 to 12 risers to provide enough coverage (greater than 95 percent by area) of the annulus floor. Video camera units are deployed by hand and dangled from the end of a tether. Each video inspection requires an average of 8 to 10 personnel to enter the tank farm and nominally record an hour of video.

Camera stability throughout the inspection limits the quality and makes post processing of the video a time-consuming process. The benefits of a permanently, mounted, automated annulus riser camera system have been recognized, and a recommendation to pursue a solution was made in Section 4.2.1 of RPP-PLAN-57352.

The visual baseline information is documented in the *Tank Integrity Inspection Guides* (TIIG). The TIIG contains photographic information of notable indications (areas of interest) and specifies their location on each DST, and also shows the tank regions examined by UT. The TIIG incorporates a variety of information, including previous inspection results, construction drawings, certified vendor information, etc. The information provided by the construction drawings provides the ability to pinpoint the location of the vertical welds along the primary and secondary walls of the DST. This mapping process is then linked with the steel plate data to form the TIIG.

Figure 4-2 provides an example of the inspection map section of the TIIG, and Figure 4-3 illustrates the information in the guide section of a TIIG. These figures are annotated with descriptions for each item. These example figures can be used as a template for understanding the TIIGs. Each item of interest has been mapped and is given a unique tank-specific photo identification number, which enables the region to be identified and explained in the TIIG. The areas of interest identified in previous inspections and documented in the TIIG will be revisited in future inspections.

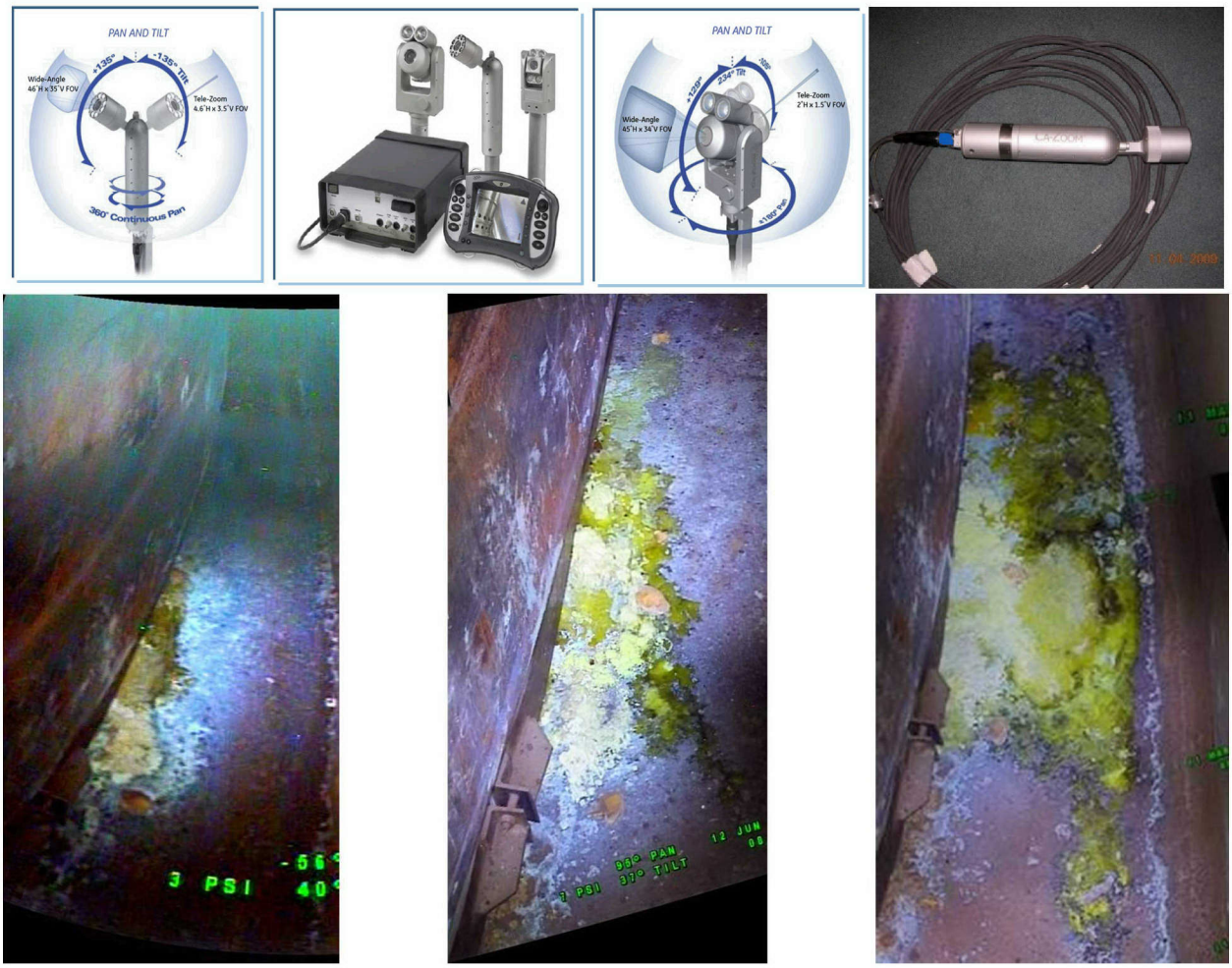


Figure 4-1. Radiation Hardened, Pan, Tilt, Zoom Autofocus Inspection Cameras.

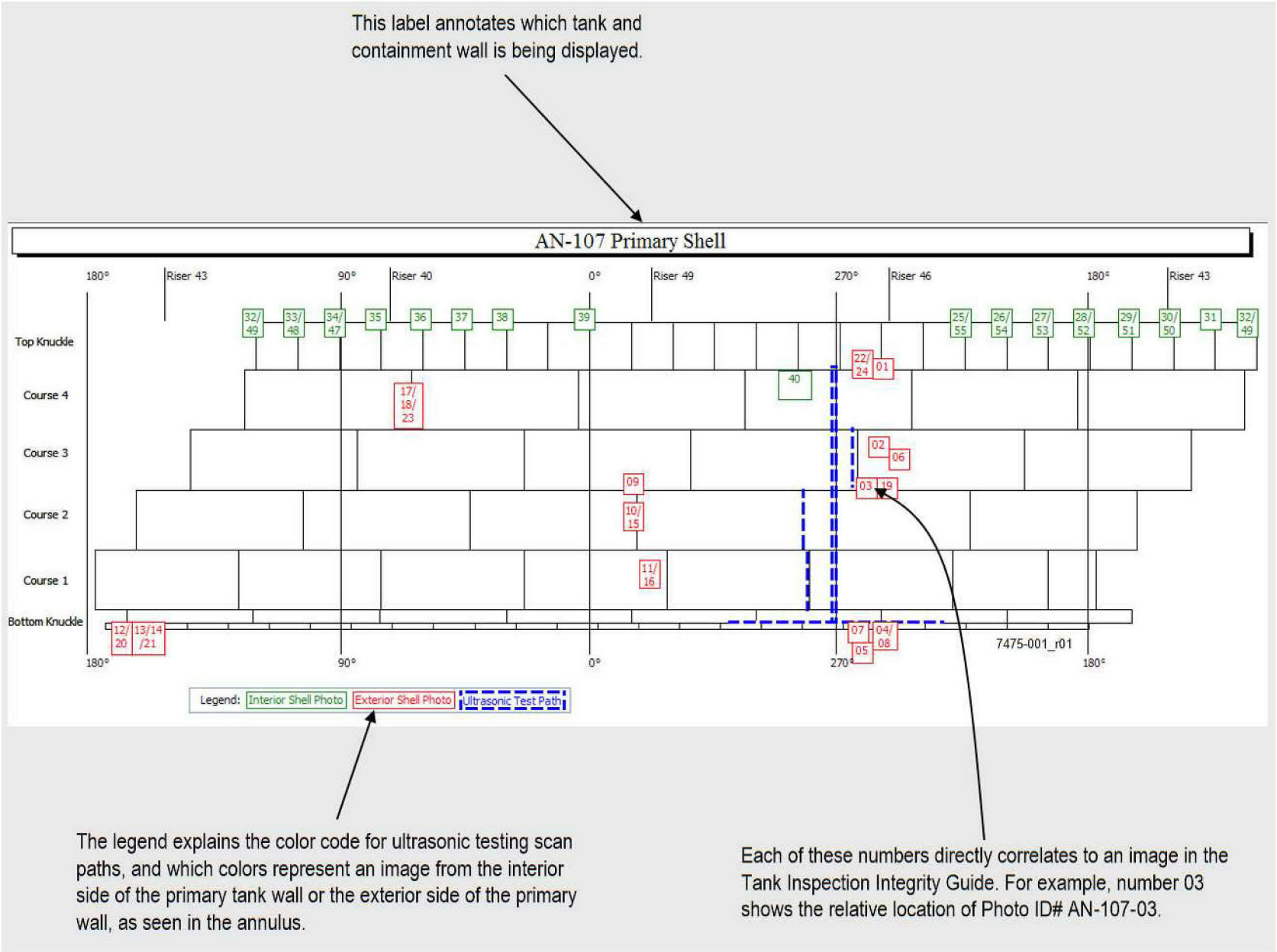


Figure 4-2. Tank AN-107 Integrity Inspection Map Example.

The **Photo ID** is the number used to identify the picture and relevant data. The first five characters (e.g., AN-107) identify which tank the photo is from, while the last two digits of this number (e.g., 03) are used to correlate this entry with the Tank Integrity Inspection Map.

Date of Inspection lists the date the visual inspection was performed.

Date of Review lists the fiscal year an inspection report commented on this region.

Photo ID	AN-107-03
Date of Inspection	5/19/1992
Date of Review	FY2006
Location	Exterior of primary tank shell, along Courses 3 and 2, joining bottom edge of primary shell plate F7301M2 number 5A and primary shell plate F7301M2 number 5B, Riser 46.
Description	DVDID# 10258 Corrosion along circumferential weld joining Course 2 and 3. Noticeable corrosion product directly above weld continues up to Course 1. Possible surface condensation on the outside of primary shell has accelerated corrosion along this area

The **Description** and **Location** fields give a verbal description of the area of interest and how to locate it, respectively. The DVDID# is the reference number used to identify the DVD from which the photo was taken. The number represents the number of the DVD stored in the Visual Inspection Archive.

7475-002_r01

Color photo of area of interest

Shipping Mark	*Heat #*	*Ingot & Cut*	*Nominal Thickness*	*Nominal Length*	*Nominal Width*
F7301M2	3G5922	0400C	0.500	471.25	92.75
F7301M2	3G5922	0600C	0.500	471.25	92.75

Details indicate wall plate data taken from the Certified Material Test Reports.

Figure 4-3. Tank AN-107 Integrity Inspection Guide Example.

The TIIGs for each tank farm are compiled into a single document and updated within a calendar year from when a tank primary or annulus inspection is conducted as follows:

- 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-39149, *Double-Shell Tank Integrity Inspection Report for 241-SY Tank Farm; and*
- RPP-RPT-42147, *Double-Shell Tank Integrity Inspection Report for 241-AW Tank Farm.*

The DST integrity assessment reports differentiate between general (uniform) corrosion at tank surfaces in contact with waste and, general (uniform) corrosion at tank surfaces in contact with the atmosphere in the interior of the primary tank and annulus region. The DST integrity assessment reports consider both to be potentially significant.

The WRPS proposed an enhanced visual inspection in WRPS-1204931, "Double-Shell Tank 241-AY-102 Primary Tank Leak Extent of Condition Evaluation and Recommended Annulus Visual Inspection Intervals" (Washenfelder 2012), which recommended increased annulus visual inspection frequencies for all 28 DSTs, varying from annually to once every three years, following completion of a greater than or equal to 95 percent inspection of the viewable area in the annulus. The frequency depends on the extent of similarity between the tanks construction and operating histories and those of Tank AY-102. This information was transmitted to ORP in WRPS-1302595, "Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Recommended Modifications to Double-Shell Tank Visual Inspections" (Clark 2013).

4.2 LEAK INTEGRITY

In addition, to the visual inspection used for leak integrity the DSTs are equipped with liquid level detecting instruments. The DST liquid levels in the primary tank are monitored daily using Enraf® surface level gauges. Leak detection probes in the DST annuli are routinely monitored. The primary tank surface level Enraf and the three annulus leak detection on Enrafs make up the Ecology-approved leak system (Consent Decree 2010).

4.3 ULTRASONIC TESTING EXAMINATION OF DOUBLE-SHELL TANK PRIMARY TANK SIDEWALLS

The DSTIP uses UT with remote robotic crawlers to examine the DST primary tank sidewalls for thinning, pitting, and cracking. This type of inspection provides a volumetric examination of the metal examined. The examinations are performed using a magnetic crawler that holds the transducers to conduct the examination.

The crawler used during most Pulse-echo ultrasonic inspection (P-scan™) imaging is shown in Figure 4-4. The traveling bridge on the crawler can be outfitted with various ultrasonic transducer configurations. The crawler system is deployed through a 24-in. annulus inspection riser using customized deployment tools. Water is used as the couplant (to maintain contact between the transducer and metal) and is continuously fed to all transducers at a rate needed to maintain an acceptable signal.

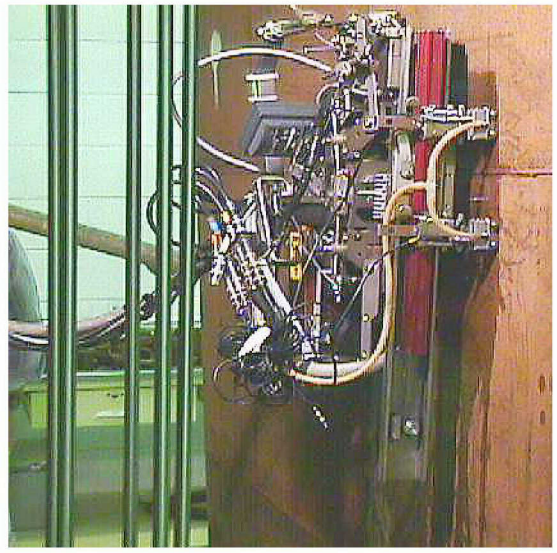


Figure 4-4. P-scan Crawler System on Tank Mockup.

The P-scan system is manufactured by FORCE Technology. The device acquires data from zero and angle beam transducers mounted on the crawler. FORCE Technology has designated "P-scan mode" to represent the angle beam (flaw length) view and "T-scan mode" to represent the zero beam (thickness) view. T-scan mode is used for normal operation and, if crack-like indications are detected, then the P-scan mode is employed.

During normal T-scan and P-scan operations, the waveforms of the reflected sound wave signals for each transducer are displayed in the "A-scan monitoring mode." The A-scans are primarily used to verify that the transducers are functioning properly (e.g., proper probe contact, adequate water flow, and correctly operating transducer cables). When an indication is detected, the area is rescanned using the "A-scan recording mode."

4.3.1 Ultrasonic Testing Inspection Performance

Ultrasonic examinations of the 28 DSTs are carried out as follows:

- Entrance to the annulus is made through two risers, and the same two risers are revisited every cycle to allow comparison and accurate wall loss estimates.
- Four 15-in. wide vertical scans of the primary tank wall 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 HAZ for all DSTs.
- A 20-ft length of vertical weld joining shell plate courses of the primary tank is scanned, 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 in the vertical portion of the primary tank wall corresponding to a static liquid/vapor interface level that existed for any five-year period, extending at least 1 ft above that liquid/vapor interface.
- A 20-ft long circumferential scan is performed of the predicted maximum stress region of the primary tank lower knuckle for selected DSTs.

The TSIP guidelines criteria for thinning, pitting, and cracking, and DSTIP reporting criteria are provided in Table 4-1.

A list of the UT test reports and a summary of the results are provided in Appendix F.

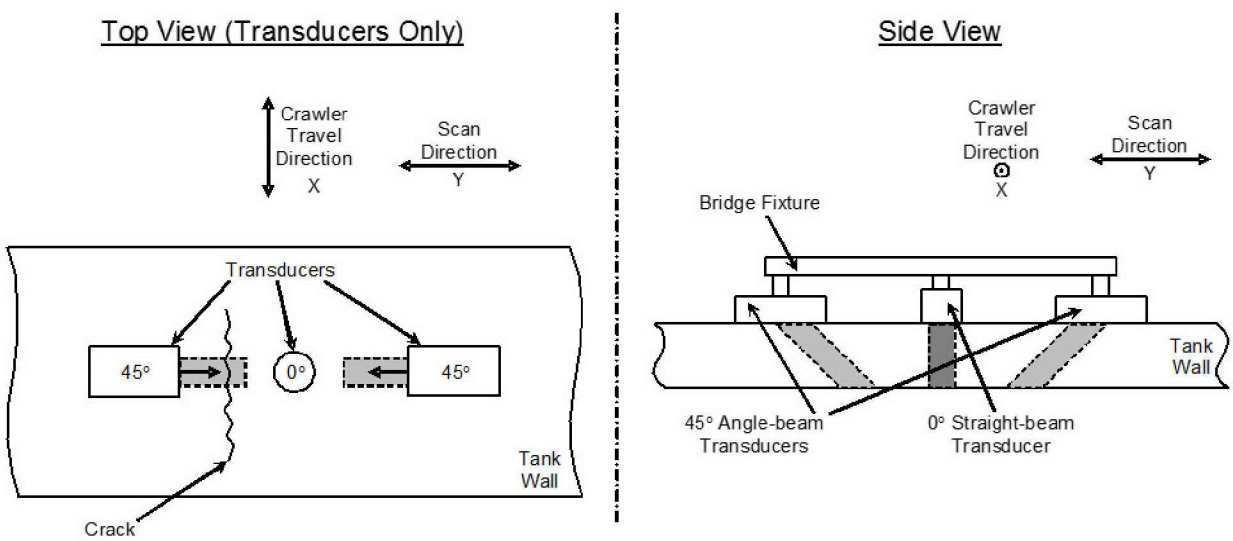
Table 4-1. Ultrasonic Testing Evaluation Guidelines and Reportable Values

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 Project.
TSIP = Tank Structural Integrity Panel.

4.3.1.1 Examination of Tank Walls and Knuckle

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 4-5.



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

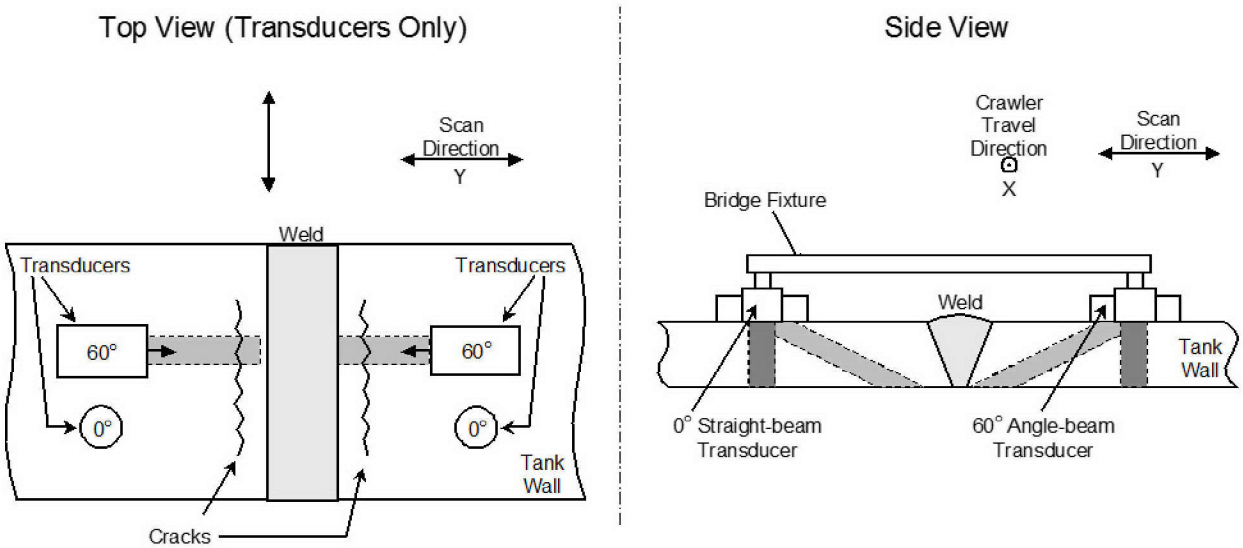
Figure 4-5. Ultrasonic Testing Setup for Vertical Wall Scan Inspections.

4.3.1.2 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 4-6). The examination of the HAZ using 60-degree angle beams does provide some coverage of the actual weld metal, through to the inside surface.

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 4-5).



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 4-6. Schematic of Ultrasonic Testing Setup for First Pass of Weld Inspections.

4.3.2 Tandem-Synthetic Aperture Focusing Technique

Structural analysis indicates that the most highly stressed region of the lower knuckle, which would be most susceptible to SCC, is from the middle to lower part of the knuckle. The TPA Milestone M-48-02 series required the development of technology for examining the lower knuckle. The flexible extended arm for the AWS-5d crawler was selected, tested, and then deployed in FY 2002. Also, during FY 2003, technology development was completed for the Tandem-Synthetic Aperture Focusing Technique (T-SAFT) for lower knuckle examination. The T-SAFT was successfully deployed and used for knuckle examination starting in December 2002. The performance demonstration test has been completed for this system for the Level III Inspector using the Y-arm adapter for the crawler.

Pacific Northwest National Laboratory (PNNL) conducted feasibility testing for the T-SAFT (PNNL-15136, *Feasibility Test Report SAFT/T-SAFT Scanning on the Curved Knuckle of Hanford's Double Shell Tanks*), which produced results that support the use of T-SAFT for examination of the curved knuckle region. The most highly capable transducer configuration was the 45-degree shear wave. This 45-degree inspection can detect smaller flaws than 60- and 70-degree transducers. Therefore, a flaw as small as 0.025 in. deep can be detected, but it is sized at 0.13 in. This size is considered to be a marked improvement over the previous design, which detected flaws as small as 0.006 in. and sized them at almost 0.25 in.

The T-SAFT performance demonstration test (PNNL-14072, *Annual Report: Remotely Operated NDE System for Inspection of Hanford's Waste Tank Knuckle Regions and Development of a Small Roving Annulus Inspection Vehicle T-SAFT Scanning Bridge for Savannah River Site Applications*) showed that the Level II NDE technician could dimension linear indication in the knuckle region with a high-confidence level to a depth of 180 mil. This depth is essentially the same value required by BNL-52527/UC-406 of 0.2 nominal wall thickness (175 mil) for the 7/8-in. plate in the lower knuckle.

4.3.3 Nondestructive Testing Improvements

The DSTIP has two new methods of examination of the DSTs under development and plans to explore techniques for the examination of the tank bottoms. The deployment of these technologies has the goal of improving knowledge of tank integrity. With this better knowledge, the DSTIP can develop better information about the risk of continued use of the DSTs and better inform the RPP of the need for replacement of DSTs.

4.3.3.1 Electromagnetic Acoustic Transducers

Electromagnetic Acoustic Transducer (EMAT) has been under development since 2003 as a Tank Focus Area task. A blind performance test was performed using the EMAT guided wave tool on the double-walled storage tank mockup at PNNL. The test was generally successful in finding the known flaw features in the steel and achieved the desired sensitivity to meet the specification; however, no system optimization was performed. One of the conclusions was that the EMAT transducers could be retrofitted onto the existing FORCE Technology scanner as a supplemental inspection to the P-Scan system. The goal for EMAT implementation within the DST NDE program is to become a supplemental inspection technology to the current P-Scan UT inspections being deployed in the DSTs with the ability to inspect additional plate material at accelerated rates in the same insertion cycle. Additional details related specifically to the testing and implementation of EMAT into the DSTIP are provided in RPP-RPT-58473, *Implementation Strategy for Electromagnetic Acoustic Transducer System into DST Non-Destructive Examination Program*.

In February 2014, a contract was placed with PNNL to develop an EMAT system to enhance the DST NDE program capability. Procurement of the EMAT system consisted of an integration effort between Innerspec Technologies Inc., FORCE Technology, Adaptive Energy, and AREVA Federal Services LLC. Innerspec Technologies supplied the EMAT system, while Adaptive Energy performed the physical integration of the EMAT system into the existing FORCE Technology magnetic crawler. The fully integrated system was delivered to PNNL where system acceptance testing was conducted in parallel with qualification of NDE technicians and operators.

Use of the EMAT technology offers faster scanning rates and the capability of inspecting without the addition of water to the annulus. The EMAT technology allows for rapid scanning of large areas of steel plate to detect pitting, thinning, or cracking. The EMAT device induces a signal into the plate, as it scans, and, unlike UT, the EMAT device does not require surface preparation (e.g., rust or scale removal) to obtain good results.

In August 2014, the HIAP made recommendations for improvement of the DST integrity program (RPP-ASMT-57582). One of the recommendations made by the panel suggested prioritization of NDE efforts to the primary tank bottom. The initiation of a new inspection

program will consume limited DSTIP resources. As a result, the future of the Hanford Site DST integrity program may see added stress to complete P-scan UT inspections of the primary tank wall as a focus is placed on the tank bottoms. However, with implementation of a NDE tool, such as EMAT, the DST NDE program will possess a means of establishing confidence in DST integrity by looking at more plate area at accelerated inspection speeds. Accelerated inspection speeds will allow more time to focus on tank bottom NDE efforts without compromising the collection of valuable primary tank wall integrity data.

4.3.3.2 Phased Array Ultrasonic Testing

Phased Array Ultrasonic Testing (PAUT) has been developed throughout the industry. The DSTIP is assessing its use on DST weld and HAZ inspections. In February 2014, a contract was placed with PNNL to procure and evaluate a PAUT system to enhance the DST NDE program's capability. The P-scan stack system manufactured by FORCE Technology was selected for evaluation and testing. As part of the procurement of the EMAT system, WRPS also acquired a PAUT capability, but resources necessary to support system evaluation/testing were unavailable at the time of delivery of the system. In the fourth quarter of FY 2015, PNNL hosted a week-long on-site training class provided by FORCE Technology specific to the P-scan stack system. Future efforts related to PAUT and its implementation into the DST NDE program will continue in FY 2016.

4.3.3.3 Tank Bottom Inspections

Discovery of the first failed DST at the Hanford Site highlighted an integrity monitoring weakness in the DSTIP. Current NDE inspection methodology has not revealed the specific Tank AY-102 failure mechanism. Follow-up extent-of-condition construction research of the remainder of the DSTs, combined with analysis of current monitoring capabilities, identified the need to further develop the integrity program and add the capability to inspect the primary tank bottom of DSTs for trending degradation.

Access is limited, but prior attempts have been made to use the refractory pad air slots as a point of access to the primary bottom plate for inspection, with limited success (RPP-RPT-58525, *Remote Ultrasonic Testing and Inspection of Double-Shell Tank Air Slots with a Robotic Crawler (1999-2003*). Tank configuration variations and construction conditions present several access challenges that will need to be overcome in future crawler and sensory device design. In July 2015, the TIEP reiterated the prior recommendation made by the HIAP, which was to prioritize the acquisition of technology to enable NDE of the primary tank bottom.

4.4 INSPECTION DATA REVIEW

Data collected as part of the DSTIP requires review by one of the integrity leads or their designee prior to release. Should the lead deem that the data needs further review the Integrity Data Review Team (IDRT) shall be convened. The IDRT shall consist of the Chief Engineer, the Manager of Tank and Pipe Line Integrity, and the 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 shall be documented by a technical evaluation, unless directed by the Chief Engineer to perform another type of documentation.

5.0 CORROSION CONTROL

Washington River Protection *Solutions*, LLC controls the corrosion in the DSTs by ensuring there is a sufficient concentration of chemical species to inhibit the aggressive species present. The Operating Specifications Document (OSD-T-151-00007) requires that the waste be maintained within specification for hydroxide and nitrite concentration for a given nitrate ion concentration.

The *Tank Farms Waste Transfer Compatibility Program* (HNF-SD-WM-OCD-015) is a safety program that provides a formal process for evaluating waste transfers and chemical additions through the preparation of documented waste compatibility assessments. The primary purpose of the program is to ensure that sufficient controls are in place to prevent the formation of incompatible mixtures as the result of waste transfer operations. The program defines a consistent means of evaluating compliance with administrative controls, safety, operational, regulatory, and programmatic criteria and specifies considerations necessary to assess waste transfers and chemical additions.

To ensure compliance with OSD-T-151-00007, the DSTs are sampled in accordance with RPP-7795, *Technical Basis for the Chemistry Control Program* and RPP-8532, *Double-Shell Tanks Chemistry Control Data Quality Objectives* to identify those tanks that are either out of specification or approaching specification boundaries. These documents require that all DSTs be sampled on a periodic basis, dependent on the tank chemistry. The management of tank chemistry for corrosion is shown in Figure 5-1.

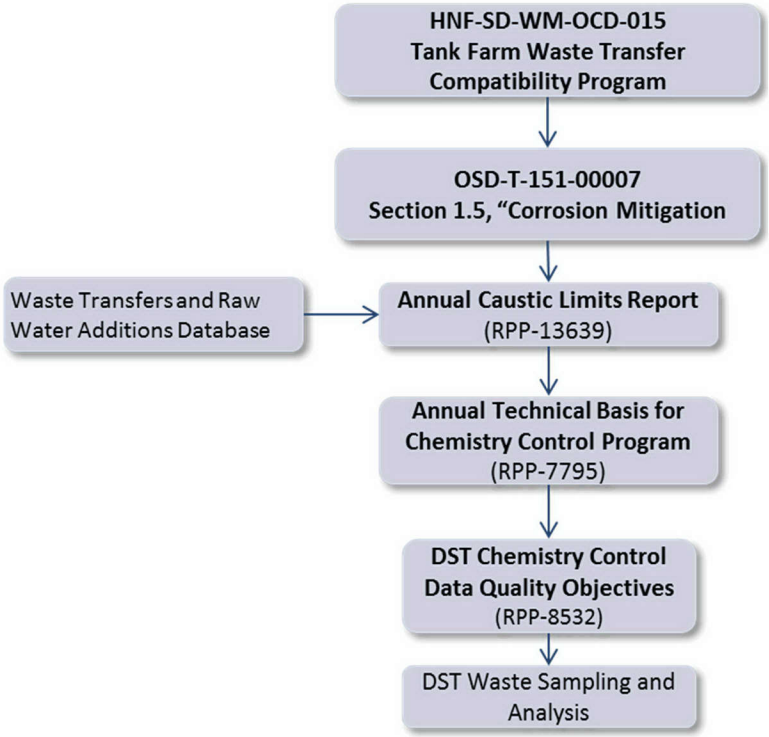


Figure 5-1. Corrosion Mitigation Logic Diagram.

Chemical changes can occur during waste storage. Hydroxide concentrations in tank waste are affected by ongoing chemical reactions with organics in the waste and carbon dioxide in the vapor space. These reactions generally deplete the free hydroxide concentration with time. Reaction rates for these hydroxide consumption mechanisms increase with increasing temperature. Hydroxide depletion caused by reaction with carbon dioxide is generally more pronounced near the waste surface. DST chemistry controls are specified in terms of limits on nitrate, nitrite, and hydroxide concentrations per OSD-T-151-00007 as shown in Table 5-1.

Table 5-1. Waste Chemistry Limits.

For $[NO_3^-]$ range	Variable	For waste temperature (T) range		
		T < 167 °F	167 °F ≤ T ≤ 212 °F	T > 212 °F
$[NO_3^-] \leq 1.0M$	$[OH^-]$	$0.010M \leq [OH^-] \leq 8.0M$	$0.010M \leq [OH^-] \leq 5.0M$	$0.010M \leq [OH^-] < 4.0M$
	$[NO_2^-]$	$0.011M \leq [NO_2^-] \leq 5.5M$	$0.011M \leq [NO_2^-] \leq 5.5M$	$0.011M \leq [NO_2^-] < 5.5M$
	$[NO_3^-] / ([OH^-] + [NO_2^-])$	< 2.5	< 2.5	< 2.5
$1.0M < [NO_3^-] \leq 3.0M$	$[OH^-]$	$0.1 ([NO_3^-]) \leq [OH^-] < 10M$	$0.1 ([NO_3–]) \leq [OH–] < 10M$	$0.1 ([NO_3^-]) \leq [OH^-] < 4.0M$
	$[OH^-] + [NO_2^-]$	$\geq 0.4 ([NO_3^-])$	$\geq 0.4 ([NO_3–])$	$\geq 0.4 ([NO_3^-])$
$[NO_3^-] > 3.0M$	$[OH^-]$	$0.3M \leq [OH^-] < 10M$	$0.3M \leq [OH–] < 10M$	$0.3M \leq [OH^-] < 4.0M$
	$[OH^-] + [NO_2^-]$	$\geq 1.2M$	$\geq 1.2M$	$\geq 1.2M$
	$[NO_3^-]$	$\leq 5.5M$	$\leq 5.5M$	$\leq 5.5M$

Carbon steel corrosion testing was performed at the Savannah River National Laboratory on SRS waste, documented in DP-1478, *Prediction of Stress Corrosion of Carbon Steel by Nuclear Process Liquid Wastes*, and at PNNL on simulated waste stored in Hanford Site tanks, documented in PNL-5488, *Prediction Equations for Corrosion Rates of A-537 and A-516 Steels in Double Shell Slurry, Future PUREX, and Hanford Facilities Waste.* The results of this testing led to the establishment of the present waste chemistry controls to minimize DST corrosion and the risk of tank failure because of general corrosion, pitting, or stress corrosion cracking.

5.1 CORROSION TESTING

The chemistry control limits are determined from testing conducted to investigate SCC, pitting, and vapor space corrosion (VSC). 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 on understanding the pitting corrosion in the DSTs and developing a protocol to allow a new specification to be developed.

5.1.1 Stress Corrosion Cracking

Although there may be some risk for pitting in these mixed tank environments, results do not imply that these mixed chemistries pose any significant threat for SCC except at low pH (11.0), high temperature (60 °C), high plastic strain, and high potential (0 mV versus saturated calomel electrode [SCE]). These conditions are unlikely to develop during normal DST operations.

Table 5-2. 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

Specifications for minimization of the threat of SCC in the DSTs are listed in Table 5-2 and documented in RPP-RPT-47337, *Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*. The wastes in these tanks

have cooled significantly since the present chemistry control limits were first adopted, which provides an opportunity for the adjustment of the controls without compromising the integrity of the waste tanks.

5.1.2 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 testing is used. The first electrochemical test used is the cyclic potentiodynamic polarization (CPP) test (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 or if additional testing is necessary. The second electrochemical test used is the Tsujikawa Hisamatsu Electrochemical (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 potential necessary to repassivate a growing pit and thereby determine the practical pitting risk.

Pitting corrosion testing for Hanford Site tanks gained strength in 2004 and 2005 with a series of tests conducted in Argentina, as documented in *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 at the present tank waste compositions and temperatures. 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 testing is completed using that protocol.

Testing in FY 2013 through FY 2015 focused largely on evaluating 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 and anticipated waste chemistries at a variety of temperatures. This testing is required to support returns from the Direct-Feed Low-Activity Waste System, Low-Activity Waste Pretreatment System (LAWPS), Waste Treatment and Immobilization Plant (WTP), and SST retrievals. These streams contain concentrations and ratios of both aggressive species and inhibitors not evaluated when the current operating specification limits were established.

5.1.3 Vapor Space Corrosion Testing

Concern for DST VSC arose from notable VSC in some SRS tanks and some apparent VSC tank wall thinning at the Hanford Site. An expert panel workshop was held in July 2006 to discuss VSC and LAI corrosion of DSTs at the Hanford Site and SRS (RPP-RPT-31129). The recommended approach to the investigation of the phenomenon started with a literature search,

followed by thermodynamic modeling of species present in the vapor that deposit on the tank surface.

In FY 2007, 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*). Savannah River National Laboratory 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." The completion of this work has been delayed because of uneven funding for DSTIP.

As such, a VSC program is underway 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; and
- 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).

5.1.4 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 ten LDPs have been subject 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 was conducted in FY 2014.

Total immersion testing, VSC testing, and LAI testing using LDP and ground water simulants were performed (SRNL-STI-2014-00616, *Hanford Double Shell Waste Tank Corrosion Studies – Final Report FY2014*). 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 five to 10 mil/yr. The LDP testing is complete.

Corrosion testing has shown that exterior corrosion because of constant moisture is the biggest threat to secondary liner integrity. In FY 2015, UT scans of the secondary liner floor became a standard requirement during all annulus UT inspections. At the end of FY 2015, three tanks showed areas of secondary liner thinning via the UT scans: Tanks AN-103, AN-104, and AP-102. These three tanks had not been subject to LDP water accumulation. To minimize secondary liner exposure to moisture, maximum authorized LDP levels are specified in

OSD-T-151-00007, and the LDPs are pumped before they reach those levels. UT scans of the secondary liner will also continue to monitor the wall loss of secondary liners.

5.1.5 Waste Corrosion Potential Measurement

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 wall in the knuckle-region of the DST where the sludge is in contact with the wall. Sample collection, sample extrusion, and the electrochemical corrosion testing are performed while maintaining the waste under anaerobic conditions, like those found in 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 under tank storage conditions. The CPP measurements can be performed to evaluate the propensity of the steel undergoing pitting in the waste environment.

5.2 CORROSION MONITORING IN DOUBLE-SHELL TANKS

Washington River Protection *Solutions*, LLC uses corrosion probes and coupons to evaluate the corrosion threat in the DSTs. The probes monitor the electrochemical potential between the tank and reference electrodes. In addition, coupons have been installed, which are forensically examined for the presence of corrosion. Removal of these probes occurs either periodically or when there is an indication of corrosion from another source.

In 1996, under a DOE technology initiative, the Tank Operations Contractor launched an effort to improve the Hanford Site DST corrosion monitoring program. Proof-of-principle testing conducted at Oak Ridge National Laboratory and PNNL for the initial corrosion monitoring systems developed under this program is documented in WHC-SD-WM-TI-772, *Technical Basis for Electrochemical Noise Based Corrosion Monitoring of Underground Nuclear Waste Storage Tanks*. A three-channel prototype corrosion probe was designed, constructed, and deployed in Tank AZ-101 in August 1996 based on these studies.

Six similar corrosion monitoring systems were installed in Hanford Site DSTs over the next ten years based on the successful operation of the prototype system. These systems were first of a kind instruments that implemented the electrochemical noise and linear polarization resistance techniques to monitor the onset of SCC and pitting (should they occur) and uniform corrosion rate in real-time in the DSTs. These systems proved to be difficult to maintain and operate on a long-term basis. None of these original systems shown in Table 5-3 are still in service.

Table 5-3. Inactive Double-Shell Tank Corrosion Probe Installations

Number	Tank	Dates in tank[a]	Design
1.	AZ-101	August 1996	Prototype Electrochemical Noise System
2.	AN-107	September 1997 to August 2001	First-generation full-scale Electrochemical Noise System, which was removed in August 2001 and was forensically examined.
3.	AN-102	August 1998	Second-generation full-scale Electrochemical Noise System.
4.	AN-105	January 2000	Third-generation full-scale Electrochemical Noise System.
5.	AN-104	January 2001	Fourth-generation full-scale Electrochemical Noise System.
6.	AN-107	August 2001 to September 2006	Fourth-generation full-scale Electrochemical Noise System, which was removed in September of 2006 and was forensically examined.
7.	AN-107	September 2006 to August 2012	Integrated multi-function corrosion probe, with electrochemical resistance, linear polarization resistance, electrochemical noise, and reference electrodes. This probe was removed and forensically examined in 2012.

[a] Probes without removal dates are still in the tank and will remain in the tank.

In 2007, the design and purpose of the DST corrosion monitoring systems were revised to improve reliability and data quality. The resulting design, 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 (via electrochemical resistance sensors), and coupon weight-loss data. The MPCMS uses a long fixed probe to locate electrodes at various elevations in the DST. The MPCMS also contains removable coupon racks that can be pulled for analysis without removing the fixed probe.

The first MPCMS was installed in Tank AN-102 in 2008. Four additional systems of similar design were installed by the end of 2010, with a replacement system in Tank AN-107. Data is being collected from the five MPCMSs, but many of the probes are not operational. The corrosion data obtained from the probes is updated quarterly in RPP-RPT-51766, *Corrosion Probe Monitoring Systems: July, August, & September 2014 Quarterly Report*.

The MPCMS first contained a variety of primary reference electrodes (e.g., SCEs, silver/silver-chloride electrodes, copper/copper-sulfate electrodes) for use in making corrosion potential measurements. With the installation of Tank AY-101 and Tank AN-107 replacement probes, the design evolved to using just silver/silver-chloride reference electrode and the copper/copper-secondary electrodes, along with tank material reference electrodes. These probes were selected because they were the most stable in tank conditions. The MPCMS also contains electrochemical resistance sensors in each waste layer in the tank.

The MPCMS design has proven to be expensive to fabricate and install and, more importantly, does not facilitate troubleshooting, repair, or replacement of in-tank components in the event of failure. As discussed in RPP-RPT-51766, many of the probes have failed because of fabrication and installation errors. Finally the removal of the corrosion coupons is an expensive and dose intensive operation.

In response to these challenges, a new corrosion monitoring system design, known as the retractable corrosion monitoring probe (RCMP), was developed in 2012. The mechanical design

of the RCMP is significantly different than the previous DST corrosion monitoring systems, using a cable reel and retractable replaceable probe head instead of a long fixed probe to position a set of reference electrodes at various elevations in the tank. The RCMP is designed to be installed only in the supernatant (or possibly into the top of the sludge layer) in the tank.

The RCMP probe head is not heavy enough to penetrate a substantial distance into the sludge. However, since work sponsored by the EPOC has demonstrated that it is possible to measure DST corrosion potential from any elevation within the waste, the probe head does not need to penetrate into the sludge to obtain accurate information about the propensity for corrosion in the tank. The reports documenting this analysis and the EPOC assessment of the work are RPP-RPT-51764, *Boundary Element Analysis of Corrosion Potential Distribution in Hanford Waste Tanks* and RPP-ASMT-56781, respectively. The first RCMP was installed in Tank AW-105 in August 2013 and the second was installed in Tank SY-101 in July 2014. Table 5-4 summarizes the DSTs with installed corrosion monitoring systems.

Table 5-4. Active Double-Shell Tanks Corrosion Probe Installations.

Tank	Date installed	Probe type specification[a]	At risk for SCC?	Corrosion (mil/yr)
AN-102	May 2008	MPCMS RPP-SPEC-32496	No	<< 1
AY-102	March 2009	MPCMS RPP-SPEC-35429	No	<< 1
AY-101	April 2009	MPCMS RPP-SPEC-38427	No	<< 1
AN-107	June 2010	MPCMS RPP-SPEC-35672	No	<< 1
AW-104	July 2010	MPCMS RPP-SPEC-43207	No	<< 1
AW-105	August 2013	RCMP RPP-SPEC-49792	No	N/A
SY-101	July 2014	RCMP RPP-SPEC-49792	No	N/A

[a] Full references are provided in Section 11.0.

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

5.2.1 Electrical Resistance

In the case of general corrosion, the electrochemical resistance is the most common technique used to monitor corrosivity. The technique can be used in air, liquid, or at the LAI. This technique operates by measuring the change in electrical resistance of a metallic element immersed in solution relative to a reference element sealed within the probe body. Since temperature changes can have an effect on the resistance of both the exposed and protected element equally, measuring the resistance ratio minimizes the influence of changes in the ambient temperature. Therefore, any net change in the resistance ratio is solely attributable to metal loss from the exposed element once temperature equilibrium is established.

5.2.2 Reference and Surrogate Reference Electrodes

The DSTIP has undertaken a program to find surrogate reference electrodes to measure the open circuit potential (OCP), also known as the free corrosion potential (E_{corr}) in the DSTs. Laboratory testing has shown a strong correlation between the value of the OCP/E_{corr} and the propensity for pitting and cracking corrosion by waste simulants. Safe regions of E_{corr} values are known, and as such, the ability to measure the OCP/E_{corr} in DSTs is a key function of the monitoring program. The typical approach to measuring the OCP/E_{corr} is to monitor potential in a chemical environment versus a reference electrode.

6.0 STRUCTURAL INTEGRITY

Washington River Protection *Solutions*, LLC has two elements that assess the structural integrity of the DSTs: (1) the dome load program and structural analysis. The dome load program measures the tank dome elevations to monitor any changes.

The structural analysis assessed the structural integrity of the DSTs using a modern finite analysis. This assessment evaluated the integrity of the tanks through 2028.

6.1 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 if 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-151-0007, 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 6-1 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 6-1. 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 11.0.

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 tank farm hazardous facilities. The procedure identifies the requirements for compliance with vehicle or related equipment dome load impacts in tank farm hazardous facilities, requirements for bringing a vehicle or dome loads into tank farm facilities, and identifies personnel responsibilities associated with vehicle movement or dome loads.

The surveys are performed on a frequency of no more than three 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 (0.25 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*.

6.2 LOADING CONDITIONS AND STRUCTURAL ANALYSIS

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, but DOE considered it prudent to update the seismic guidelines for existing tanks to ensure compliance with current requirements. As noted previously, the DOE employed BNL to develop methodology of performing structural analysis of existing tanks, which was documented in BNL-52361.

These guidelines provided recommendations on structural analysis methodology, which were used in the Hanford Site structural evaluation criteria that specifies the loads required for verification of structural adequacy of tanks. The site-specific evaluation criteria are found in WHC-SD-WM-DGS-003 and specify many load combinations and the allowable stresses for each load combination that must be considered.

Finite element analysis (FEA) models have been used to represent the reinforced concrete and steel-plate structural components of the DSTs. The FEA models are used to 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 analysis 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.

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. The analysis of record for TOLA and

seismic loads considering the increased waste level in AP Farm tanks is documented in RPP-RPT-32237.

6.3 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 6-1 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 4-2. 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 will be reassessed in the future to raise the fill height.

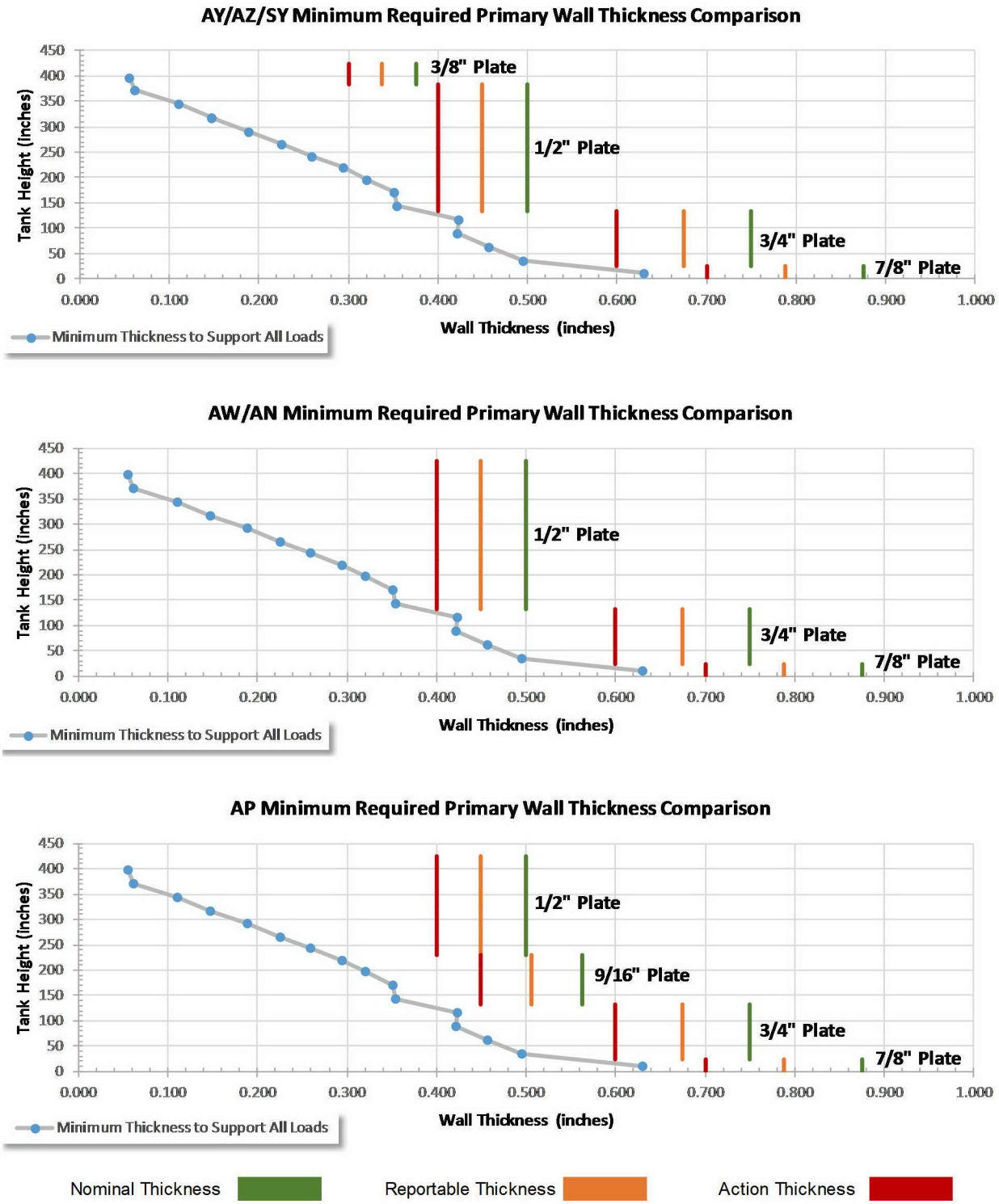


Figure 6-1. Analysis of Minimum Wall Thickness for Structural Integrity.

7.0 WASTE TRANSFER SYSTEM

The DST waste transfer system conveys waste between the tanks and process facilities. All waste transfer lines are designed with a secondary containment system capable of detecting and collecting releases and accumulated liquids in the event of a primary line failure. The waste transfer system includes pump pits, valve pits, pumps, jumpers, valves, actuators, piping, and hose-in-hose transfer lines within the DST farms.

7.1 PUMP AND VALVE PITS

A typical central pump pit consists of a waste transfer pump, a jumper connecting the pump discharge to the pit wall nozzles, a drain, and leak detection. The valve pits consist of multiple jumpers, a drain, and leak detection. The waste transfer pumps in the DST System are vertical turbine pumps with rigid intake and submersible pumps.

The central pump pits and valve pits must be cleaned and have their coatings re-inspected by a qualified National Association of Corrosion Engineer (NACE) International coating inspector at the following periodicities for the pits (RPP-RPT-58441):

- Pits/vaults with polyurea coatings: Every 15 to 18 years.
- Pits with epoxy paint coatings: Every 10 to 12 years or after work activities associated with the pit as described below, whichever is shorter. Note that NACE inspections to support work activities in a specific portion of a pit do not automatically trigger an inspection of the entire pit (i.e. Full Inspection per TO-040-050), but ensure that the applicable work area effected within the pit (i.e. Partial Inspection per TO-040-050) is left in a compliant state. Only Full Inspections per TO-040-050 reset the inspection to the next due date.
    - Manned entries into a pit
    - Equipment installation or removal (e.g. jumper, pump, blank/seal removal and installation).
    - Placing equipment on the pit floor
    - Work activities that are identified by the field crew which potentially compromised the integrity of the existing coating (e.g. dropping a tool into a pit).
- Vaults with epoxy paint coatings: Every 12 to 14 years.
- Pits/vaults with stainless steel liners: Every 15 to 20 years.

The schedule for pit inspections and pressure testing is included in the project baseline.

7.2 JUMPERS

Jumpers are located inside concrete pits that are designed to contain and detect a leak in the event of a jumper failure (Figure 7-1). The jumpers are connected to nozzles within the pits, thereby directing the waste to different locations. Jumpers are attached to the wall nozzles via plutonium-uranium extraction (PUREX) connectors. These connectors provide the clamping force to maintain a seal between the connector block and the nozzle.

Figure 7-1. Jumpers in Valve Pit.

The rigid jumpers in the DST System are either carbon or stainless steel. Older jumpers installed as part of the original DST construction are typically ASTM A53/A 53M (*Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*), Type S, Grade B, Schedule 40 carbon steel.

The jumpers were designed and fabricated in accordance with ASME B31.1, *Power Piping* or ASME B31.3, *Process Piping*. New rigid jumpers are typically ASTM A312/A312M, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes,* GR Type 304L stainless steel, and designed and fabricated in accordance with ASME B31.3.

Flexible jumpers found in the DST System can be either metallic or nonmetallic material. Metallic flexible hose has a corrugated hose section typically ASTM A240/A240M, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*, Type 316L and hose braiding typically ASTM A580/A580M, *Standard Specification for Stainless Steel Wire*, Type 304L. The non-metallic flexible hose is made of ethylene propylene diene monomer.

7.3 VALVES AND ACTUATORS

The Waste Transfer System uses primarily 2-way or 3-way ball valves. Both T-port and L-port valve configurations are used for the 3-way valves. Valve positioning is achieved by valve stops, T-handle, or gear actuator.

7.3.1 Double-Valve Isolation Valves

In the Waste Transfer System, 2- and 3-in. ball valves for double-valve isolation (DVI) provide a barrier to physically disconnect interfacing systems and inactive portions of the system from the active portion during a waste transfer. Leakage past the ball valve seats must be limited to mitigate potential chemical or radiation exposure because of leaked fluid. For DVI valves, leakage is limited to less than or equal to 0.1 gal/min throughout the service life of the valve.

During 2011 and 2012, DVI valve cycle testing was performed to determine the service life impact of continuously cycling the valves exposed to simulated slurry waste transfer conditions.

Testing consisted of cycle tests, leak rate tests and pre- and post-test valve teardown evaluations according to RPP-PLAN-44556, *Simulant Test Plan for Safety Significant Isolation Valves for Double Valve Isolation*. Figure 7-2 illustrates the testing and evaluation sequence.

The test simulant represented the 75th percentile by volume of characterized Hanford Site waste particulate based on property comparisons. Valve surface abrasion properties given highest priority. Simulant degradation testing was performed and evaluation criteria developed to ensure that the simulant characteristics remained within acceptable performance boundaries. When necessary conditioning/replenishing of the simulant was performed to maintain its characteristics.

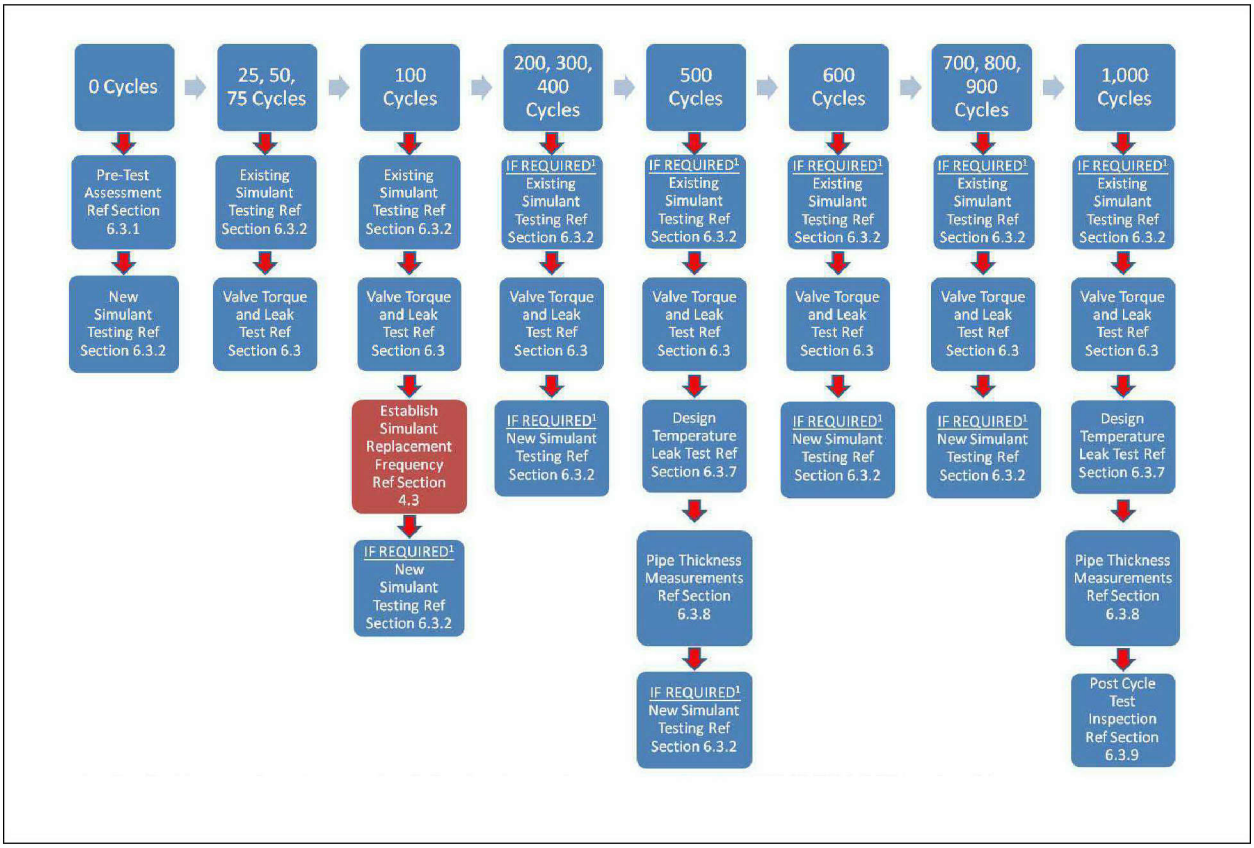


Figure 7-2. Double-Valve Isolation Valve Cycle Test Sequence.

The valves evaluated were manufactured by Pittsburgh Brass Manufacturing (PBM®), deployed in the 2- and 3-in. DST portion of the Waste Transfer System; and Bray International, Inc. (Flow-Tek®) 2-in valves deployed in the SST portion of the Retrieval/Closure Waste Transfer System. The valves were equipped with resilient seat materials of Tefzel®, Kynar®, and ultra-high molecular weight polyethylene (UHMWPE). The testing consisted of periodically measuring leak rates and maximum operational torques on the DVI valves after prescribed numbers of valve operational cycles in a flow loop representing the physical configuration of the Waste Transfer System. A valve operational cycle consisted of slurry flow, slurry gravity drain, flush water flow, and flush water gravity drain.

All test objectives were met for the PBM valves with Kynar seats and the Flow-Tek valves with UHMWPE seats. Because of torque limitations of the test setup, not all test objectives were completed for all of the PBM valves with Tefzel seats. In particular, the 3-in., 3-way PBM valves with Tefzel seats generated torques beyond the original specifications for the test setup.

The test results allowed predictions for design life to be made for all valves except the PBM 3-way valve with Tefzel seats. Based on the relatively low-leak rates obtained, the predictions for design life are limited by the number of operating cycles completed rather than any observed trend in the measured leak rates. Maximum leak rates for the seat materials tested as a fraction of the allowable leak rate of 0.1 gal/min are provided in Table 7-1.

Table 7-1. Double-Valve Isolation Valve Cycle Test Configuration Leakage.[a,b,c]

Valve configuration	Manufacturer	Seat material	Fraction of allowable leak rate	Test cycles completed
2 in., 2-way	Flow-Tek®	UHMWPE	0.03	1,000
2 in., 3-way	Flow-Tek®	UHMWPE	0.04	1,000
3 in., 2-way	PBM®	Kynar®	0.09	975
3 in., 2-way	PBM®	Tefzel®	0.04	500
3 in., 3-way	PBM®	Kynar®	0.25	500
3 in., 3-way	PBM®	Tefzel®	0.14	< 500

[a] RPP-RPT-41859, 2015, *Safety-Significant Isolation Valves for Double Valve Isolation - Functions and Requirements Evaluation Document*, Revision 7, Washington River Protection *Solutions*, LLC, Richland, Washington.
[b] RPP-RPT-54347, 2013, *Simulant Development for Hanford Tank Farms Double valve Isolation (DVI) Valves Testing*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.
[c] RPP-RPT-56061, 2013, *Tank Farms Double Valve Isolation (DVI) Cycle Test Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

PBM = Pittsburgh Brass Manufacturing.
UHMWPE = ultra-high molecular weight polyethylene.

7.4 DOUBLE-SHELL TANK SYSTEM TRANSFER PIPING

Waste Transfer System piping is a pipe-in-pipe design. The supernatant pipelines are 3-in., Schedule 40 primary pipe with a 6-in., Schedule 40 encasement, and the slurry lines are generally a 2-in., Schedule 40 primary pipe with a 4-in., Schedule 40 encasement. All of the pipelines were designed, fabricated, and installed in accordance with ASME B31.1 or ASME B31.3. The pipelines are either carbon-steel ASTM A53/A53M Type S Grade B or ASTM A106/A106M, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service* Grade B, or stainless-steel ASTM A312/A312M Type 304L primary pipe. The encasements are carbon steel.

All piping encasements feature a protective coating. Most have a factory-applied coal tar enamel and a sprayed polyurethane insulation. However, 14 of the pipelines in the DST System are installed with a special coating system considered waterproof, which eliminates the need for cathodic protection. The system consists of an epoxy coating bonded to the external surface of the encasement pipeline, a high-density foam layer covering the epoxy coating, and a protective

fiberglass reinforced plastic covering the foam. The design of the coating system was derived from the Steel Tank Institute's ACT-100™ specification for underground storage tanks installed without cathodic protection.

7.5 WASTE TRANSFER SYSTEM FITNESS-FOR-SERVICE

The 28 DSTs are interconnected by the Waste Transfer System network of buried steel encased pipelines and pipe jumpers in below-grade pits. The pipeline material is stainless steel or carbon steel in 2 in. to 6 in. sizes. The pipelines carry slurries ranging up to 20 volume percent solids and supernatants with less than one volume percent solids at velocities necessary to prevent settling.

The primary pipelines in contact with the radioactive waste during transfers are 2- and 3-in.-diameter, Schedule 40 ASTM A312/A312M stainless steel, ASTM A53/A53M, Type S, Gr. B, or ASTM Al06/A106M, Grade A or B carbon steel [4, 5, 6]. The 4- and 6-in.-diameter, Schedule 40 ASTM A53/A53M, Type S, Grade B or ASTM Al06/A106M, Grade A or B carbon steel encasements enclose the 51- and 76-mm (2- and 3-in.) primary pipelines, respectively. The encasements confine any leakage from a primary pipeline and route it into one of the tanks. Figure 7-3 illustrates the current design used for Hanford Site Tank Farms pipeline installations.

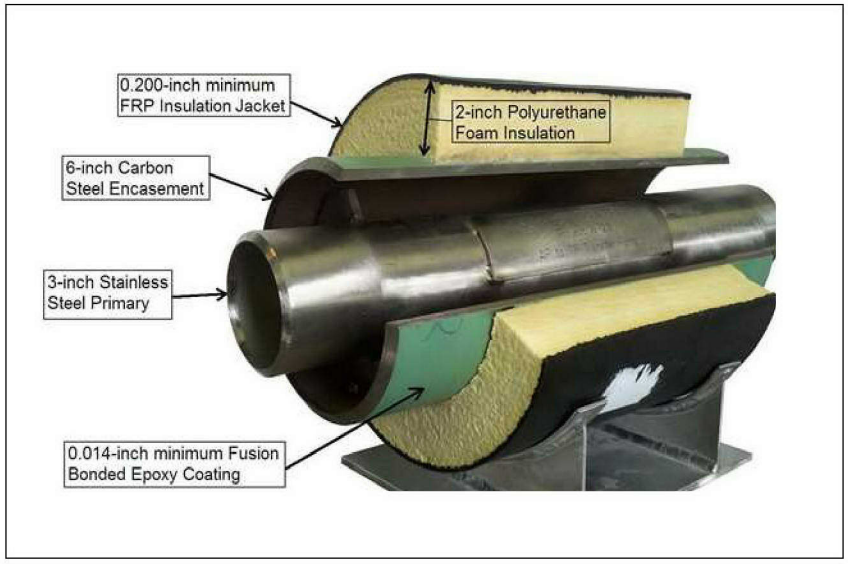


Figure 7-3. Hanford Site Tank Farm Pipeline Design.

In 2010, a systematic evaluation of the Waste Transfer System pipeline conditions was initiated applying guidelines from API 579-1/ASME FFS-1, *Fitness-For-Service*. Between 2010 and 2014, Fitness-for-Service examinations of 35 straight and 17 elbow specimens from primary pipelines and encasements were examined for wall thinning. About 3,200 ultrasonic wall thickness measurements were made longitudinally along the length of the specimens and radially around the circumference using a 1-in. spacing grid, as shown in Figure 7-4. Straight sections and components including 1 Diameter ("short radius"), 1.5 Diameter ("long radius"), and 5 Diameter bend elbows were examined. In parallel, waste throughput histories were prepared allowing side-by-side pipeline wall thinning rate comparisons between carbon- and stainless-steel slurries, supernatants, and throughput volumes.

When possible wall thinning measurements were supplemented by forensic analysis at the on-site radiochemical laboratory. Analyses were performed on the pipeline interior surfaces and cross-sections, and scrapings from the surfaces using a combination of photomicroscopy, scanning electron microscopy, and energy dispersive spectrometry. These methods allowed identification and examination of material and features smaller than 20 µm (0.8 mil).

Of the 35 straight and 17 elbow sections evaluated, six sections had measurable wall thinning and two were confirmed with forensic examinations. Wall thinning rates of -0.2 mil/yr for primary piping, and -0.6 mil/yr for secondary, encasement piping were determined from the examinations. The thinning rates have been adopted for the carbon-steel and stainless-steel segments of the Waste Transfer System as the bases for predicting its estimated remaining useful life. Based on the wall thinning rates, the estimated remaining useful life for the Waste Transfer System ranges from approximately 100 years to 400 years.

Within the detection threshold of the UT pipe wall examination method employed, there was no difference in thinning rates for stainless-steel and carbon-steel pipeline materials, pipeline sizes, elbow and straight sections, elbow bend radii, or supernatant and slurry waste material, for service lives up to 36 years and volume throughputs as high as 161 Mgal. The methodology and calculation bases supporting the Fitness-For-Service conclusions are provided in RPP-RPT-52791 *Tank Farm Waste Transfer System Fitness-for-Service Erosion and Corrosion Basis*.

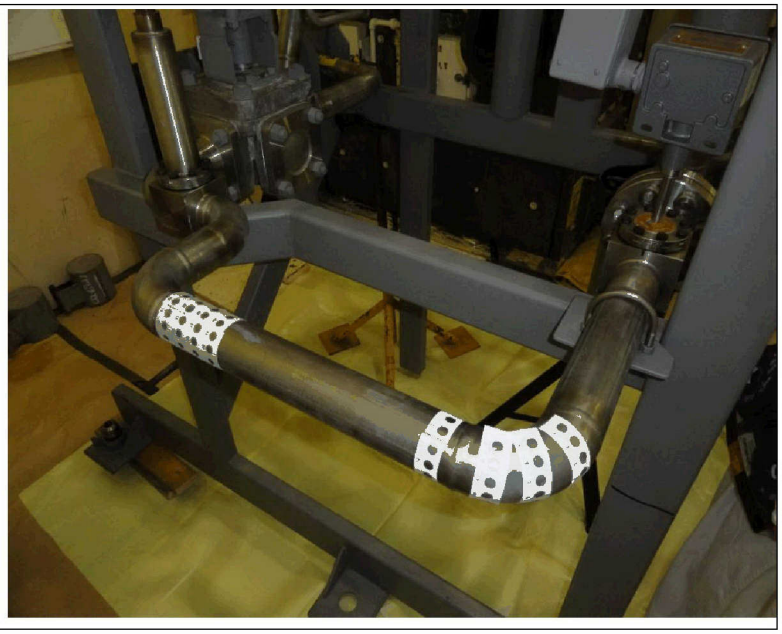


Figure 7-4. Ultrasonic Testing Measurement Templates.

Deployment of a Fitness-For-Service strategy for the Waste Transfer System has resulted in a variety of activities to monitor failure mechanisms (RPP-PLAN-52788). That body of work defines a basis for service life, is documented in RPP-RPT-52791. Fitness-For-Service activity is summarized annually in RPP-RPT-52790, *Tank Farm Waste Transfer System Fitness-for-Service Annual Status Report*.

8.0 CATCH TANK 241-AZ-301

The AZ-301 condensate receiver tank, shown in Figure 8-1, 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 is pumped to an 8,000-gal tanker truck (AZ301TK-COND) for transport to the 200 East Area Effluent Treatment Facility.

Figure 8-1. Aboveground Portion of AZ-301 Condensate Receiver Tank Secondary Containment Vessel.

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9.0 242-A EVAPORATOR

The 242-A Evaporator is used to treat mixed waste from the DST System by removing water and most volatile organics (Figure 9-1). The 242-A Evaporator process uses a conventional forced-circulation, vacuum evaporation system to concentrate mixed waste solutions from the DST System tanks. The concentrated slurry is pumped back into the DST System. The process condensate, which is primarily water with trace amounts of organic material and a low concentration of radionuclides, is routed to the Liquid Effluent Retention Facility to await further treatment at the 200 East Area Effluent Treatment Facility. Offgases from the process are cleaned before being discharged to the environment. The 242-A Evaporator is permitted to treat up to 230,000 gallons of mixed waste per day. The typical feed flow rates are 90 to 140 gal/min.

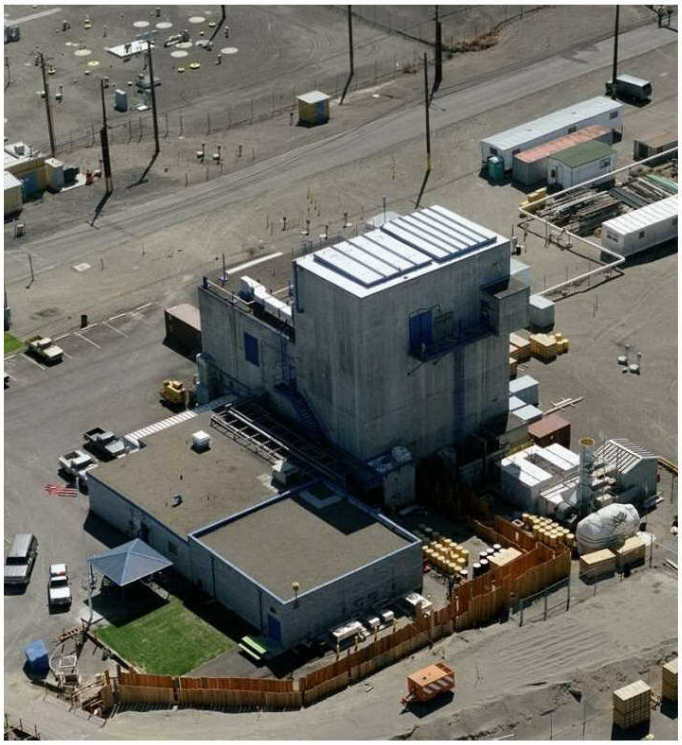

Figure 9-1. 242-A Evaporator.

9.1 PRIMARY CORROSION MECHANISMS

Materials used for the 242-A Evaporator components and piping includes austenitic stainless steels (ASTM A240/A240M, Type 304L) and low-alloy carbon steels (primarily ASTM A53/A53M and ASTM A106/A106M). Austenitic stainless steels are subject to pitting in the presence of chloride ions, especially at low pH. Pitting corrosion was concluded to be unlikely because of the high pH, dynamic operation, and low-chloride concentrations (RPP-RPT-33306, *IQRPE Integrity Assessment Report for the 242-A Evaporator Tank System*).

Other forms of corrosion, such as SCC, crevice corrosion, and general corrosion, are unlikely to be corrosion failure modes because the pH of waste material in the 242-A Evaporator is highly alkaline, temperatures are below the 122 to 140 °F range needed for SCC onset, and chloride concentrations are low.

9.2 INSPECTION AND MAINTENANCE

Portions of 242-A Evaporator that must be assessed to meet the requirements of the *Permit for Dangerous and or Mixed Waste Research, Development, and Demonstration* (WA 7890008967) under the WAC 173-303-640 include the following:

- Visual inspection of the vapor-liquid separator, reboiler, condenser, and all accessible pipelines, pumps, instruments, valves, and flanges;
- UT inspection of the 242-A Evaporator at 2,042 test points at 18 locations (945 UT points in the evaporator room, and 1,107 UT points in the condenser room);
- Hydrostatic testing of the 242-A Evaporator vessel; and
- Pressure leak testing of the PC-5000 process condensate transfer line to Liquid Effluent Retention Facility, vapor-liquid separator subsystem, and condensate collection subsystem.

The current inspection was conducted in December 2007 (RPP-RPT-33306). The assessment is limited to the provisions of WAC 173-303-640, Section (2) for assessment of existing tank system integrity. This assessment is performed on a 10-year cycle, with the next assessment scheduled to be performed in 2017.

10.0 MANAGEMENT APPROACH

Success of the DSTIP requires a structured and disciplined management process. This process starts with a clear definition of objectives and requirements; is supported by solid planning to establish technical, cost, and schedule baselines; and implements proven management controls to guide the work process and adjust to change. Sections 10.1 through 10.6 describe the key elements of the management approach.

10.1 ORGANIZATIONAL STUCTURE

The DSTIP is an element of the Tank Farm Projects organization. Project responsibility rests with the Project Manager for the DSTIP.

10.2 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 with and carried out with the support of Production Operations, in accordance with applicable procedures and work control processes.

10.3 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 Plan."

10.4 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, staff members shall strive for NACE certification as a Corrosion Technologist with the goal of becoming a Senior Corrosion Technologist.

10.5 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. Enhance quality applies to such tasks as chemistry control testing, visual inspections, and UT inspections.

10.6 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*).

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11.0 REFERENCES

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.

API 579-1/ASME FFS-1, 2007, *Fitness-For-Service*, American Petroleum Institute, Washington, D.C. and American Society of Mechanical Engineers, New York, New York.

ASME B31.1, 2012, *Power Piping*, American Society of Mechanical Engineers, New York, New York.

ASME B31.3, 2012, *Process Piping*, American Society of Mechanical Engineers, New York, New York.

ASTM A53/A53M, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, American Society of Testing and Materials, West Conshohocken, Pennsylvania.

ASTM A106/A106M, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service,* American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM A240/A240M, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM A312/A312M, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM A580/A580M, *Standard Specification for Stainless Steel Wire*, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM G5-94, 1999, *Standard Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements*, ASTM International, West Conshohocken, Pennsylvania.

ASTM G61-86e1, 2003, *Standard Test Method for Conducting Cyclic Potentiodynamic Polarization Measurements for Localized Corrosion Susceptibility of Iron-, Nickel-, or Cobalt-Based Alloys*, ASTM International, West Conshohocken, Pennsylvania.

ASTM G192-08, 2014, *Standard Test Method for Determining the Crevice Repassivation Potential of Corrosion-Resistant Alloys Using a Potentiodynamic-Galvanostatic-Potentiostatic Technique*, ASTM International, West Conshohocken, Pennsylvania.

BNL-52361, 1995, *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Tanks and Appurtenances*, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York.

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.

Carranza, R., Giordano, C., Saenz, E., and Weier, D., 2006, *Corrosion of Steel Tanks in Liquid Nuclear Wastes*, NACE-06635, Paper presented at CORROSION 2006, San Diego, California.

Clark, W. C., 2013, "Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Recommended Modifications to Double-Shell Tank Visual Inspections," (external letter WRPS-1302595, Reissue, to T. W. Fletcher, U.S. Department of Energy, Office of River Protection, July 3), Washington River Protection *Solutions* LLC, Richland, Washington.

Consent Decree, 2010, *State of Washington v. DOE,* Case No. 08-5085-FVS (October 25), Eastern District of Washington.

DOE M 435.1, 2001, *Radioactive Waste Management Manual*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, 2001, *Radioactive Waste Management*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE STD-1020, 2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, U.S. Department of Energy, Washington, D.C.

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.

DP-1478, 1978, *Prediction of Stress Corrosion of Carbon Steel by Nuclear Process Liquid Wastes*, E. I. du Pont de Nemours & Co., Savannah River National Laboratory, Aiken, South Carolina.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement,* 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

HNF-SD-WM-OCD-015, 2015, *Tank Farms Waste Transfer Compatibility Program*, Revision 38, Washington River Protection *Solutions*, LLC, Richland, Washington.

LAB-RPT-15-00002, 2015, *Final Report for the Corrosion Potential Investigation of Leak Detection Pit Water from Tank 241-AY-102*, Revision 0, Washington River Protection *Solutions* LLC, Richland, Washington.

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

Permit No.: WA 7890008967, 2004, *Permit for Dangerous and or Mixed Waste Research, Development, and Demonstration*, Washington State Department of Ecology, Richland, Washington.

PNL-5488, 1985, *Prediction Equations for Corrosion Rates of A-537 and A-516 Steels in Double Shell Slurry, Future PUREX, and Hanford Facilities Waste*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-13571, 2001, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-14072, 2002, *Annual Report: Remotely Operated NDE System for Inspection of Hanford's Waste Tank Knuckle Regions and Development of a Small Roving Annulus Inspection Vehicle T-SAFT Scanning Bridge for Savannah River Site Applications*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-15136, 2004, *Feasibility Test Report SAFT/T-SAFT Scanning on the Curved Knuckle of Hanford's Double Shell Tanks*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19767, 2010, *Chemical Species in the Vapor Phase of Hanford Double-Shell Tanks: Potential Impacts on Waste Tank Corrosion Processes*, Pacific Northwest National Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

RPP-7725, 2012, *Washington River Protection Solutions LLC Project Control System Description*, Revision 16, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-7795, 2009, *Technical Basis for the Chemistry Control Program*, Revision 7, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-8532, 2009, *Double-Shell Tanks Chemistry Control Data Quality Objectives*, Revision 10, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-13033, 2016, *Tank Farm Documented Safety Assessment*, Revision 6, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-16922, 2015, *Environmental Specifications Requirements*, Revision 29, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-19438, 2005, *Report of Expert Panel Workshop for Hanford Site Double-Shell Tank Waste Level Increase*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-20257, 2004, *241-AN Tank Farm Historic Dome Load Record Data,* Revision 0, COGEMA Engineering Corporation, Richland, Washington.

RPP-20258, 2004*, 241-AP Tank Farm Historic Dome Load Record Data*, Revision 0, COGEMA Engineering Corporation, Richland, Washington.

RPP-20259, 2004, *241-AW Tank Farm Historic Dome Load Record Data,* Revision 0, COGEMA Engineering Corporation, Richland, Washington.

RPP-20260, 2004, *241-AY Tank Farm Historic Dome Load Record Data,* Revision 0, COGEMA Engineering Corporation, Richland, Washington.

RPP-20261, 2004, *241-AZ Tank Farm Historic Dome Load Record Data,* Revision 0, COGEMA Engineering Corporation, Richland, Washington.

RPP-20262, 2004, *241-SY Tank Farm Historic Dome Load Record Data,* Revision 0, COGEMA Engineering Corporation, Richland, Washington.

RPP-20473, 2007, *Design and Dome Load Criteria for Hanford Waste Storage Tanks*, Revision 1A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-20556, 2007, *Volume 7: IQRPE DST System Integrity Assessment – Evaluation of the Dome Load Program for Double Shell Tanks*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-22604, 2007, *Volume 6: IQRPE DST System Integrity Assessment – Evaluation and Documentation of DST Secondary Liner Issues*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25153, 2007, *Volume 3: IQRPE DST System Integrity Assessment – Waste Compatibility*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25299, 2007, *Volume 4: IQRPE DST System Integrity Assessment – Cathodic Protection for DST Transfer Lines*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-25782, 2005, *DST Dome Survey Program*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-27591, 2007, *Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-27097, 2007, *Volume 5: IQRPE DST System Integrity Assessment – Waste Transfer Line Encasement Integrity Technology Study*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-28538, 2008, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14,* Revision 5, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-ASMT-56781, 2014, *Outcomes from the August 2013 Expert Panel Oversight Committee Meetings*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-ASMT-57582, 2014, *Second Workshop of the High Level Waste Integrity Assessment Panel: Extent of Condition and Balance of Program*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-ASMT-60518, 2015, *Tank Integrity Expert Panel July 2015 Meeting Outcomes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-PLAN-44556, *Simulant Test Plan for Safety Significant Isolation Valves for Double Valve Isolation*, Revision 2, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-PLAN-46847, 2014, *Visual Inspection Plan for Single-Shell Tanks and Double-Shell Tanks,* Revision 2, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-PLAN-52788, 2014, *Waste Transfer System Fitness-for-Service Implementation Plan*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-PLAN-57352, 2015, *Double-Shell Tank Integrity Improvement Plan*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-22126, 2004, *Expert Panel Workshop on Tank Chemistry Optimization – Status of Oxygen Generation and Depletion Modeling*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-25608, 2005, *Hanford Double-Shell Tank Thermal and Seismic Project—Increased Concentrated Load Analysis*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-28967, *Hanford Double-Shell Tank Thermal and Seismic Project – Buckling Evaluation Methods and Results for the Primary Tanks,* Revision 2, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-28968, 2009, *Hanford Double-Shell Tank Thermal and Seismic Project – Summary of Combined Thermal and Operating Loads with Seismic Analysis,* Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-31129, 2006, *Expert Panel Workshop on Double-Shell Tank Vapor Space Corrosion Testing*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-31599, 2013, *Double-Shell Tank Integrity Inspection Report for 241-AN Tank Farm*, Revision 5, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-32237, 2009, *Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-32238, 2007, *Hanford Double-Shell Tank Thermal and Seismic Project – Primary Tank Minimum Wall Thickness Analysis*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-33306, 2008, *IQRPE Integrity Assessment Report for the 242-A Evaporator Tank System*, Revision 0A, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-34310, 2007, *Double-Shell Tank Integrity Inspection Report for 241-AZ Tank Farm*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-34311, 2012, *Double-Shell Tank Integrity Inspection Report for 241-AY Tank Farm*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-37505, 2008, *Effects of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking in Hanford Double-Shell Tanks*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-38738, 2012, *Double-Shell Tank Integrity Inspection Report for 241-AP Tank Farm*, Revision 3, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-39149, 2010, *Double-Shell Tank Integrity Inspection Report for 241-SY Tank Farm*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-42147, 2009, *Double-Shell Tank Integrity Inspection Report for 241-AW Tank Farm*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-47337, 2011, *Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-50440, 2013, *Double-Shell Tank Integrity Assessment Recommendation Dispositions*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-51764, 2012, *Boundary Element Analysis of Corrosion Potential Distribution in Hanford Waste Tanks*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-51766, 2014, *Corrosion Probe Monitoring Systems: July, August, & September 2014 Quarterly Report*, Revision 10, Washington River Protection *Solutions*, LLC, Richland, Washington

RPP-RPT-52790, 2015, *Tank Farm Waste Transfer System Fitness-for-Service Annual Status Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-52791, 2015, *Tank Farm Waste Transfer System Fitness-for-Service Erosion and Corrosion Bases*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-55666, 2013, *Double-Shell Tank Tertiary Leak Detection System Evaluation*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-57774, 2015, *Evaluation of Tank 241-AY-102 Secondary Containment System*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-58473, 2015, *Implementation Strategy for Electromagnetic Acoustic Transducer System into DST Non-Destructive Examination Program*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-58525, *Remote Ultrasonic Testing and Inspection of Double-Shell Tank Air Slots with a Robotic Crawler (1999-2003*), Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-SPEC-32496, 2007, *Procurement Specification for AN-102 Corrosion Probe Assembly*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-SPEC-35429, 2009, *Procurement Specification for AY-102 Corrosion Probe Assembly*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-SPEC-35672, 2009, *Procurement Specification for 241-AN-107 Corrosion Probe Assembly*, Revision 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-SPEC-38427, 2008, *Procurement Specification for 241-AY-101 Corrosion Probe Assembly*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-SPEC-43207, 2009, *Procurement Specification for 241-AW-104 Retractable Corrosion Monitoring Probe Assembly*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-SPEC-49792, 2012, *Procurement Specification for 241-AW-105 Corrosion Probe Assembly*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

SRNL-STI-2010-00509, 2010, *Corrosion Testing in Simulated Tank Solutions*, Savannah River National Laboratory, Aiken, South Carolina.

SRNL-STI-2014-00616, 2014, *Hanford Double Shell Waste Tank Corrosion Studies – Final Report FY2014*, Revision 0, Savannah River National Laboratory, Aiken, South Carolina.

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

TFC-OPS-OPER-C-10, 2015, "Vehicle and Dome Load Control in Tank Farm Facilities," Revision B-26, Washington River Protection *Solutions*, LLC, Richland, Washington.

TFC-PLN-02, 2015, "Quality Assurance Program Description," Revision H-1, Washington River Protection *Solutions*, LLC, Richland, Washington.

TFC-PLN-84, 2015, "Tank Operations Contractor Project Execution Plan," Revision D-8, Washington River Protection *Solutions*, LLC, Richland, Washington.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

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

Washenfelder, D. J., 2012, "Double-Shell Tank 241-AY-102 Primary Tank Leak Extent of Condition Evaluation and Recommended Annulus Visual Inspection Intervals," (Memorandum WRPS-1204931 to D. B. Little, November 26), Washington River Protection *Solutions*, LLC, Richland, Washington.

WHC-SD-WM-DGS-003, 1995, *Structural Acceptance Criteria for the Evaluation of Existing Double-Shell Waste Storage Tanks Located at the Hanford Site, Richland, Washington*, Revision 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-TI-772, 1996, *Technical Basis for Electrochemical Noise Based Corrosion Monitoring of Underground Nuclear Waste Storage Tanks*, Revision 0, Lockheed Martin Hanford Company, Richland, Washington.

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APPENDIX A

CONSTRUCTION OF THE DOUBLE-SHELL TANK FARMS

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A1.0 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, the U.S. Department of Energy) in the 1960s to initiate construction of double-shell tanks (DST) 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 (Mgal) waste capacity, with design lives of 20 to 50 years.

The DST design allows the detection of any potential leaks. Leaking waste would be held in the secondary containment, allowing for corrective action before there could be any release of waste to the environment. Table A-1 lists the construction dates, year of initial service, and the expected design life at the time of construction.

Table A-1. Double-Shell Tank Construction and Age as of 2016.

Tank farm	Number of tanks	Construction period	Construction project	Initial operation	Design life	Current Age
AY	2	1968 – 1970	IAP-614	1971	40	45
AZ	2	1970 – 1974	HAP-647	1976	20	40
SY	3	1974 – 1976	B-101	1977	50	39
AW	6	1976 – 1979	B-120	1980	50	36
AN	7	1977 – 1980	B-130, B-170	1981	50	35
AP	8	1982 – 1986	B-340	1986	50	30
Total	28					

DSTs consist of a primary steel tank inside of a secondary steel liner (Figure A-1). 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 and leak detection channels under the primary tank bottom plate. An annular space of 2.5 ft exists between the secondary liners and primary tanks, allowing visual examination of the tank wall and secondary liner annulus surfaces. The annular space also allows for visual surface and ultrasonic volumetric inspections of the primary tank walls and secondary liners.

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.

All DSTs are buried underground, 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.

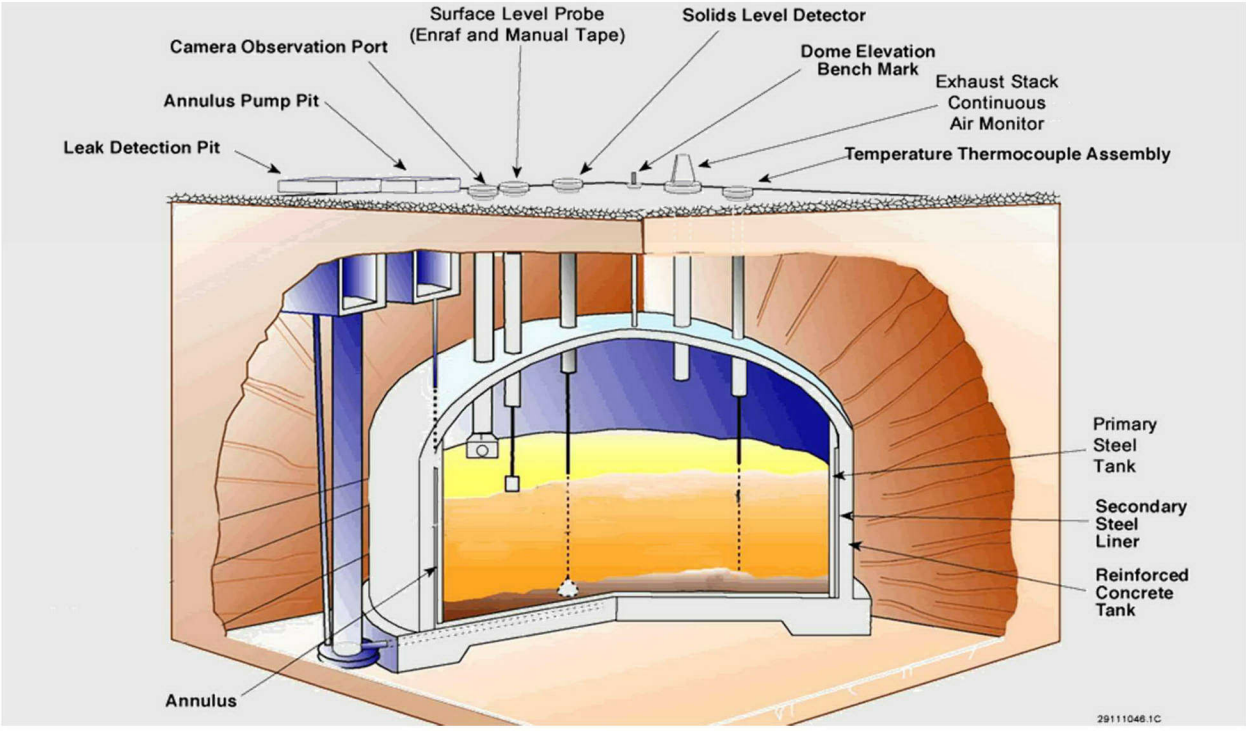


Figure A-1. Double-Shell Tank Construction.

A1.1 SECONDARY LINER

The secondary liner of a DST is 80 ft in diameter, and measures approximately 40 ft in height. The secondary liner consists of a bottom, bottom knuckle, wall, and top knuckle. The liner bottom rests on a refractory concrete pad and is joined to a bottom knuckle. The bottom knuckle of the secondary liner includes a bottom transition plate, which connects to the vertical wall plates. Four vertical plates form the wall of the secondary liner of the DST, which is topped by an inwardly curved secondary top knuckle. Dimensions of these components are shown in Figure A-3 (see Page A-3) for each of the Hanford Site's six DST Farms.

The secondary top knuckle approaches the top knuckle of the primary tank where a small gap (from 0.5 to 1 in. in width in AY Farm and from 0 to 1 in. in width in all of the other tank farms) exists between the two. This gap is overlapped by a series of 14-in. wide, 18-gauge flashing strips. These strips are tack-welded to the primary tank and extend approximately 4 in. past the secondary liner gap. An example of this primary tank and secondary liner top knuckle interface is shown in Figure A-2.

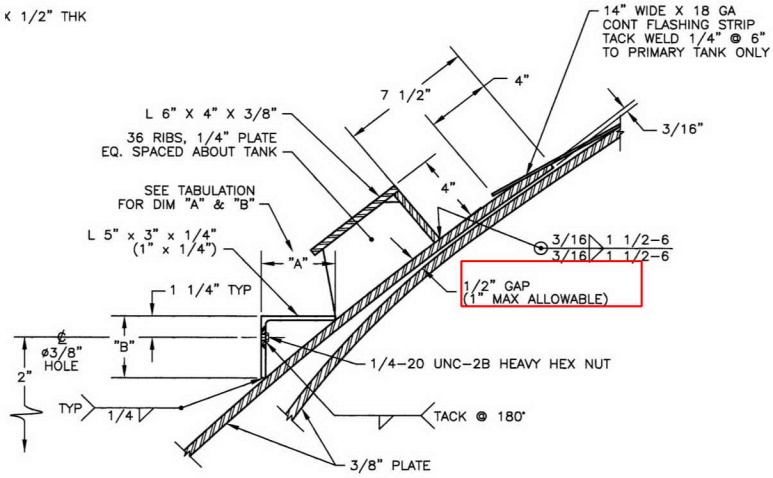
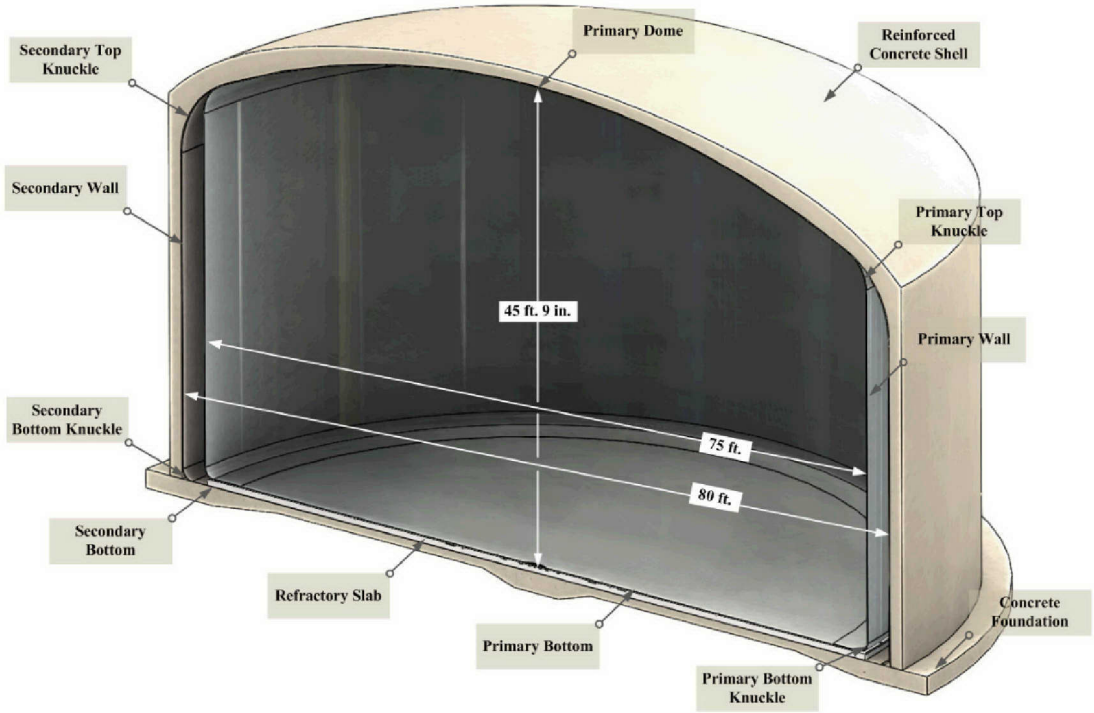


Figure A-2. Representative AY Farm Primary and Secondary Top Knuckle Interface.



Secondary Liner Top Knuckle	Plate Material	Primary Tank Bottom Knuckle
AY – ⅜ in.	AY – ASTM A515-65	AY – ⅞ in.
AZ – ⅜ in.	AZ – ASTM A515-69	AZ – ⅞ in.
SY – ⅜ in.	SY – ASTM A516-72	SY – ⅞ in.
AW – ⅜ in.	AW – ASTM A537-74a	AW – ⅞ in.
AN – ⅜ in.	AN – ASTM A537-75	AN – ⅞ in.
AP – ⅜ in.	AP – ASTM A537-80 or 79	AP – 15/16 in.
Secondary Liner Wall	**Primary Tank Dome**	**Primary Tank Bottom**
AY – ¼ in.	AY – ⅜ in. and ½ in.	AY – ⅜ in. and 1 in.
AZ – ⅜ in.	AZ – ⅜ in. and ½ in.	AZ – ½ in. and 1 in.
SY – ⅜ in.	SY – ⅜ in. and ½ in.	SY – ½ in. and 1 in.
AW – ⅜ in.	AW – ⅜ in. and ½ in.	AW – ½ in. and 1 in.
AN – ⅜ in.	AN – ⅜ in. and ½ in.	AN – ½ in. and 1 in.
AP – ⅜ in. and ½ in.	AP – ⅜ in. and ½ in.	AP – ⅞ in., ½ in., and 1 in.
Secondary Liner Bottom Knuckle	**Primary Tank Top Knuckle**	**Bottom Primary Tank Wall**
AY – ¼ in.	AY – ⅜ in.	AY – ¾ in. and ½ in.
AZ – ½ in.	AZ – ⅜ in.	AZ – ¾ in. and ½ in.
SY – ½ in.	SY – ⅜ in.	SY – ¾ in. and ½ in.
AW – ½ in.	AW – ⅜ in.	AW – ¾ in. and ½ in.
AN – ½ in.	AN – ⅜ in.	AN – ¾ in. and ½ in.
AP – 9/16 in.	AP – ½ in.	AP – ½ in., ¾ in., 9/16 in., ⅞ in.
Secondary Liner Bottom		
AY – ¼ in.		
AZ – ⅜ in.		
SY – ⅜ in.		
AW – ⅜ in.		
AN – ⅜ in.		
AP – ⅜ in.		

Figure A-3. Double-Shell Tank Detail by Tank Farm.

A1.2 REFRACTORY

An insulating refractory pad is placed on top of the secondary liner bottom. The primary purpose of the refractory is to act as an insulating barrier between the primary tank and the concrete foundation during post-weld stress relieving where temperatures of up to 1,100 °F were required in the primary tank. The refractory prevents the structural concrete foundation temperature from rising above 500 °F.

Table A-2. Tank Farm Refractory Materials.

Tank farm	Refractory material
AY	Kaolite 2200-LI
AZ	Kaolite 2000
SY	Lite-Wate 50
AW	Lite-Wate 50 and 70
AN	Lite-Wate 70
AP	Lite Crete 60M

The refractory layer houses air ventilation piping, thermocouple conduit, and air distribution slots. The air distribution slots allow airflow to cool the primary tank bottom and direct potential leaks to the tank annulus where leak detectors are installed. Several refractory materials were used over the years of DST construction. Table A-2 provides an overview of those materials used in each DST farm.

Refractory air distribution slot design was similar for the majority of the tank farms, with the exception of the AY Farm. Figure A-4 shows the difference.

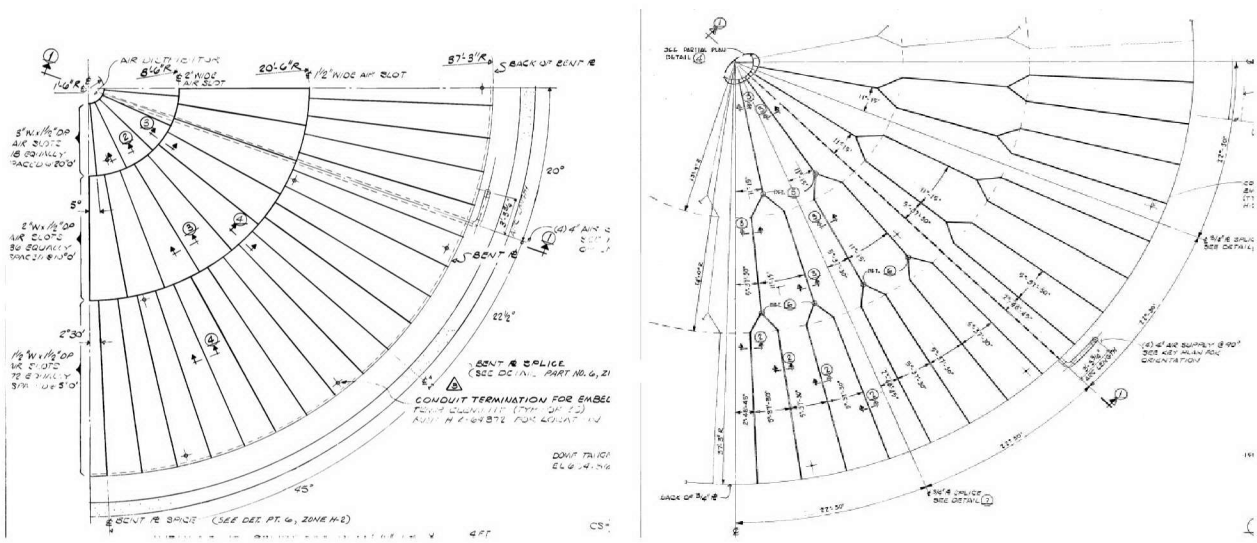


Figure A-4. Refractory Air Slot Design (AY Farm on the Left; AZ, SY, AW, AN, and AP Farm on the Right).

A1.3 PRIMARY TANK

The primary tank consists of a bottom, bottom knuckle, wall, top knuckle, and dome. The primary tank bottom rests on the refractory slab and joins to the bottom knuckle. The primary tank of a DST is 75 ft in diameter and measures approximately 46 ft-9 in. in height at the dome center. The bottom knuckle is an inwardly curved section of plate that transitions up to the tank wall.

In the AY, AZ, and SY Farms, the wall consists of three plates that are approximately 10 ft in height, followed by a “top transition plate” that is approximately 3 ft in height. In the AW, AN,

and AP Farms, there are four plates that are approximately 8 ft in height. An inwardly curved section, referred to as the top knuckle, joins the vertical wall with the roof section of the tank. Dimensions of these components are provided in Figure A-3 for each of the six DST farms.

A1.4 CONCRETE STRUCTURE

The concrete foundation of the DSTs is 88 ft-6 in. in diameter for AY Farm, and 89 ft-6 in. in diameter for the remaining farms. The foundations are designed to uniformly distribute all loads.

For the foundation of the AY, AZ, SY, AW, and AN Farms, the center portion is 2-ft thick and 3-ft in diameter. From the center, the bottom side of the foundation tapers to a thickness of about 1 ft, which then returns to 2-ft thick at the outer edge. The AP Farm has no taper, and the entire foundation is 2-ft thick. The foundations contain slots and drain lines to collect any leakage from the secondary tank. Any leakage from the bottom of the secondary liner is directed to a leak detection pit.

The outside of the 1.5-ft-thick concrete shell is 83 ft in diameter and rests on steel plates supported by the tank foundation. The concrete of the dome is 1.25-ft thick. Both the walls and dome contain reinforcing steel. Anchor bolts are threaded into studs that are welded to the secondary steel liner wall and the primary tank dome, after which the concrete is cast around the rebar and anchor bolts.

A1.5 LEAK DETECTION SYSTEMS

The DST leak detection pits are tertiary containment systems designed to collect any liquid draining from beneath the secondary liner. The DST leak detection pits were patterned after the last single-shell tank farm constructed (AX Farm), which was the first design to incorporate leak detection pits.

Each tank in the AY, AZ, SY, AW, and AN Farms is equipped with a separate leak detection pit and drain system. In the AP Farm, four tanks share a common leak detection pit via an interconnected drain manifold. In the AP Farm, the leak detection well does not have an enlarged bottom section and is 24 in. diameter for the entire depth.

The concrete foundation beneath the secondary liner is slotted. In the AY, AZ, and SY Farms, tank foundations are fitted with drain pipe connections at the center, mid-point, and edge of the slab. Figure A-5 shows this leak detection pit drain design. The AW, AN, and AP Farm tank foundations use a drain slot cut from the center of the foundation to the outer edge. The slot then drains into a drain pipe and to a leak detection pit.

The leak detection pits are ventilated via a 2-in. line connected to the DST annulus ventilation exhaust. The leak detection pump pits are equipped with floor drains. In the AY and AZ Farms, these floor drains are connected to a drop leg in the primary tank. In all other DST farms, these pump pit drains are routed back to the leak detection pit riser.

In the event of a secondary liner breach, tank waste would accumulate in drain slots (Figure A-6), cut or cast into the tank foundation, and drain into a leak detection pit. The leak would be indicated by an increase in the leak detection pit liquid level.

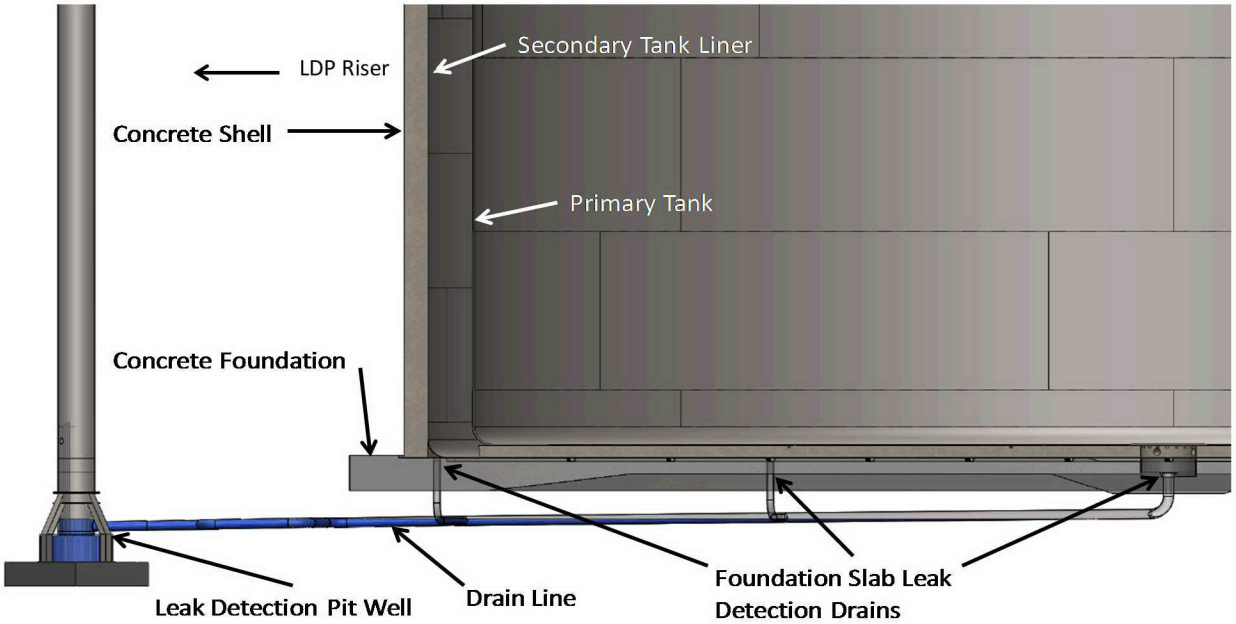


Figure A-5. Diagram of AY, AZ, and SY Farm Leak Detection Pit Drain System.

Figure A-6. Concrete Base Slabs for AY Farm Showing Drain Slots (8041-1) (Tank AY-102 in foreground).

A1.6 RISERS, PUMP PITS, VALVE PITS

Between 59 and 126 steel riser pipes penetrate the concrete dome and the top of the primary tank and secondary liner. The risers provide access to the primary tank and the annulus space for waste transfer operations, equipment installation, and monitoring. The risers are accessible from covered pits or at grade level at specific locations.

Concrete pump pits located above the concrete dome provide access to pipelines, used for transferring liquid waste between tanks. Additionally, the pits are used for structural support, allowing the use of large pumps and other equipment. The largest risers in the tanks lead to these pump pits. These pits are kept covered with large concrete blocks to prevent personnel exposure to radioactive materials.

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APPENDIX B

TANK AY-102 STATUS

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B1.0 TANK AY-102 LEAK ASSESSMENT

In August 2012, unexplained material was discovered on the double-shell tank (DST) AY-102 annulus floor near risers 83 and 90. Samples from both sites confirmed that the material was tank waste. This finding led to conducting a formal leak assessment using TFC-ENG-CHEM-D-042, "Tank Leak Assessment Process."

B1.1 LEAK ASSESSMENT

A formal leak assessment, published as RPP-ASMT-53793, *Tank 241-AY-102 Leak Assessment Report*, concluded that the origin of the material was a leak from the primary tank.

B1.2 EXTENT OF CONDITION

To assess the potential for other DST leaks, Washington River Protection *Solutions*, LLC (WRPS) conducted a visual and construction extent of condition review following the determination that Tank AY-102 was leaking.

B1.2.1 Extent of Condition Visual Inspection

The Hanford Site DSTs are examined visually for conditions, both inside the primary tank and on the annulus surface of the primary tank and secondary liner, using remote video equipment during planned periodic visual inspections. Annulus visual inspections were first performed in 1992 through a limited number of risers (typically two) and, eventually evolved to using four risers for periodic annulus inspections. Prior to 2012, annulus visual inspections were performed as much as possible in conjunction with periodic schedule ultrasonic testing, or approximately every 5 years (not to exceed 7 years between inspections).

After the primary tank (Tank AY-102) was declared to be leaking, enhanced visual inspections were performed on the six oldest DSTs that used 10 to 12 risers, covering greater than 95 percent of the annulus floor area and the portion of the primary tank (i.e., dome, sidewall, lower knuckle, and insulating refractory) that is visible from the annulus inspection risers. Photographs of the general condition of the upper haunch of the primary tank, the bottom knuckle, insulating refractory, refractory slots, stiffener ring, and annulus floor were included in the reports with any areas of interest identified. The condition of the primary tank sidewall was also noted in these reports. Any anomalies identified in the enhanced inspections were compared to previous visual inspections to identify any possible changes in the condition of the area of interest.

The reports issued to date, which include results of the enhanced baseline inspections are:

- RPP-RPT-54814, *Tank 241-AY-101 Annulus Extent of Condition Baseline Inspection*;
- RPP-RPT-54815, *241-AZ Annulus Extent of Condition Baseline Inspection*; and
- RPP-RPT-54816, *241-SY Annulus Extent of Condition Baseline Inspection*.

After performing these inspections, there was no evidence indicative of water intrusion or a primary tank leak for all six of these tanks. Some changes were noted from the previous inspection that were attributed to couplant water used during ultrasonic testing, accumulation of condensation on the annulus floor, and/or removal of the annulus pump.

B1.2.2 Extent of Condition Construction Reviews

Another immediate action from the leak assessment was to conduct a review of construction histories for the tanks in AY, AZ, and SY Farms. The formal leak assessment for Tank AY-102 identified first-of-a-kind construction difficulties and trial-and-error repairs as major contributing factors to tank failure (RPP-ASMT-53793).

To determine if improvements in DST construction occurred after construction of Tank AY-102, a detailed review and evaluation of historical construction records was performed for Hanford's remaining 27 DSTs. Review involved research of 241 boxes of historical project documentation to better understand the condition of the Hanford Site DST farms, noting similarities in construction difficulties and issues compared to those seen during construction of Tank AY-102.

The reviews revealed that most of the problems seen in construction of the first DST did not repeat in later DSTs. Although some issues were noted with the refractory in other DST farms, none were damaged to the point of requiring repair as seen in the AY Farm. Stress relief operations were also improved, but only three DSTs were stress-relieved at the desired temperature of 1,100 °F; all others met alternate code provisions of lower temperature and longer soak times. Bottom plate thickness was increased after AY Farm, but bottom plate bulges were still an issue in SY Farm. Problems with high-weld rework returned in the SY and AW Farms each time a new contractor was selected for construction.

Information gathered provides valuable insight regarding construction difficulties, future tank operations decisions, and guidance of the current tank inspection program. If new waste storage tanks are constructed in the future, these reviews also provide valuable lessons learned.

Complete information on the extent of condition construction reviews is provided in:

- RPP-RPT-54817, *241-AY-101 Tank Construction Extent of Condition Review for Tank Integrity*;
- RPP-RPT-54818, *241-AZ Tank Farm Construction Extent of Condition Review for Tank Integrity*;
- RPP-RPT-54819, *241-SY Tank Farm Construction Extent of Condition Review for Tank Integrity*;
- RPP-RPT-55981, *241-AW Tank Farm Construction Extent of Condition Review for Tank Integrity*;
- RPP-RPT-55982, *241-AN Tank Farm Construction Extent of Condition Review for Tank Integrity*; and
- RPP-RPT-55983, *241-AP Tank Farm Construction Extent of Condition Review for Tank Integrity*.

B1.2.3 Leak Detection Pit Inspection

In November 2013, a robotic crawler was used to inspect the Tank AY-102 leak detection pit drain line. The leak detection pit sump has accumulated water at about 2 to 3 gal/day since the ventilation was connected with the annulus ventilation in 1996. The liquid is slightly contaminated so that the integrity of the tertiary leak collection system was questioned. The

video inspection showed the drain line to be in good condition. No material was found in the inspection that looked like tank waste or the material seen in the Tank AY-102 annulus (no greenish or yellowish deposits or dark fluids, dried salt deposits, or crystalline material). The contamination levels seen on the crawler were consistent with past values seen on leak detection pit pumping equipment. Sampling and analysis of the recovered residues from the crawlers did not find material consistent with tank waste. The intrusion appears to be from soil moisture rather than tank waste. The visual inspection results are documented in RRP-RPT-56464, *241-AY-102 Leak Detection Pit Drain Line Inspection Report*.

B1.2.4 Tank AY-102 Waste Accumulation Sites

Tank AY-102 is currently being monitored on a periodic basis through Risers 77, 83, and 87. Figure B-1 through Figure B-3 provide panoramic views from Risers 77, 83, and 87, respectively, which were constructed after the video inspections were conducted on June 30, 2015.

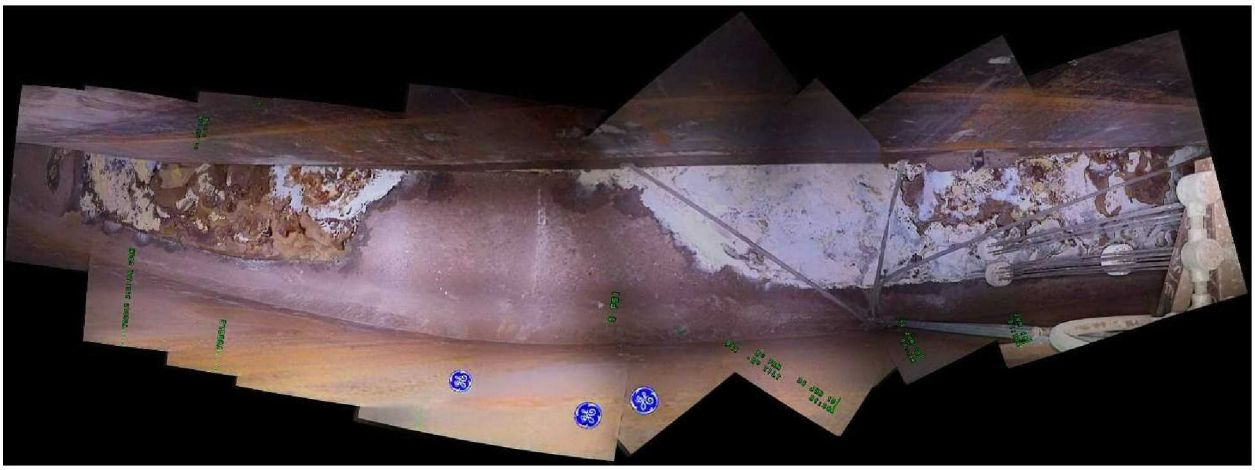

Figure B-1. Accumulated Waste in Tank AY-102, View from Riser 77.

As of June 30, 2015, there is approximately 12.5 gallons of waste that has accumulated below Riser 77.

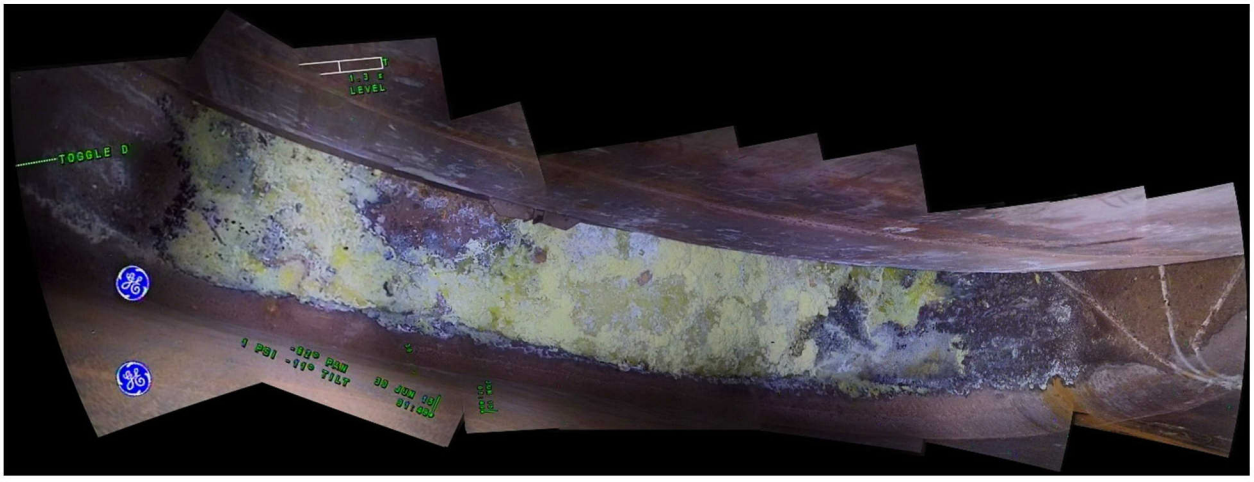

Figure B-2. Accumulated Waste in Tank AY-102, View from Riser 83.

As of June 30, 2015, there is approximately 7 gallons of waste that has accumulated below Riser 83.

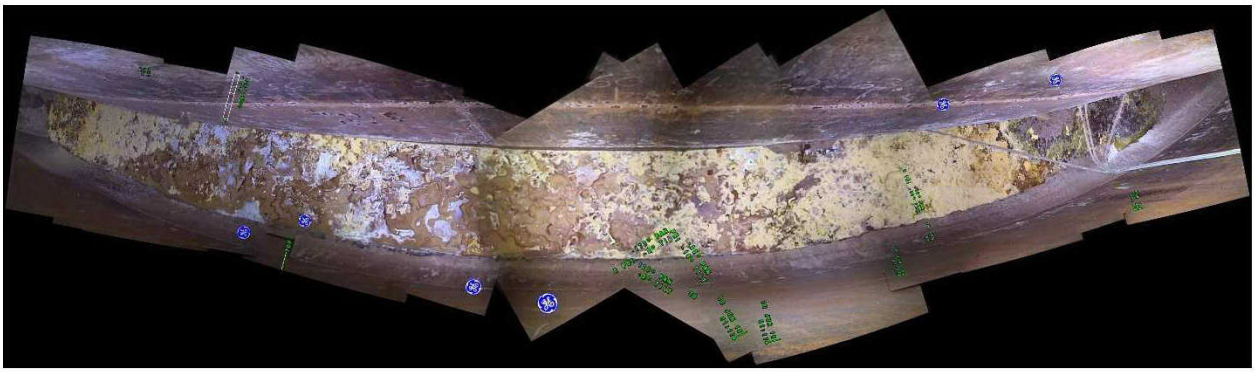

Figure B-3. Accumulated Waste in Tank AY-102, View from Riser 87.

As of June 30, 2015, there is approximately 39 gallons of waste that has accumulated below Riser 87. Overall, less than 60 gallons of accumulated waste is estimated to be in the annulus of Tank AY-102.

B2.0 REFERENCES

RPP-ASMT-53793, 2012, *Tank 241-AY-102 Leak Assessment Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54814, 2013, *Tank 241-AY-101 Annulus Extent of Condition Baseline Inspection*, Revision 0, Washington River Protection I, LLC, Richland, Washington.

RPP-RPT-54815, 2013, *241-AZ Annulus Extent of Condition Baseline Inspection*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54816, 2013, *241-SY Annulus Extent of Condition Baseline Inspection*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54817, 2013, *241-AY-101 Tank Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54818, 2013, *241-AZ Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54819, 2013, *241-SY Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-55981, 2013, *241-AW Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-55982, 2013, *241-AN Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-55983, 2013, *241-AP Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RRP-RPT-56464, 2014, *241-AY-102 Leak Detection Pit Drain Line Inspection Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

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

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APPENDIX C

DOUBLE-SHELL TANK INTEGRITY PROJECT COMPARISON OF PROGRAM ELEMENTS WITH TANK STRUCTURAL INTEGRITY PANEL GUIDELINES

CONTENTS

C1.0 TANK AY-102 LEAK ASSESSMENT COMPARISON OF PROGRAM ELEMENTS WITH TANK STRUCTURAL INTEGRITY PANEL C-1

C2.0 REFERENCES C-2

TABLES

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements C-4

Table C-2. Hanford Double-Shell Tank Integrity Visual Program Elements C-11

Table C-3. Hanford Site Double-Shell Tank Integrity Ultrasonic Testing Program Schedule Projection C-13

Table C-4. Hanford Site Double-Shell Tank Integrity Visual Inspection Program Schedule Projection C-14

C1.0 TANK AY-102 LEAK ASSESSMENT COMPARISON OF PROGRAM ELEMENTS WITH TANK STRUCTURAL INTEGRITY PANEL

Table C-1 and Table **C-2** provide comparisons of the Double-Shell Tank Integrity Project (DSTIP) inspection criteria to those identified in Brookhaven National Laboratory (BNL) guidelines for developing structural integrity programs for tank systems (BNL-52527/UC-406, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*). The U.S. Department of Energy (DOE) developed the guidelines because of concerns related to aging radioactive waste storage facilities throughout the DOE complex. 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.

The DOE has subsequently adopted these guidelines and requires site operators to have a program consistent with them (DOE M 435.1, *Radioactive Waste Management Manual*). The 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).

The DOE provides requirements for tank integrity in Chapter II of DOE G 435.1-1, *Implementation Guide for Use with DOE M 435.1-1*. This guide requires that existing tanks have the following (except from Page II-166):

II. Q. (2) Structural Integrity Program.

(a) Leak-Tight Tanks In-Service. A structural integrity program shall be developed for each high-level waste storage tank site to verify the structural integrity and service life of each tank to meet operational requirements for storage capacity. The program shall be capable of:

1. *Verifying the current leak-tightness and structural strength of each tank in service;*
2. *Identifying corrosion, fatigue and other critical degradation modes;*
3. *Adjusting the chemistry of tank waste, calibrating cathodic protection systems, wherever employed, and implementing other necessary corrosion protective measures;*
4. *Providing credible projections as to when structural integrity of each tank can no longer be assured; and*
5. *Identifying the additional controls necessary to maintain an acceptable operating envelope.*

(b) *In-Service Tanks that Have Leaked or Are Suspect. For each high-level waste storage tank in-service that is known to have leaked, or is suspect, a modified structural integrity program shall be developed and implemented to identify the safe operational envelope. The modified program shall be capable of:*

1. *Verifying the structural strength of each tank in-service which has leaked or is suspect;*
2. *Identifying corrosion, fatigue and other critical degradation modes;*
3. *Adjusting the chemistry of tank waste, calibrating cathodic protection systems, wherever employed, and implementing other necessary corrosion protection measures;*
4. *Determining which of the tanks that have leaked or are suspect may remain in service by identifying an acceptable safe operating envelope;*
5. *Providing credible projections as to when the acceptable safe operational envelope can no longer be assured; and*
6. *Identifying the additional controls necessary to maintain the acceptable safe operational envelope.*

(c) *Other Storage Components. The structural integrity of other storage components shall be verified to assure leak tightness and structural strength.*

DOE G 435.1-1 states that the BNL TSIP document provide the basis for an acceptable program:

> *BNL-UC-406, Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks, (referred to subsequently as "Guidelines") provides an acceptable process for establishing a structural integrity program. This set of Guidelines was finalized in January 1997 to promote the structural integrity of high-level waste storage tanks and transfer lines at facilities of the Department. In summary, the document lays out the essential elements of a structural integrity program. The procedures contained in the Guidelines provide an acceptable methodology to assess the structural integrity of existing tanks and to estimate the end of service life.*

These BNL guidelines, recommended by DOE, provide the basis for the Tank Operations Contractor Program. Table C-1 compares the nondestructive examination program to the guidelines found in BNL-52527/UC-406.

Table C-3 and Table C-4 provide the Ultrasonic Testing and Visual Inspection Programs schedule projection.

C2.0 REFERENCES

10 CFR 820, "Procedural Rules for DOE Nuclear Activities," *Code of Federal Regulations*, as amended.

36 CFR 1234, "Electronic Records Management," *Code of Federal Regulations*, as amended.

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

Section XI, "Rules for In-service Inspection of Nuclear Power Plant Components," 2001, (Appendix VIII; sub-article IWC-2430, paragraph IWC-2424; and sub-article IWA-2430, paragraph IWA-2432).

ANSI/ANST CP-189, 1995, *ASNT Standard for Qualification of Nondestructive Testing Personnel*, The American Society of Nondestructive Testing, Inc., Columbus, Ohio.

ASNT Recommended Practice SNT-TC-1A, 2011, *Personnel Qualification and Certification in Nondestructive Testing,* The American Society of Nondestructive Testing, Inc., Columbus, Ohio.

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.

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

DOE M 435.1, 2001, *Radioactive Waste Management Manual*, Change 1, U.S. Department of Energy, Washington, D.C.

DOE O 200.1, 1996, *Information Management Program*, U.S. Department of Energy, Washington, D.C.

DOE O 414.1A, 2001, *Quality Assurance*, U.S. Department of Energy, Washington, D.C.

DOE O 1324.5B, 1995, *Records Management Program*, U.S. Department of Energy, Washington, D.C.

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.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement,* 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia,

Huber, J., 2003, "Contract 17432, Evaluation of Additional DSTIP NDE Inspection Team Member Qualifications," (Letter LATA-JHH-03-014 to P. McDonald, February 7), LATA Inc., Richland, Washington.

RPP-6839, 2000, *Engineering Task Plan for the Ultrasonic Inspection of Hanford Double-Shell Tanks – FY 2001*, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-58301, 2015, *Summary of Initial Two Rounds of Double-Shell Tank Ultrasonic Testing*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

WHC-SD-WM-ER-529, 1996, *Description of Double-Shell Tank Selection Criteria for Inspection,* Revision 0, Westinghouse Hanford Company, Richland Washington.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Tank selection	At least 10% (or 1 if < 10%); selection based on age, severity of operating conditions, and transients; if not homogenous, > 10% may be required to represent worst-case	• Tank selection based on weighted averages of waste composition, least waste height variation, temperature, age, and material. All 28 DSTs are prioritized based on this criterion. • All 28 DSTs were initially inspected (UT baseline) by the end of FY 2005 as part of the M-48 Milestones of the Tri-Party Agreement (Ecology et. al. 1989*). The UT inspections are repeated in successive 8- to 10-year cycles. The second round of UT was completed in FY 2015. The summary of the first two rounds of UT was documented in RPP-RPT-58301*. • Six DSTs selected for examination of tank bottoms and six DSTs selected for examination of lower knuckles were selected based on a variety of factors as documented in RPP-6839*.	• N/A—exceeds TSIP guidance. • Examination of all 28 DSTs will be performed in accordance with the M-48 milestone agreement with Ecology. • Number of DSTs selected for examination of tank bottoms and lower knuckles was agreed on by Ecology.	Rationale for UT of all 28 DSTs versus three required by TSIP is that the DSTs have different service dates and different types of waste (WHC-SD-WM-ER-529*).
	If > 10% are examined, opt to reduce percent per tank accordingly	No reduction used.	The initial round of inspections were required by the agreement of the M-48 milestones with Ecology. The IQRPE assessment, performed to satisfy the M-48-14 milestone, recommended this practice continue as part of the ongoing assessments of the integrity of the DSTs.	None.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Extent of examination	5% of liquid-vapor interface	Initially, the liquid and vapor interface on six DSTs were examined over a 20-ft length, 15-in. wide centered on the estimated location of the static LAI that existed for a minimum of 5 years. This area was examined for pits, cracks, and wall thinning. The liquid and air interface of all the DSTs shall be examined.	The initial basis for this scope of examination is as agreed to by DOE and Ecology in draft Milestone M-48-14. A 20-ft length in a 75-ft diameter tank exceeds 5% of the LAI. The 15 in. centered on the LAI does not comply with the TSIP guidance of ± 1 ft, but can be accomplished in a single scan otherwise two scans would be required to encompass 12 in. above and 12 in. below the interface. However, this scope can be increased depending on the condition of the tank. For example, two scans were done on Tank AY-101 on the LAI because thinning was found over a fairly large vertical range in the two 15-in. wide vertical scans on the east side of the tank. In all 28 DSTs, any previous or existing LAI is examined in the top-to-bottom 30-in. wide vertical strip (consisting of two 15-in. wide vertical strips) that is scanned in each tank.	
	5% of liquid-sludge interface	Any liquid-sludge interface above the lower knuckle weld is examined over a 60-in. length, within the 60-in. vertical strip examined on each DST. No horizontal scan of the liquid-sludge interface is conducted.	UT results to date for vertical scans in DSTs have not found any evidence of accelerated degradation or flaws at a liquid-sludge interface that exists now, or may have existed during the tank operating history. With the completion of the initial round of UT inspections in FY 2005, all 28 DSTs were examined over approximately a 35-ft by 30-in. wide vertical strip. The second round of UT inspections increased this area to 60 in. per tank. In both rounds of inspections, no evidence of accelerated degradation or flaws at a liquid-sludge interface was found. If evidence is found in future inspections, expansion of the examination scope for that tank would be implemented.	None.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Extent of examination (cont.)	5% divided between knuckle[a] base metal and lower weld if accessible. Otherwise 5% of knuckle divided into two or more segments.	• Six DSTs have been identified for examination of a 20-ft circumferential length of the lower knuckle. Examinations are to be conducted on the entire 20-ft length in each interval, rather than partially in subintervals. • SAFT and T-SAFT will inspect the lower knuckle region to the lower knuckle and bottom plate weld. • Extended arm P-scan® will overlap the SAFT and T-SAFT inspection from the lower knuckle top weld to just above the maximum stress region. • The bottom/lower knuckle weld is not examined, except through air slots when tank bottoms are examined. • 20 ft of weld and HAZ joining the vertical wall to lower knuckle is examined, if accessible.[b] The entire 20-ft length is examined at one time—not in two or more subintervals.	• N/A—exceeds TSIP guidelines for lower knuckle region. Examination scope is not presently planned to be apportioned among subintervals because of higher costs associated with multiple tank entries. Examination of lower knuckle region is dependent on accessibility. • Frequency of successive lower knuckle region examinations will be increased if significant degradation or evidence of SCC, or any cracking is observed. • No cracks, significant wall thinning, or other problems have been observed to date in examination of the welds and HAZ in the DSTs.	Development of a T-SAFT was accomplished and deployed on one DST (January 2003), demonstrating the ability to examine the high-stress region and lower knuckle to bottom weld. An extended arm for UT examination allows more area of the knuckle to be examined above the high-stress region. An improved T-SAFT system was developed in FY 2014.
	Examine primary tank bottom as practical for cracks, pits, and wall thinning, on a "best effort" basis.	Primary tank bottoms were scheduled to be examined through accessible air-slots for wall thinning and circumferential cracks, on six DSTs. However this work was cancelled because of access issues. Per Milestone M-48, the examination shall extend at least 10 ft toward the center of the tank from the lower knuckle joint or to the length practical within the limits of best available equipment. Extent of examination is dependent on surface conditions, obstructions, and geometry constraints.	N/A—current approach complies with TSIP guidance for tank bottoms.	None.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Extent of examination (cont.)	External surface of primary tank. In accessible regions: Ten areas of 1 ft^2 thickness measurements.	Each of the 28 DSTs were examined over an approximately 35-ft by 60-in. wide vertical strip, regardless of waste surface level. Overall coverage of vertical wall exam is approximately 175 ft^2. Wall examinations also include 20 ft of vertical welds, and 20 ft of vertical wall/lower knuckle weld.	N/A—current approach complies with and exceeds TSIP guidance.	None.
	Secondary tank: Five areas of 1 ft^2 and 5% of knuckle region welds.	Examination of a 20-ft length of the secondary tank knuckle (for selected tanks) and, at a minimum, 25 ft^2 of the secondary tank floor (all of the DSTs), for wall thinning, pits, and cracks.	N/A—current approach exceeds TSIP guidance.	None.
Evaluation criteria and acceptance levels	• Wall thinning: 20% of nominal wall thickness (t) • Pits: 50% t • Cracks < 12 in.: 50% t • Cracks > 12 in.: 20% t	Action level for review— • Wall thinning: ≥ 20% t • Pits: ≥ 50% t • Cracks < 12 in.: 3/16 in. • Cracks > 12 in.: 3/16 in. Reportable level for documentation— • Wall thinning: ≥ 10% t • Pits: ≥ 25% t • Cracks > 6 in.: ≥ 10% t Notable level— • Pits: ≥ 10% t	• N/A—for wall thinning and pits (same as TSIP) • Hanford acceptance criteria for crack depth is equal to or more stringent than TSIP guidance for crack length < 12 in., but less stringent for crack length > 12 in. Hanford acceptance criteria for crack length > 12 in. is to have a single conservative value for crack-depth acceptance criteria, independent of plate thickness, is less prone to error than one that varies with plate thickness (i.e., used 50% of 3/8-in. plate). • The level was established to distinguish between thinning caused by thinning and that associated with localized corrosion.	ASME B&PV Code (Section XI, IWC-2424)* was used as a reference in developing Hanford reportable levels.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Evaluation criteria and acceptance levels (cont.)	Additional examinations are to follow ASME B&PV Code (Section XI, IWC-2430)*. Examination results that exceed acceptance criteria require extending the examination to include additional areas of similar material and service	Where indications are found, additional examinations are performed, as directed by an expert panel (IDRT, as described in Section 4.4).	N/A—practice at Hanford has evolved: • Increasing the sample size to all 28 DSTs versus original scope of 6 DSTs. • Extending examinations, in the same tank, when acceptance criteria was triggered or approximated, based on recommendations of the IDRT.	ASME B&PV Code (Section XI, IWC-2430 and IWA-2430)* were used as references in developing Hanford standards.
	Repair or corrective action for > 75% t.	Repair not currently an option.	N/A.	None.
Acceptance criteria	None.	Evaluation of indications exceeding the acceptance levels are documented, tracked, and evaluated by the Hanford occurrence reporting system. Part of this disposition includes assembling a UT inspection review panel comprised of appropriate subject matter experts. Analysis of indications is performed in accordance with industry-accepted methods (e.g., ASME B&PV Code (Section XI)*, American Petroleum Institute, Electric Power Research Institute, or National Aeronautics and Space Administration).	N/A–not covered by TSIP guidelines.	None.
Frequency	10 years.	• Initial inspection occurred more than 10 years after DSTs placed in service. • Repeat inspections planned at 8- to 10-year intervals.	• UT program for DSTs established when draft TSIP guidelines became available, codified in Milestone M series. • Intervals for repeat inspections are consistent with TSIP guidelines.	ASME B&PV Code (Section XI, IWA-2432)* is used as a reference for development of frequencies.
Schedule	None.	See frequency.	N/A.	None.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Equipment	Capability of detection and sizing – must detect 50% of nominal wall thickness (t) pits, 20% t thinning, 20% t for 1-ft length, and 50% t for shorter cracks; uncertainty no more than ± 20% of these values	• Wall thinning: ± 0.02 in. • Pits: ± 0.05 in. • Cracks: ± 0.1 in.	Rationale: Accuracy limits for Hanford DSTs were established not as a function of plate thickness, but based on actual equipment capability as demonstrated in performance demonstration tests administered by the Pacific Northwest National Laboratory in 1998 and 2000. Accuracy limits for thinning and pitting in Hanford DSTs are equal to or more stringent than TSIP recommendations for 1/2 in. or heavier plate sizes, but less stringent for 3/8-in. plate size. Accuracy limits for crack depth in Hanford DSTs are less stringent than TSIP recommendations.	ASME B&PV Code (Section XI, Appendix VIII)* used for SCC.
Inspector qualifications	ANSI/ASNT CP-189*[a]	NDE personnel are qualified in accordance with ASNT Recommended Practice SNT-TC-1A-92*.	Both ASNT CP-189 and SNT-TC-1A-92[a] were considered in establishing qualification requirements for personnel. SNT-TC-1A was considered adequate for tank inspections, and was selected. At the time of selection, most NDE technicians were being qualified to SNT-TC-1A. Additionally, intergranular-stress corrosion cracking training is required for NDE Level III technicians.	None.
UT procedure requirements	Applicable portions of ASME B&PV Code (Section XI Appendix VIII) should be limited to 2100 (a), (b), (c), and (d); and Supplements 2 and 3.	The ultrasonic test contractor procedure includes all elements in ASME B&PV Code (Section XI, Appendix VIII-2100)*, does not include Supplements 2 and 3 since they do not apply to tanks.	N/A—the UT procedure for DSTs complies with TSIP guidance. Supplements 2 and 3 apply to piping—not to tanks.	None.
Action limits	See evaluation criteria.	See evaluation criteria.	See evaluation criteria.	None.

Table C-1. Hanford Double-Shell Tank Integrity Ultrasonic Testing Program Elements. (7 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Records management	None.	• 10 CFR 820 • 36 CFR 1234 • DOE O 200.1 • DOE O 414.1A • DOE O 1324.5B	None.	None.

*See Section C2.0.

[a]Lower knuckle of primary tank. Predicted maximum stress region of base metal plus lower weld, if accessible.

[b]Exceptions: On Tanks AY-101 and AY-102, lower knuckle weld could not be examined because concrete splatter. Instead, 20 ft of the lowest accessible horizontal weld is examined, which in Tank AY-102 was the weld joining plate #2 to plate #3. On Tank AW-103 (the first tank examined—in 1997) welds were not examined, except where included in the 10.25 in. wide vertical strips.

ANSI® = American National Standards Institute, Inc.
ASME® = American Society of Mechanical Engineers.
B&PV = Boiler and Pressure Vessel.
BNL = Brookhaven National Laboratory.
DOE = U.S. Department of Energy.
DST = double-shell tank.
Ecology = Washington State Department of Ecology.
FY = fiscal year.
HAZ = heat-affected zone.
IDRT = Integrity Data Review Team.
IQRPE = Independent Qualified Registered Professional Engineer.
LAI = liquid-air interface.
N/A = not applicable.
NDE = nondestructive examination.
P-scan™ = pulse-echo ultrasonic inspection. Trade name used by FORCE Technology, Brøndby, Denmark.
SAFT = Synthetic Aperture Focusing Technique.
t = thickness.
T-SAFT = Tandem-Synthetic Aperture Focusing Technique.
TSIP = Tank Structural Integrity Panel.
UT = ultrasonic testing.

Table C-2. Hanford Double-Shell Tank Integrity Visual Program Elements. (2 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Tank selection	At least 10% (or one, if < 10%); selection based on age, severity of operating conditions, and transients; if not homogenous, > 10% may be required to represent worst-case	All DSTs, both primary interior and annulus examinations.	Exceeds TSIP guidelines.	None.
	If > 10% are examined, opt to reduce percent per tank accordingly.		No reduction used.	None.
Extent of examination	External surface of primary tank, if accessible, and internal surface of secondary tank, if such exists. Overall scan of accessible regions.	Examination form four risers providing close to 360-degree coverage of primary tank external and secondary liner internal surfaces.	Accessible areas examined,	None,
	Vapor region at top of primary tank.	The internal dome and wall above the liquid level.	Accessible areas examined,	None,
	Overall scan of internal surface when tank is essentially empty.	Examination to be performed.	Accessible areas examined,	None,
Evaluation criteria	Any signs of degradation must be evaluated.	Signs of degradation and/or leakage must be evaluated. Compare results to previous inspections for signs of change.	Meets guidelines,	None,
Acceptance criteria	Any signs of degradation must be evaluated.	Signs of degradation and/or leakage must be evaluated.	Meets guidelines.	None.
Frequency	At least once each inspection interval (10 years).	Examinations done routinely on a 5- to 7-year frequency and when UT examinations indicate conditions requiring visual examination.	Exceeds guidelines.	Visual baseline complete in FY 2003.
Schedule	None.	See frequency.	See frequency.	None.

Table C-2. Hanford Double-Shell Tank Integrity Visual Program Elements. (2 sheets)

Ultrasonic testing	Tank structural integrity panel (BNL-52527/UC-406)*	Hanford double-shell tank integrity program	Rationale for departure from tank structural integrity panel guidelines	Comments
Equipment	None.	Video cameras are used to visually examine areas.	N/A.	WRPS qualifications for equipment and operators are used.
Inspector qualifications	ANSI/ANST CP-189*	No certified visual examiners are used. Engineers with experience are used to determine degradation.	ASME B&PV Code examinations are not performed. However, inspection team member qualifications have been reviewed and approved by the IQRPE (per Huber 2003*).	None.
Action limits	See evaluation criteria.	See evaluation criteria.	See evaluation criteria.	None.
Records management	None.	• 10 CFR 820 • 36 CFR 1234 • DOE O 200.1 • DOE O 414.1 • DOE O 1324.5B	N/A.	None.

ANSI® = American National Standards Institute, Inc.
DST = double-shell tank.
FY = fiscal year.
IQRPE = Independent Qualified Registered Professional Engineer.
N/A = not applicable.
TSIP = Tank Structural Integrity Panel.
UT = ultrasonic testing.
WRPS = Washington River Protection Solutions, LLC.

Table C-3. Hanford Site Double-Shell Tank Integrity Ultrasonic Testing Program Schedule Projection.

Fiscal year	Tank	Last report release date	Performance (+8 year)	Performance (+10 year)
FY 16	AN-105	3/8/2006	3/8/2014	3/8/2016
	AW-103	12/21/2006	12/21/2014	12/21/2016
FY17	AY-101	7/30/2007	7/30/2015	7/30/2017
	AN-106	8/3/2007	8/3/2015	8/3/2017
	AZ-101	8/27/2007	8/27/2015	8/27/2017
FY 18	AP-107	6/2/2008	6/2/2016	6/2/2018
	AP-108	8/29/2008	8/29/2016	8/29/2018
	AN-102	9/29/2008	9/29/2016	9/29/2018
FY 19	AW-101	4/24/2009	4/24/2017	4/24/2019
	AW-105	6/22/2009	6/22/2017	6/22/2019
	AW-106	9/28/2009	9/28/2017	9/28/2019
FY 20	AW-102	5/13/2010	5/13/2018	5/13/2020
	AW-104	7/12/2010	7/12/2018	7/12/2020
	AP-103	8/30/2010	8/30/2018	8/30/2020
FY 21	AN-107	5/1/2011	5/1/2019	5/1/2021
	AN-101	9/23/2011	9/23/2019	9/23/2021
	AZ-102	1/23/2012	1/23/2020	1/23/2022
	AP-105	3/8/2012	3/8/2020	3/8/2022
FY 22	SY-101	7/18/2012	7/18/2020	7/18/2022
	SY-103	2/25/2013	2/25/2021	2/25/2023
	SY-102	8/27/2013	8/27/2021	8/27/2023
FY 23	AP-101	9/20/2013	9/20/2021	9/20/2023
	AP-104	6/10/2014	6/10/2022	6/10/2024
	AP-106	9/11/2014	9/11/2022	9/11/2024
FY 24	AP-102	3/10/2015	3/10/2023	3/10/2025
	AN-103	8/3/2015	8/3/2023	8/3/2025
	AN-104	9/16/2005	9/16/2013	9/16/2015

Table C-4. Hanford Site Double-Shell Tank Integrity Visual Inspection Program Schedule Projection. (2 pages)

Fiscal year	Tank	Date of last visual inspection	DUE early by (+33 months)	Periodicity (+36 months)	DUE latest by (+45 months)	95% inspection round
FY 16	AN-101	4/7/2011	1/7/2014	4/7/2014	1/7/2015	Round 1
	AN-103	3/25/2013	12/25/2015	3/25/2016	12/25/2016	Round 1
	AN-104	12/2/2009	9/2/2012	12/2/2012	9/2/2013	Round 1
	AN-105	12/4/2009	9/4/2012	12/4/2012	9/4/2013	Round 1
	AN-106	2/2/2011	11/2/2013	2/2/2014	11/2/2014	Round 1
	AW-106	5/14/2009	2/14/2012	5/14/2012	2/14/2013	Round 1
	AW-103	5/12/2011	2/12/2014	5/12/2014	2/12/2015	Round 1
	SY-101	2/8/2013	11/8/2015	2/8/2016	11/8/2016	Round 2
	SY-102	3/8/2013	12/8/2015	3/8/2016	12/8/2016	Round 2
	SY-103	2/7/2013	11/7/2015	2/7/2016	11/7/2016	Round 2
FY 17	AZ-101	1/15/2013	10/15/2015	1/15/2016	10/15/2016	Round 2
	AZ-102	2/27/2013	11/27/2015	2/27/2016	11/27/2016	Round 2
	AW-105	4/23/2014	1/23/2017	4/23/2017	1/23/2018	Round 2
	AN-102	5/27/2014	2/27/2017	5/27/2017	2/27/2018	Round 2
	AN-107	5/29/2014	3/1/2017	5/29/2017	3/1/2018	Round 2
	AP-107	8/9/2013	5/9/2016	8/9/2016	5/9/2017	Round 2
	AP-101	11/7/2013	8/7/2016	11/7/2016	8/7/2017	Round 2
	AY-101	9/10/2014	6/10/2017	9/10/2017	6/10/2018	Round 2
FY 18	AW-101	12/18/2014	9/18/2017	12/18/2017	9/18/2018	Round 2
	AW-102	1/21/2015	10/21/2017	1/21/2018	10/21/2018	Round 2
	AW-104	1/21/2015	10/21/2017	1/21/2018	10/21/2018	Round 2
	AP-104	11/20/2014	8/20/2017	11/20/2017	8/20/2018	Round 2
	AP-102	1/14/2015	10/14/2017	1/14/2018	10/14/2018	Round 2
	AP-106	1/15/2015	10/15/2017	1/15/2018	10/15/2018	Round 2
	AP-108	1/19/2015	10/19/2017	1/19/2018	10/19/2018	Round 2
	AP-103	1/20/2015	10/20/2017	1/20/2018	10/20/2018	Round 2
	AP-105	1/20/2015	10/20/2017	1/20/2018	10/20/2018	Round 2

Table C-4. Hanford Site Double-Shell Tank Integrity Visual Inspection Program Schedule Projection. (2 pages)

Fiscal year	Tank	Date of last visual inspection	DUE early by (+33 months)	Periodicity (+36 months)	DUE latest by (+45 months)	95% inspection round
FY 19	AN-103	November-15	8/1/2018	11/1/2018	8/1/2019	Round 3
	AN-104	December-15	9/1/2018	12/1/2018	9/1/2019	Round 3
	AN-105	January-16	10/1/2018	1/1/2019	10/1/2019	Round 3
	AN-106	February-16	11/1/2018	2/1/2019	11/1/2019	Round 3
	AN-101	October-15	7/1/2018	10/1/2018	7/1/2019	Round 3
	AN-102	February-17	11/1/2019	2/1/2020	11/1/2020	Round 3
	AN-107	March-17	12/1/2019	3/1/2020	12/1/2020	Round 3
	AZ-101	October-16	7/1/2019	10/1/2019	7/1/2020	Round 3
	AZ-102	October-16	7/1/2019	10/1/2019	7/1/2020	Round 3
FY 20	AW-106	March-16	12/1/2018	3/1/2019	12/1/2019	Round 3
	AW-103	April-16	1/1/2019	4/1/2019	1/1/2020	Round 3
	AW-105	January-17	10/1/2019	1/1/2020	10/1/2020	Round 3
	SY-101	May-16	2/1/2019	5/1/2019	2/1/2020	Round 3
	SY-102	June-16	3/1/2019	6/1/2019	3/1/2020	Round 3
	SY-103	July-16	4/1/2019	7/1/2019	4/1/2020	Round 3
	AW-101	October-17	7/1/2020	10/1/2020	7/1/2021	Round 3
	AW-102	November-17	8/1/2020	11/1/2020	8/1/2021	Round 3
	AW-104	December-17	9/1/2020	12/1/2020	9/1/2021	Round 3
FY 21	AP-107	April-17	1/1/2020	4/1/2020	1/1/2021	Round 3
	AP-101	May-17	2/1/2020	5/1/2020	2/1/2021	Round 3
	AY-101	June-17	3/1/2020	6/1/2020	3/1/2021	Round 3
	AP-104	January-18	10/1/2020	1/1/2021	10/1/2021	Round 3
	AP-102	February-18	11/1/2020	2/1/2021	11/1/2021	Round 3
	AP-106	March-18	12/1/2020	3/1/2021	12/1/2021	Round 3
	AP-108	April-18	1/1/2021	4/1/2021	1/1/2022	Round 3
	AP-103	May-18	2/1/2021	5/1/2021	2/1/2022	Round 3
	AP-105	June-18	3/1/2021	6/1/2021	3/1/2022	Round 3

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APPENDIX D

ROADMAP OF DOUBLE-SHELL TANK REFERENCES

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TERMS

CPP	cyclic potentiodynamic polarization
DLR	dome load record
DLRSS	dome load records summary sheet
DNV, Inc.	Det Norske Veritas, Inc.
DOE	U.S. Department of Energy
DST	double-shell tank
DSTAR	Double-Shell Tank Integrity Assessment Report
DSTIP	Double-Shell Tank Integrity Project
Ecology	Washington State Department of Ecology
EMAT	electromagnetic acoustic transducer
EPOC	Expert Panel Oversight Committee
FFS	fitness-for-service
FY	fiscal year
HIAP	High-Level Waste Integrity Assessment Panel
HLW	high-level waste
IDMS	Integrated Data Management System
IQRPE	Independent Qualified Registered Professional Engineer
LAI	liquid-air interface
LDP	leak detection pit
MPCMS	Multi-Probe Corrosion Monitoring System
NDE	nondestructive examination
OSD	Operating Specification Document
PNNL	Pacific Northwest National Laboratory
PUREX	plutonium-uranium extraction
RCMP	retractable corrosion monitoring probe
RCRA	*Resource Conservation and Recovery Act of 1976*
SCC	stress corrosion cracking
SRNL	Savannah River National Laboratory
SST	single-shell tank
SSTIP	Single-Shell Tank Integrity Panel
TPA	Tri-Party Agreement
TSD	treatment storage and disposal
TSIP	Tank Structural Integrity Panel
UT	ultrasonic testing
WAC	*Washington Administrative Code*
WRPS	Washington River Protection *Solutions*, LLC
WTS	Waste Transfer System

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D1.0 INTRODUCTION

The Double-Shell Tank Integrity Project (DSTIP) has sought advice from numerous expert panels, conducted inspection of the double-shell tanks (DSTs) since 1992, and developed data and technology to enhance the knowledge of tank integrity. Though this information is available through either U.S. Department of Energy- (DOE)-wide or Hanford Site-specific information systems, the collection of pertinent documents may not be apparent to all parties. This appendix provides the correlation to key documents to the areas of importance for tank integrity.

The areas of importance in tank integrity, shown in Figure D-1, include:

- Expert Panel advice, which has guided the DSTIP;
- Integrity Assessments, which demonstrate the adequacy of design or investigate events;
- Operating Specifications, which govern the operation of the DSTs;
- Integrity Inspections, which provide data as to condition of the DSTs
- Structural Integrity, which evaluate the DSTs against consensus code;
- Corrosion Control, which defines acceptable chemistry ranges for the tanks and monitors tank corrosion potential; and
- Waste Transfer System, which establishes fitness-for-service criteria for piping systems.

Figure D-2 and Figure D-3 depict the work associated with the DSTIP. The headings are indexed to a section number in this appendix that contains the full reference and abstract for each document.

Figure D-4 shows the Waste Transfer System work done to establish corrosion rates for the Waste Transfer System piping. This body of work is documented in RPP-RPT-52791, *Tank Farm Waste Transfer System Fitness-for-Service Erosion and Corrosion Basis*.

Future activities are shown in Figure D-5. These activities generally come from two sources:

1. The required periodic visual, ultrasonic, and dome deflection inspection of the tanks and the maintenance activities that go with monitoring the corrosion probes and keeping the operating specifications current.
2. The technology development and corrosion testing that originated from the Tank Integrity Expert Panel and Expert Panel Oversight Committee recommendations. These recommendations are documented in RPP-PLAN-57352, *Double-Shell Tank Integrity Improvement Plan*.

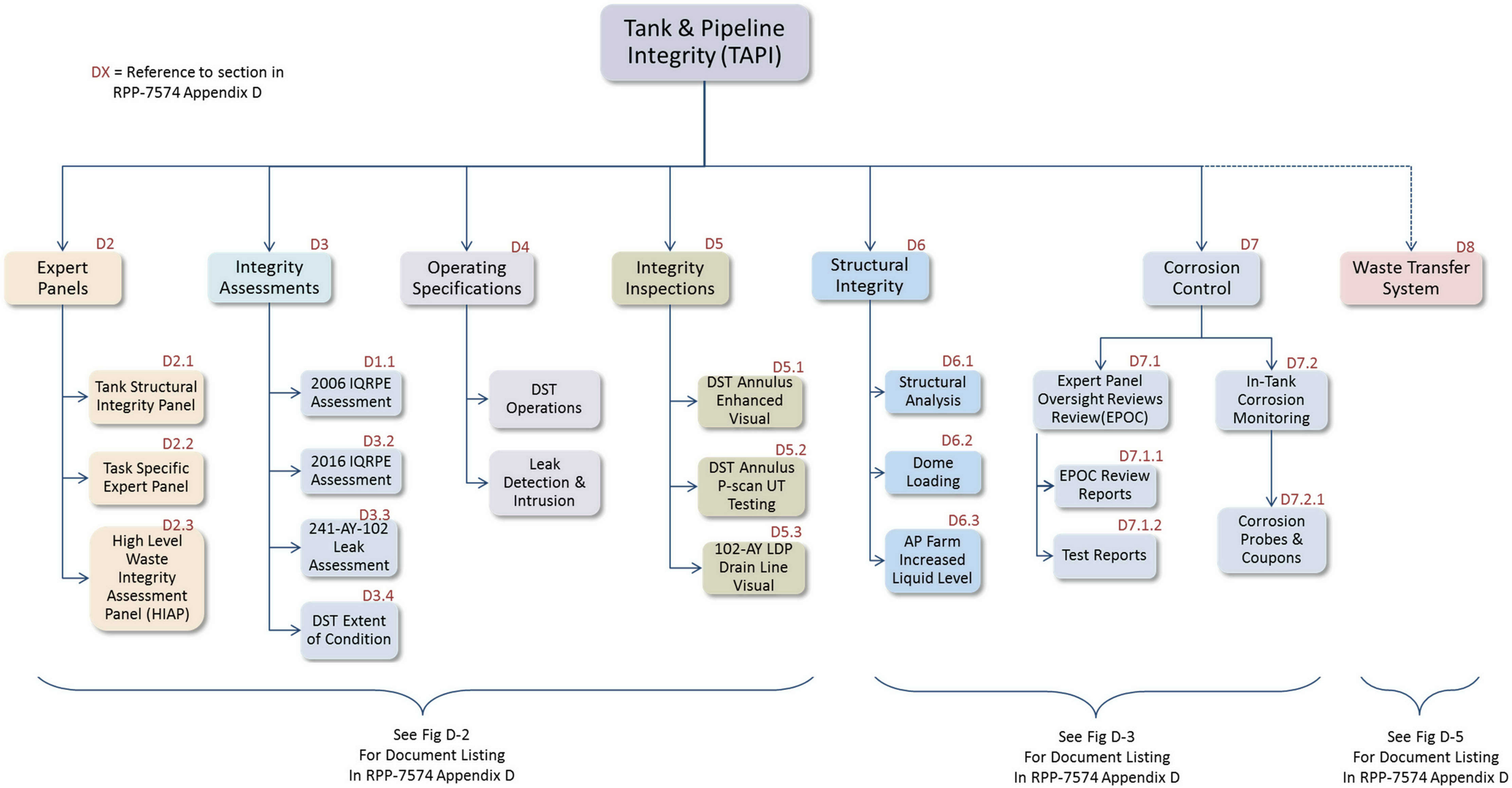

Figure D-1. Double-Shell Tank Integrity Project Functions.

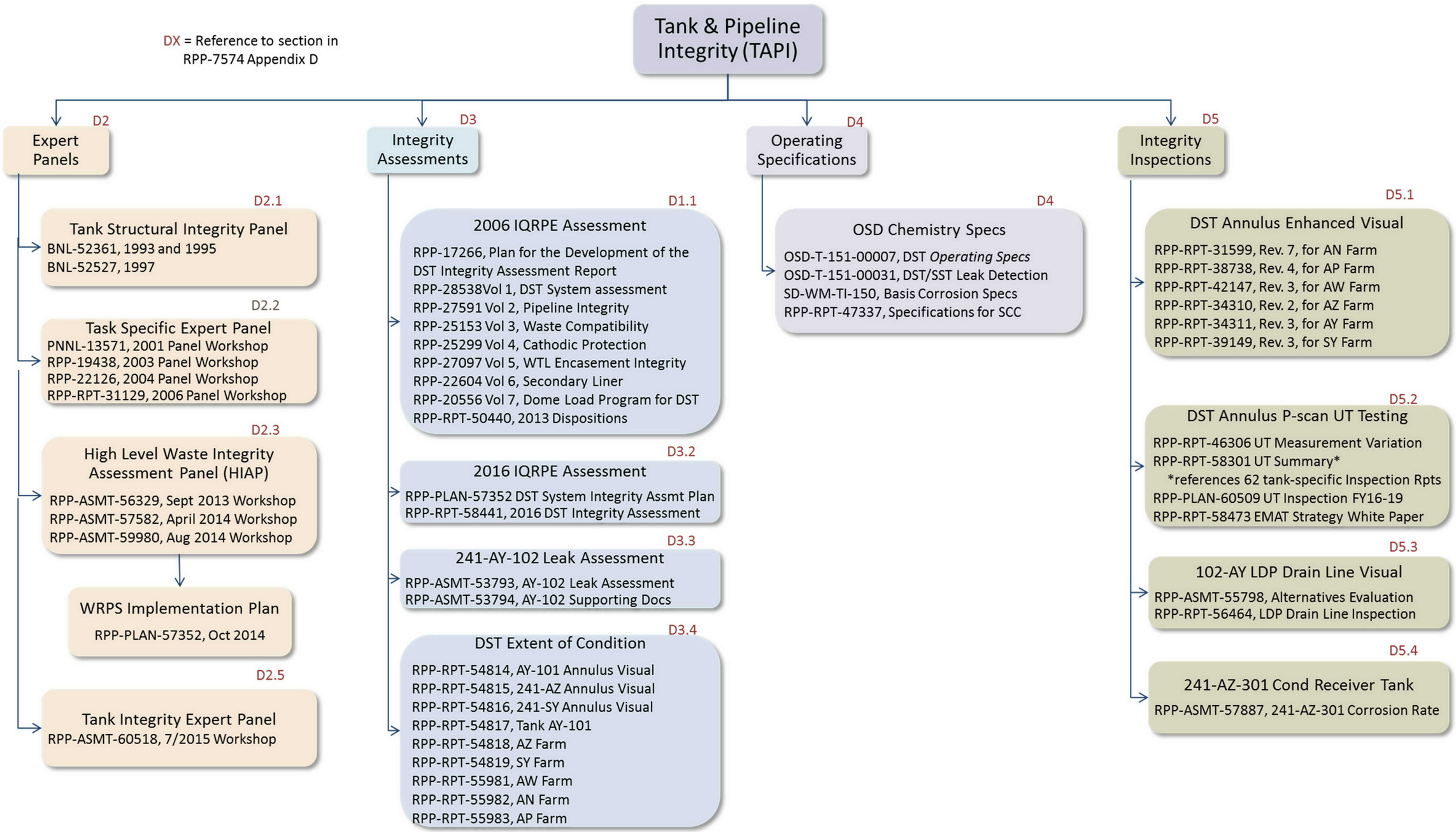

Figure D-2. Completed Work Associated with the Double-Shell Tank Integrity Program Reviews. (Sheet 1)

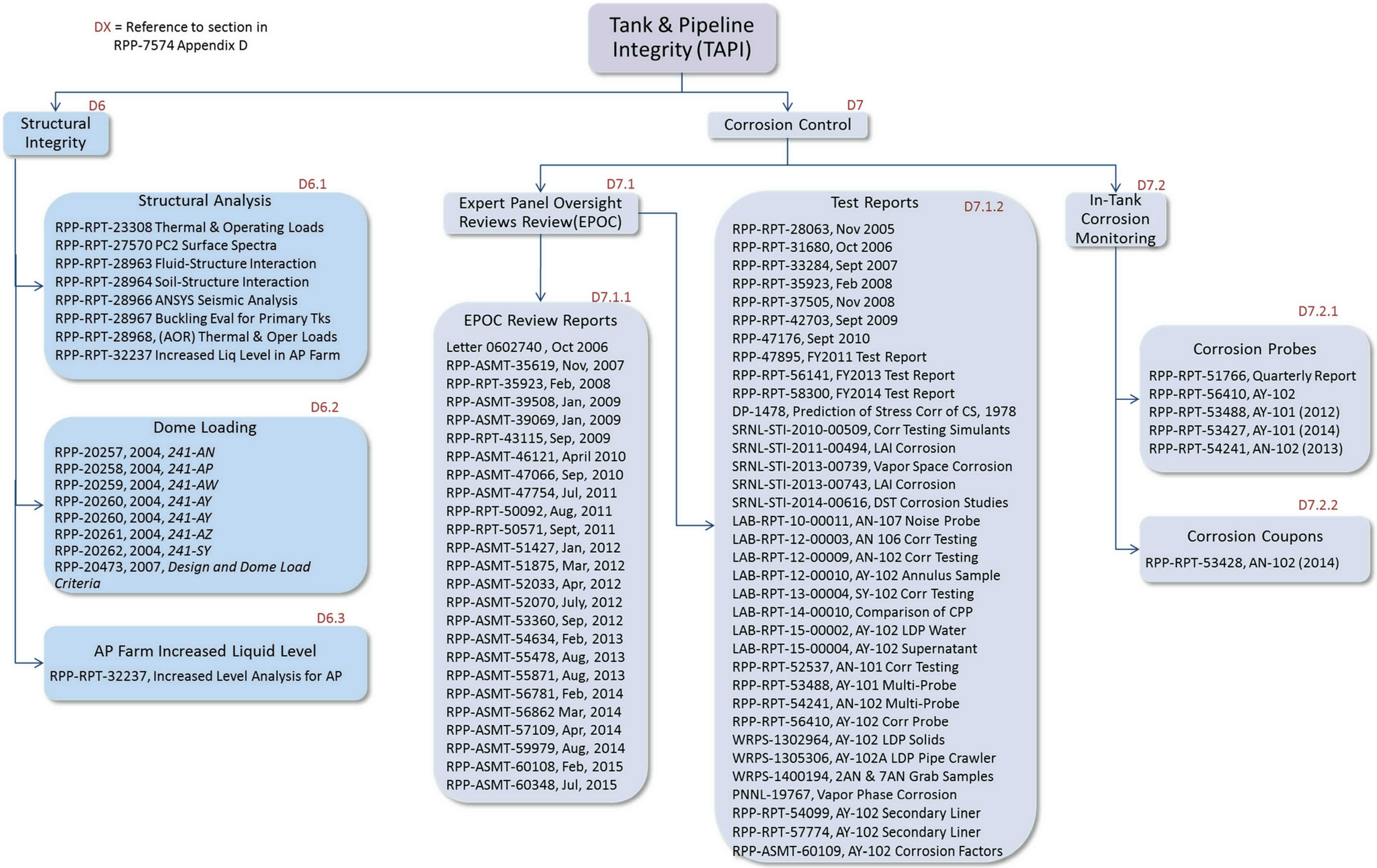

Figure D-3. Completed Work Associated with the Double-Shell Tank Integrity Program Reviews. (Sheet 2)

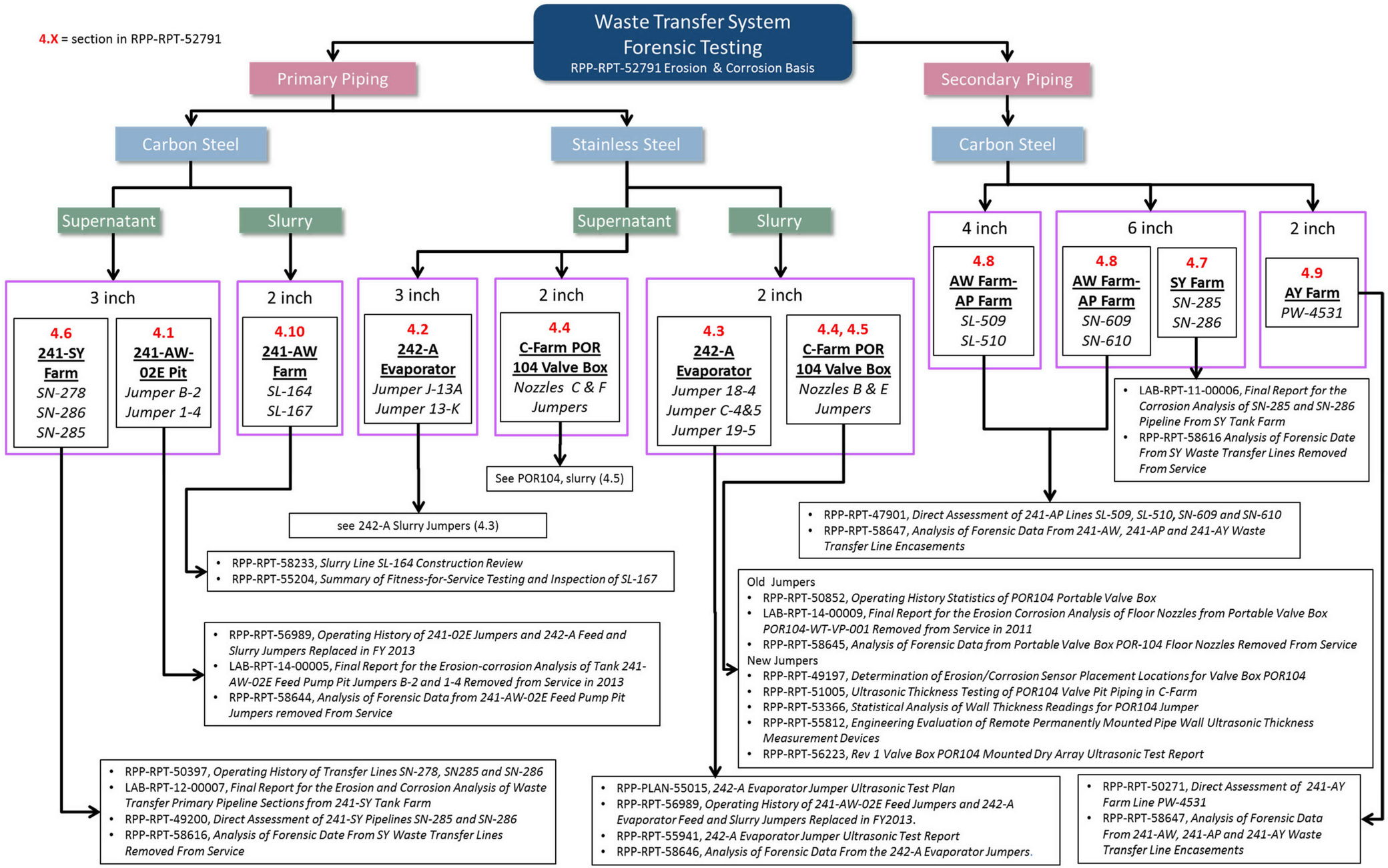

Figure D-4. Waste Transfer Line Erosion/Corrosion Assessments.

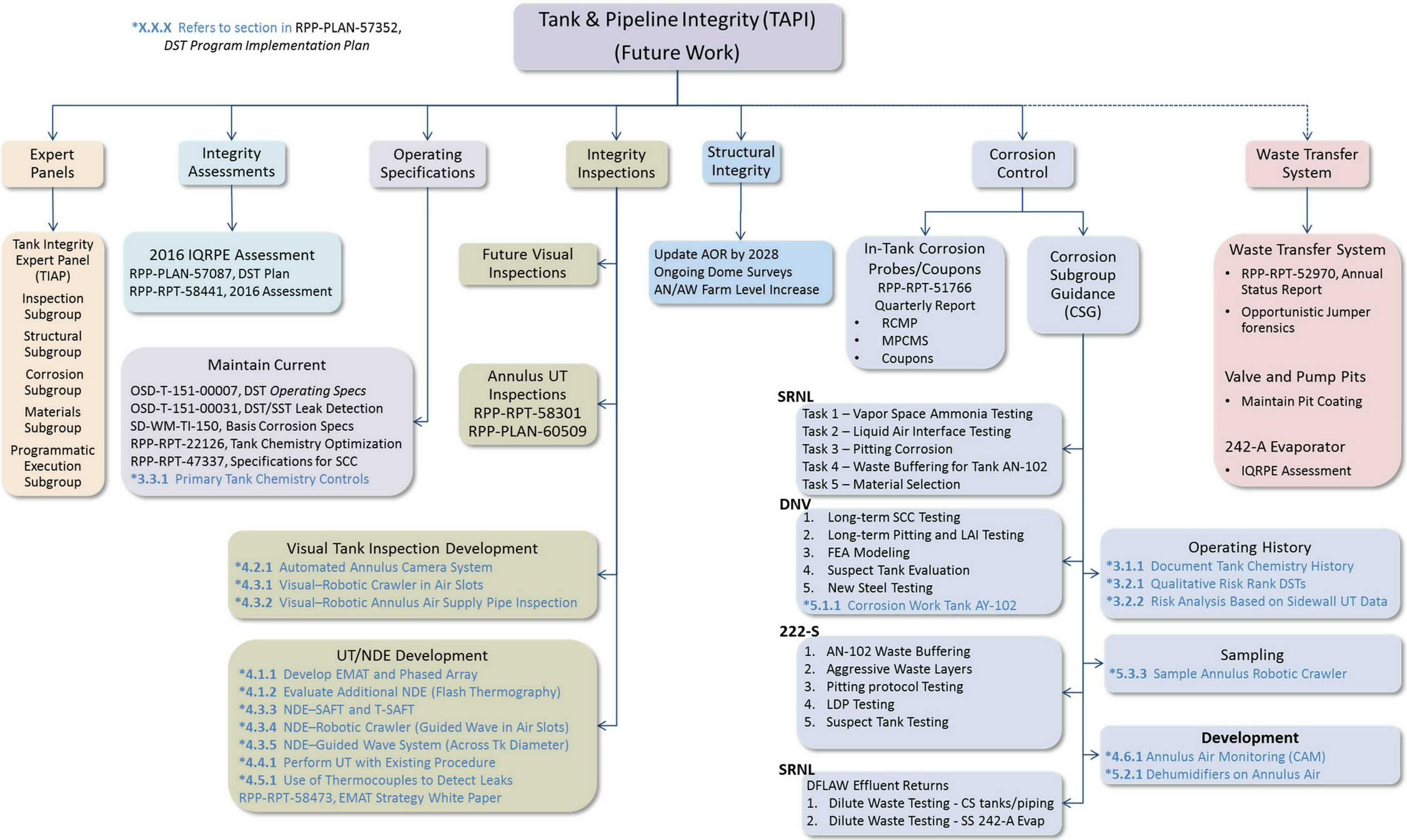

Figure D-5. Future Double-Shell Tank Integrity Program Activities.

D2.0 EXPERT PANELS

A number of expert panels has advised DOE and its contractors with respect to tank integrity. The DSTIP has used this advice in the development of its program and activities. Currently the DSTIP is advised by the Tank Integrity Expert Panel, which is a consolidation of members from the Expert Panel Oversight Committee, Single-Shell Tank Integrity Panel, and the High-Level Waste Integrity Assessment Panel.

D2.1 TANK STRUCTURAL INTEGRITY PANEL

BNL-52361, 1993 and 1995
BNL-52527, 1997

The lack of a consensus standard for the storage of high-level waste (HLW) led the DOE to convene the Tank Structural Integrity Panel (TSIP). This panel produced two reports: (1) the first dealt with structural analysis of HLW storage tanks and (2) the second addressed the overall program for tank integrity. These reports were used to develop site-specific plans for DOE sites.

BNL-52361, 1993 and 1995, *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Tanks and Appurtenances*, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York.

> **Abstract:** This report provides seismic design and evaluation guidelines for underground high-level waste storage tanks. The guidelines reflect the knowledge acquired in the last two decades in defining seismic ground motion and calculating hydrodynamic loads, dynamic soil pressures and other loads for underground tank structures, piping, and equipment. The application of the guidelines is illustrated with examples.

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

> **Abstract:** Guidelines are provided for developing programs to promote the structural integrity of high-level waste storage tanks and transfer lines at the facilities of the U.S. Department of Energy. Elements of the program plan include a leak-detection system, definition of appropriate loads, collection of data for possible material and geometric changes, assessment of the tank structure, and nondestructive examination. Possible aging degradation mechanisms are explored for steel and concrete components of the tanks, and evaluated to screen out non-significant aging mechanisms and to indicate methods of controlling the significant aging mechanisms.

D2.2 TASK-SPECIFIC EXPERT PANELS

The DSTIP used task-specific panels to address topics of special interest with respect to tank integrity. These panels worked independently of each other, but used common resources and members. The reports produced by these panels provided recommendation for the enhancement of DSTIP.

PNNL-13571, May 2001 Workshop
RPP-19438, Oct 2003 Workshop
RPP-RPT-22126, Apr/May2004 Workshops
RPP-RPT-31129, Jul 2006 Workshop

PNNL-13571, 2001, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*, Pacific Northwest National Laboratory, Richland, Washington.

> **Abstract:** An expert workshop was held in Richland, Washington, May 1 through 4, 2001, to review the Hanford Site (DSTIP and make recommendations to extend the life of the DSTs. The scope of the workshop was limited to corrosion of the primary tank liner, and the main areas for review were waste chemistry control, headspace and annulus humidity control, tank inspection, and corrosion monitoring.

RPP-19438, 2005, *Report of Expert Panel Workshop for Hanford Site Double-Shell Tank Waste Level Increase*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

> **Abstract:** An expert panel workshop was held in Richland, Washington, October 14 through 16, 2003, to review all aspects and issues associated with raising the waste levels of the Hanford Site DST above the original design basis, and to make recommendations to safely accomplish this new service rating for the DSTs. The scope of the workshop was to provide a thorough review and assessment of the Hanford Site DST integrity basis for support of the waste level increase. The expert panel was to provide recommendations for maximum waste fill height, using recommended fill controls and additional testing. The desired outcome of the workshop was to provide a credible validated technical basis for DST waste level maximums, with technical information and justification to support the independent qualified professional engineer certifications of DST adequacy.
>
> Participants included structural, nondestructive testing, statistical, mechanical, metallurgical, and corrosion experts from the Hanford Site, the Savannah River Site, Brookhaven National Laboratory, Pacific Northwest National Laboratory, Ames Laboratory, and Los Alamos National Laboratory, and several industry experts. The workshop developed specific recommendations and suggested controls to allow the DST design waste height to be raised to 460 in. and the operational waste height to 449 in., in selected tank farms. This report describes the topics, issues, and problems discussed at the workshop, the final recommendations of the workshop panel, and the rationale for their selection.

RPP-RPT-22126, 2004, *Expert Panel Workshop for Hanford Site Double-Shell Tank Waste Chemistry Optimization*, Revision 0, CH2M HILL Hanford Group Inc., Richland, Washington.

Abstract: Two expert panel workshops were held to provide a thorough and comprehensive assessment of three proposed waste chemistry initiatives. Each initiative is to develop a credible, validated, technical basis for safe implementation. The proposals reviewed were to:

I. Define an acceptable time period during which DSTs can be safely operated outside the established chemistry control limits without risking the integrity or mission life of the primary tank;

II. Identify an approach for reducing or eliminating the number of sludge core samples taken from the DSTs without risking the integrity or mission life of the primary tank; and

III. Revise the conservative chemistry control limits based on currently available information with respect to general and localized corrosion and confirm an Accelerated Stress-Corrosion Cracking Experimental Program.

The workshops, which were held in Richland, Washington, April 14 through 16 and July 13 through 15, 2004, reviewed all aspects and issues associated with three initiatives. The first workshop addressed the first two proposed initiatives and the second workshop addressed the third proposed initiative. Both workshops reviewed the assumptions, methodology, and conclusions associated with proposed revisions to the Hanford Site DST Corrosion Chemistry Program.

Participants included metallurgists, materials scientists, electrochemists, chemists, corrosion experts, and chemical and mechanical engineers from academia, industry, the Savannah River Site, Brookhaven National Laboratory, and Pacific Northwest National Laboratory. The workshop developed specific recommendations and offered additional technical guidance to enhance the conduct of the site chemistry control program. This report describes, for each proposed initiative, the topics, issues, and problems discussed during and following the workshops, the final recommendations of the workshop panel, and the rationale for those recommendations.

RPP-RPT-31129, 2006, *Expert Panel Workshop on Double-Shell Tank Vapor Space Corrosion Testing*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: An Expert Panel workshop was held to provide an assessment of Hanford Site and Savannah River Site DST vapor space and liquid/air interface corrosion, and, to develop credible, validated technical bases for corrosion and chemistry monitoring in the waste tanks, and corrosion testing in simulated tank environments. The workshop, which was held in Richland, Washington, July 10 through 12, 2006, reviewed aspects and issues associated with corrosion in the vapor space and at the liquid/air interface.

Panel Members included metallurgists, electrochemists, chemists, corrosion engineers, and chemical and mechanical engineers from academia, industry, the Savannah River National Laboratory, and Pacific Northwest National Laboratory. Individuals from the Defense Nuclear Facilities Safety Board, Washington State Department of Ecology, U.S. Department of Energy, Office of River Protection, CH2M HILL Hanford Group, Inc., and private industry also participated. The workshop developed specific recommendations and offered additional technical guidance to enhance the conduct of vapor space and liquid/air interface corrosion testing. This report describes the topics, issues, and challenges discussed during and following the workshop, the final recommendations of the workshop panel, and the rationale for those recommendations.

D2.3 HIGH-LEVEL WASTE INTEGRITY ASSESSMENT PANEL

RPP-ASMT-56329, Sept 2013 Workshop
RPP-ASMT-57582, Apr 2014 Workshop
RPP-PLAN-57352, Oct 2014 Improvement Plan
RPP-ASMT-59980, Aug 2014 Workshop

The Chief Engineer for Washington River Protection *Solutions*, LLC (WRPS) formed the High-Level Waste Integrity Assessment Panel (HIAP) as a response to the high-radioactive decay counts measured on a pump, which had been used in the Leak Detection Pit in 241-AY-102 (Tank AY-102). These high counts led to a concern that waste leaked into the annulus of Tank AY-102 had cause a breach in the secondary containment for the tank.

RPP-ASMT-56329, 2014, *First Workshop of the Comprehensive Review of Double-Shell Tank Structural and Leak Integrity Panel: 241-AY-102 Leak Assessment*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The Comprehensive Review of the DST Structural and Leak Integrity Panel reviewed the technical bases of the DST integrity program to: (1) determine why the existing program did not predict a primary tank failure in Tank AY-102, (2) recommend activities to either predict a primary tank failure or increase the probability of early warning, and (3) recommend enhancements to the program to prevent or minimize degradation of DSTs. The Panel was briefed at a meeting in September 2013 on status of the Tank AY-102 leak assessment and activities related to the continued evaluation of the leak. The attached meeting summary provided initial Panel questions, issues and concerns, and proposed next steps.

RPP-ASMT-57582, 2014, *Second Workshop of the High Level Waste Integrity Assessment Panel: Extent of Condition and Balance of Program*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The High-Level Waste Integrity Assessment Panel includes nationally recognized experts in corrosion chemistry and structural tank integrity issues who convened three times in fiscal year (FY) 2013 and FY 2014 to review Tank AY-102 status, along with the integrity of all Hanford Site DSTs. The Panel identified and documented specific recommendations.

RPP-PLAN-57352, 2014, *Double-Shell Tank Integrity Improvement Plan*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The High-Level Waste Integrity Assessment Panel includes nationally recognized experts in corrosion chemistry and structural tank integrity issues who convened three times in FY 2013 and FY 2014 to review the Tank AY-102 status, along with the integrity of all Hanford Site DSTs. The Panel identified specific recommendations documented in RPP-ASMT-57582. The WRPS engineering staff developed a path forward for each recommendation in this improvement plan.

RPP-ASMT-59980, 2014, *High Level Integrity Assessment Plan Workshop Summary,* Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The High-Level Integrity Assessment Panel reviewed the technical bases of the DST integrity program to assist WRPS to: (1) determine why the existing program did not predict a primary tank failure of Tank AY-102, (2) recommend activities to either predict a primary tank failure or increase the probability of early warning, and (3) recommend enhancements to the program to prevent or minimize degradation of DSTs. The Panel met in Richland, Washington, on August 25 and 26, 2014, to review the WRPS responses to the Panel recommendations provided in RPP-ASMT-57582. The Panel also developed recommendations for forensic analyses of Tank AY-102. This report documents the proceedings of this meeting.

D2.4 SINGLE-SHELL TANK INTEGRITY PANEL

A related body of work to the DSTIP is that associated with the Single-Shell Tank Integrity Panel (SSTIP). The experts used to guide this work included many of the DSTIP experts augmented by subject matter experts in areas of special interest to single-shell tank (SST) integrity (e.g., vadose mitigation). This panel advised WRPS from 2008 through 2015 and has been incorporated into the Tank Integrity Expert Panel.

D2.5 TANK INTEGRITY EXPERT PANEL

RPP-ASMT-60518, Jul 2015 Meeting

The Chief Engineer for WRPS formed the Tank Integrity Expert Panel in 2015 to integrate all of the tank integrity activities. This integration led to consolidation of the Expert Panel Oversight Committee, the High-Level Waste Integrity Assessment Panel, and the Single-Shell Tank Integrity Panel into one panel supported by subgroups in areas of interest for tank integrity.

RPP-ASMT-60518, 2015, *Tank Integrity Expert Panel July 2015 Meeting Outcomes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The primary challenge for the DSTIP is implementation. During the meeting, the Tank Integrity Expert Panel developed two priority activities to: (1) continue current and planned DST corrosion testing and monitoring and (2) obtain nondestructive examination (NDE) techniques to inspect DST primary

liners. This capability may be useful for determining the leak location and condition of Tank AY-102; however, the primary focus should be on assessing the condition of the remaining 27 DSTs to support the life-cycle mission.

D3.0 INTEGRITY ASSESSMENTS

The prime method of assessment conducted by the DSTIP is the use of Independent Qualified Registered Professional Engineers (IQRPEs) to comply with regulatory requirements under the *Resource Conservation and Recovery Act of 1976* (RCRA). In addition, leak assessment are conducted to assess the soundness of DSTs. Supporting leak assessment, the DSTIP has conducted an Extent of Condition Assessments to look for similar threats to other DSTs.

D3.1 INDEPENDENT QUALIFIED REGISTERED PROFESSIONAL ENGINEER DOUBLE-SHELL TANK INTEGRITY ASSESSMENT REPORT

RPP-17266, Plan for the Development of the DST Integrity Assessment Report
RPP-28538 Vol 1, DST System Assessment
RPP-27591 Vol 2, Pipeline Integrity
RPP-25153 Vol 3, Waste Compatibility
RPP-25299 Vol 4, Cathodic Protection
RPP-27097 Vol 5, Waste Transfer Line Encasement Integrity
RPP-22604 Vol 6, Secondary Liner
RPP-20556 Vol 7, Dome Load Program for DST
RPP-RPT-50440, Dispositions

Under the *Washington Administrative Code* (WAC) 173-303 ("Dangerous Waste Regulations"), the owner and operators of treatment, storage and disposal (TSD) units are required to have on file an integrity assessment performed by an IQRPE. The DSTIP prepare an integrity assessment of the DSTs in 2006 to satisfy the requirement of the *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement* (Ecology et. al 1989) Milestone M-48-14. The IQRPE developed 78 recommendations for the improvement of the DSTIP, which included a recommendation for the assessment to be prepared for release in 2016.

RPP-17266, 2005, *Plan for Development of the DST Integrity Assessment Report*, Revision 2, Los Alamos Technical Associates, Richland, Washington.

Abstract: The Hanford Site DSTs and ancillary equipment are considered a TSD unit, under regulations stemming from the RCRA. Configuration and operation of these facilities is regulated under 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart J, and WAC 173-303. These regulations require integrity assessments of tank systems that store dangerous waste and determination by an IQRPE as to whether the tank system is leak tight, with adequate structured integrity, and otherwise fit for use over the life of the mission.

The document describes the required tasks and schedule to successfully produce a DST integrity assessment report that meets Tri-Party Agreement (TPA) Milestone M-48-14 and complies with WAC 173-303-640(2), "Assessment of Existing Tank System's Integrity." This plan delineates the activities, reviews,

analyses, evaluation, and examinations necessary to support the development of the Double-Shell Tank Integrity Assessment Report (DSTAR) to be issued on or before March 31, 2006 as required per TPA Milestone M-48-14.

RPP-28538, 2008, *Volume 1: IQRPE Double-Shell Tank System Integrity Assessment, HFFACO M-48-14,* Revision 5, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract*:* This report documents the DST integrity assessment required by WAC 173-303-640, "Tank Systems," and TPA Milestone M-48-14, "Submit Written Integrity Report for the Double-Shell Tank (DST) System." This report is the authoritative document for the overall integrity assessment activity for the Hanford Site waste storage tanks, pits, vaults, and buried piping using the post-June 30, 2005 DST System configuration. This report was prepared under the direction or supervision of J. H. Huber, IQRPE), Los Alamos Technical Associates, Inc.

RPP-27591, 2007, *Volume 2: IQRPE DST System Integrity Assessment – Pipeline Integrity*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report reviews design standards, hazardous waste compatibility, existing corrosion protection measures, past pipeline integrity assessments, and results of leak tests, internal inspections, and examinations necessary to support the overall DST System integrity assessment. The report was certified by J. H. Huber, IQRPE, Los Alamos Technical Associates, Inc.

RPP-25153, 2007, *Volume 3: IQRPE DST System Integrity Assessment – Waste Compatibility*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report reviews the past, current, and projected future contents of the Hanford Site DSTs, materials of construction of the DSTs and ancillary equipment, and possible mechanisms of corrosion to reach conclusions and recommendations about waste compatibility with the existing equipment. The report was certified by J. H. Huber, IQRPE, Los Alamos Technical Associates, Inc.

RPP-25299, 2007, *Volume 4: IQRPE DST System Integrity Assessment – Cathodic Protection for DST Transfer Lines*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report assesses the DST System pipeline cathodic protection systems for those pipelines in service after June 30, 2005, as a part of the overall integrity assessment for the DST System. The report was certified by J. H. Huber, IQRPE, Los Alamos Technical Associates, Inc.

RPP-27097, 2007, *Volume 5: IQRPE DST System Integrity Assessment – Waste Transfer Line Encasement Integrity Technology Study*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report provides alternative methods of performing integrity assessment inspections of buried Hanford Site DST System waste transfer line encasements. Recommendations were provided as alternatives to costly

encasement pneumatic leak tests, along with a schedule for future encasement integrity assessments. The report was certified by J. H. Huber, IQRPE, Los Alamos Technical Associates, Inc.

RPP-22604, 2007, *Volume 6: IQRPE DST System Integrity Assessment – Evaluation and Documentation of DST Secondary Liner Issues*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report evaluates and document's issues raised in RPP-17266, related to the construction and commissioning of the DST secondary liners. The report was certified by J. H. Huber, IQRPE, Los Alamos Technical Associates, Inc.

RPP-20556, 2007, *Volume 7: IQRPE DST System Integrity Assessment – Evaluation of the Dome Load Program for Double Shell Tanks*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report evaluates and documents an assessment of the Tank Farm Contractor's dome load monitoring program. Findings, observations, and recommendations were provided. The report was certified by J. H. Huber, IQRPE, Los Alamos Technical Associates, Inc.

RPP-RPT-50440, 2013, *2006 Double-Shell Tank Integrity Assessment Recommendations Dispositions*, Revision 1, Washington River Protection *Solutions*, LLC, Richland Washington.

Abstract: A DSTAR was completed in March, 2006, as required by the TPA Milestone M-48-14. Integrity assessments are required for tank systems under WAC 173-303-640(2). The Integrity assessment was comprised of seven volumes that individually address the DSTs, waste compatibility, the waste transfer system, and the cathodic protection system (RPP-28538).

The authoritative document for the overall integrity assessment activity is RPP-28538 for the waste storage tanks, pits, vaults, and buried piping using the post June 30, 2005 DST System configuration. Appended to the report is Table G-2, "Summary of Recommendations from DSTAR," which contained the Integrity Assessment's 78 recommendations. The actions that these recommendations ensure that the integrity of the DSTs and their ancillary equipment are maintained.

Since completion of the DSTAR in 2006, the DSTIP incorporated recommendations from the Integrity Assessment into the funding baseline. Though included in the baseline, the independent documentation of actions taken to satisfy and close the recommendations in Table G-2 has been informally tracked. In addition, five revisions have been made to RPP-28538. These two conditions have led to some confusion as to the disposition of the recommendations. The purpose of this report is to collectively summarize the dispositions of actions taken to close the recommendations. All 78 recommendations have been closed. Fifteen of the recommendations require either follow-up actions (e.g., inspection of the Tank AZ-301 secondary containment) or are continuous elements of the DSTIP (e.g., ultrasonic testing

[UT] and maintenance of the cathodic protection system). These fifteen recommendations are being incorporated into this report, to allow reviewers a clear understanding of their disposition.

D3.2 INDEPENDENT QUALIFIED REGISTERED PROFESSIONAL ENGINEER DOUBLE-SHELL TANK INTEGRITY ASSESSMENT REPORT

The 2006 report recommended that the integrity assessment be re-performed in 10 years. As such, WRPS worked with an IQRPE to conduct this second assessment.

RPP-PLAN-57087, 2014, *Double-Shell Tank System Integrity Assessment Plan*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report is a work plan for the development of the DSTAR under the existing tank system requirements for a TSD facility under RCRA. In 2008, an IQRPE certified this assessment and provided recommendations for future integrity work in RPP-28538. The scope of work in this work plan covers the second IQRPE assessment to be completed by March 31, 2016.

RPP-RPT-58441, 2016, *Double-Shell Tank System Integrity Assessment Report (DSTAR)*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The purpose of this integrity assessment report is to determine that the DST system is fit for use, such that the tanks and ancillary systems are not leaking, and adequately designed, and are structurally adequate and compatible with the waste to ensure that the tank or ancillary system will not collapse, rupture, or fail and to certify the DST system as fit for use. This report documents the activities, reviews, analyses, evaluations, and examinations performed to support the IQRPE assessment of the DST system. In the process of performing this assessment, findings are discussed, observations of current DST parameters are enumerated, and recommendations for improvements are developed.

D3.3 TANK AY-102 LEAK ASSESSMENT

RPP-ASMT-53793, AY-102 Leak Assessment
RPP-ASMT-53794, AY-102 Supporting Documents

The DSTIP conducted a major review of the operation and construction of Tank AY-102 to look for issues that may have led to the tank's failure. This approach gathered the information necessary to conduct a formal leak assessment as establish in TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. Though most of the work was accomplished using tank integrity staff, the DSTIP was support by operations, environmental, and other engineering to develop a holistic assessment of the potential cause of the leak. No specific mechanism was identified the robust and definitive analysis of the issue was praised by customer and regulatory organizations.

RPP-ASMT-53793, 2012, *Tank 241-AY-102 Leak Assessment Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** A formal leak assessment of the first DST built at the Hanford Site, Tank AY-102, was performed to determine the source of an accumulation of

material discovered in August 2012 at two locations on the floor of the annulus that separates the primary tank from the secondary liner. There was consensus agreement among the leak assessment team members that the radioactive material on the annulus floor was the result of waste leaking from a breach in the bottom of the primary tank. The probable leak cause was identified as corrosion at high temperatures in a tank with waste containment margins that had been reduced by construction difficulties. The impacts that the tank bottom may have received from the dropped core sample drill string or the corrosion probe installation were judged to have negligible effect.

RPP-ASMT-53794, T*ank 241-AY-102 Leak Assessment Supporting Documentation: Miscellaneous Reports, Letters, Memoranda, and Data*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report contains reference materials cited in RPP-ASMT-53793, which were obtained from the National Archives Federal Records Repository in Seattle, Washington, or from other sources including the Hanford Site's Integrated Data Management System (IDMS) database.

D3.4 EXTENT OF CONDITION

As a result of the Tank AY-102 leak, the DSTs were reviewed with respect to the construction practices identified as a potential concern to the leak formation. These reviews focused on the construction of the concrete foundation, secondary liner, refractory concrete, and primary tank liner. As such, these reviews were not a complete review of all of the construction of DSTs (e.g., the waste transfer piping). In addition, enhanced visual inspections were conducted for the six tanks that were similar in design to Tank AY-102.

RPP-RPT-54814, AY-101 Annulus Visual
RPP-RPT-54815, AZ Annulus Visual
RPP-RPT-54816, SY Annulus Visual
RPP-RPT-54817, AY-101 Construction
RPP-RPT-54818, AZ Farm Construction
RPP-RPT-54819, SY Farm Construction
RPP-RPT-55981, AW Farm Construction
RPP-RPT-55982, AN Farm Construction
RPP-RPT-55983, AP Farm Construction

RPP-RPT-54814, 2013, *Tank 241-AY-101 Annulus Extent of Condition Baseline Inspection*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report provides the results of the comprehensive annulus visual inspection for Tank AY-101 performed in FY 2013. The inspection established a baseline covering about 95 percent of the annulus floor for comparison with future inspections. Any changes in the condition are also included in this report.

RPP-RPT-54815, 2013, *241-AZ Annulus Extent of Condition Baseline Inspection*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report provides the results of the comprehensive annulus visual inspection for Tanks AZ-101 and AZ-102 performed in FY 2013. The inspection established a baseline covering about 95 percent of the annulus floor for

comparison with future inspections. Any changes in the condition are also included in this report.

RPP-RPT-54816, 2013, *241-SY Annulus Extent of Condition Baseline Inspection*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of the comprehensive annulus visual inspection for Tanks SY-101, SY-102, and SY-103 performed in FY 2013. The inspection established a baseline covering about 95 percent of the annulus floor for comparison with future inspections. Any changes in the condition are also included in this report.

RPP-RPT-54817, 2013, *241-AY-101 Tank Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of an extent of condition construction history review for Tank AY-101. The Tank AY-101 construction history was reviewed to identify issues similar to those encountered during Tank AY-102 construction. Those issues and others impacting integrity are discussed based on information found in available construction records, using Tank AY-102 as the comparison benchmark. In Tank AY-101, the second DST constructed, similar issues to those encountered during Tank AY-102 construction occurred. The overall extent of similarity and effect on Tank AY-101 integrity is described in this report.

RPP-RPT-54818, 2013, *241-AZ Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of an extent of condition construction history review for Tanks AZ-101 and AZ-102. The construction history of the AZ Farm was reviewed to identify issues similar to those encountered during Tank AY-102 construction. Those issues and others impacting integrity are discussed based on information found in available construction records, using Tank AY-102 as the comparison benchmark. In the AZ Farm, the second DST farm constructed, both refractory quality and tank and liner fabrication were improved.

RPP-RPT-54819, 2013, *241-SY Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of an extent of condition construction history review for Tanks SY-101, SY-102, and SY-103. The construction history of the SY Farm was reviewed to identify issues similar to those encountered during Tank AY-102 construction. Those issues and others impacting integrity are discussed based on information found in available construction records, using Tank AY-102 as the comparison benchmark. In the SY Farm, the third DST farm constructed, refractory quality, and stress relief were improved, while similar tank and liner fabrication issues remained.

RPP-RPT-55981, 2013, *241-AW Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of an extent of condition construction history review for the AW Farm. The construction history of the AW Farm was reviewed to identify issues similar to those encountered during Tank AY-102 construction. Those issues and others impacting integrity are discussed based on information found in available construction records, using Tank AY-102 as the comparison benchmark. In the AW Farm, the fourth DST farm constructed, similar issues to those encountered during Tank AY-102 construction occurred. The overall extent of similarity and effect on AW Farm tank integrity is described.

RPP-RPT-55982, 2013, *241-AN Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of an extent of condition construction history review for the AN Farm. The construction history of the AN Farm was reviewed to identify issues similar to those encountered during Tank AY-102 construction. Those issues and others impacting integrity are discussed based on information found in available construction records, using Tank AY-102 as the comparison benchmark. In the AN Farm, the fifth DST farm constructed, tank bottom flatness, refractory material quality, post-weld stress relieving, and primary tank bottom weld rejection were improved.

RPP-RPT-55983, 2013, *241-AP Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the results of an extent of condition construction history review for the AP Farm. The construction history of the AP Farm was reviewed to identify issues similar to those encountered during Tank AY-102 construction. Those issues and others impacting integrity are discussed based on information found in available construction records, using Tank AY-102 as the comparison benchmark. In the AP Farm, the sixth DST farm constructed, tank bottom flatness, refractory material quality, post-weld stress relieving, and primary tank bottom weld rejection were improved.

D4.0 TANK INTEGRITY OPERATING SPECIFICATIONS

OSD-T-151-00007, DST *Operating Specs*
OSD-T-151-00031, DST/SST Leak Detection
SD-WM-TI-150, Basis Corrosion Specs
RPP-RPT-47337, Specifications for SCC

The evolution of tank chemistry controls have evolved at the Hanford Site over time and for a period of time varied based on the tank use. The initial requirement for tank chemistry was to ensure the pH of 10 or higher was maintained by the early DSTs designed to hold aging waste from the plutonium-uranium extraction (PUREX) process. With the construction of waste storage tanks (i.e., concentrated salt waste), these tanks adopted requirements that included ranges for nitrate, nitrite, and hydroxide. In 1984, a consistent set of chemistry control requirements were established and these have changed slightly with time as the understanding of corrosion control has advanced.

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

> **Abstract:** The operating specifications in this report cover storage operations for the DST Farms, including AN, AP, AW, AY, AZ, and SY.

OSD-T-151-00031, 2014, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion Detection*, Revision 7, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The main purpose of this report is to provide specification limits and recovery actions for the 200 Area Leak and Intrusion Detection Surveillance Program at the Hanford Site. This report provides requirements for SSTs, DSTs, catch tanks, and receiver tanks. Specification limits are given for monitoring frequencies and permissible variation of readings from an established baseline or previous reading.

SD-WM-TI-150, 1984, *Technical Basis for Waste Tank Corrosion Specifications*, Revision 0, Rockwell Hanford Operations, Richland, Washington.

> **Abstract**: The current operating specifications for corrosion control of the DSTs are complex and potentially limiting to tank farms and evaporator operations. The revised specifications based on Pacific Northwest National Laboratory (PNNL) experimental data development tasks were proposed. The proposed specifications control corrosion below the tank design limit without unduly restricting operations.

RPP-RPT-47337, 2011, *Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** Specifications for the minimization of the threat of stress-corrosion cracking (SCC) in DSTs are presented in this report, along with the empirical evidence that justifies specification selection. The wastes in the Hanford Site DSTs have cooled significantly since the chemistry control limits were first

adopted. This change in temperature provides an opportunity for adjustment of the controls without compromising the integrity of the waste tanks. The new specifications for the nitrate ion-rich wastes are summarized in six points, by maintaining a: (1) maximum temperature limit of 50 °C, (2) maximum nitrate concentration of 6.0 M, (3) maximum hydroxide concentration of 6.0 M, (4) minimum pH of 11, (5) minimum nitrite concentration of 0.05 M, and (6) minimum nitrite ion/nitrate ion ratio of 0.15.

D5.0 INTEGRITY INSPECTIONS

The DSTIP conducts visual inspections of the surface condition of the tanks and ultrasonic inspections of the volume of the metal. Both inspection programs follow the guidelines laid out by the Tank Structural Integrity Panel in the Guidelines for Development of Structural Integrity Programs (BNL-52527/UC-406). However negotiations between DOE and the Washington State Department of Ecology (Ecology) led to increase frequency and scope of the inspections.

D5.1 ANNULUS VISUAL INSPECTION

Initial visual inspections were conducted in 1992 as part of the M-32 TPA Milestones. The requirements were further refined with the development of the M-48 TPA Milestones. The current requirements were established following the extent of condition assessment of the DST following the Tank AY-102 leak assessment. This enhanced visual inspection examines more than 95 percent of the annulus floor.

RPP-RPT-31599, AN Farm
RPP-RPT-38738, AP Farm
RPP-RPT-42147, AW Farm
RPP-RPT-34310, AZ Farm
RPP-RPT-34311, AY Farm
RPP-RPT-39149, SY Farm

RPP-RPT-31599, 2014, *Double-Shell Tank Integrity Inspection Report for 241-AN Tank Farm*, Revision 6, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report documents the finding of the annulus visual inspections completed for each of the DSTs located in the AN Farm. This report includes Tank Integrity Inspection Guides, which map areas of interest based on previous visual inspection reports, IQRPE tank integrity assessments, and additional findings for the DSTs.

RPP-RPT-38738, 2012, *Double-Shell Tank Integrity Inspection Report for 241-AP Tank Farm*, Revision 3, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report documents the finding of the annulus visual inspections completed for each of the DSTs located in the AP Farm. This report includes Tank Integrity Inspection Guides, which map areas of interest based on previous visual inspection reports, IQRPE tank integrity assessments, and additional findings for the DSTs.

RPP-RPT-42147, 2015, *Double-Shell Tank Integrity Inspection Report for 241-AW Tank Farm*, Revision 3, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report documents the finding of the annulus visual inspections completed for each of the DSTs located in the AW Farm. This report includes Tank Integrity Inspection Guides, which map areas of interest based on previous visual inspection reports, IQRPE tank integrity assessments, and additional findings for the DSTs.

RPP-RPT-34310, 2014, *Double-Shell Tank Integrity Inspection Report for 241-AZ Tank Farm*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

> **Abstract:** This report documents the finding of the annulus visual inspections completed for each of the DSTs located in the AZ Farm. This report includes Tank Integrity Inspection Guides, which map areas of interest based on previous visual inspection reports, IQRPE tank integrity assessments, and additional findings for the DSTs.

RPP-RPT-34311, 2008, *Double-Shell Tank Integrity Inspection Report for 241-AY Tank Farm*, Revision 2, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report documents the finding of the annulus visual inspections completed for each of the DSTs located in the AY Farm. This report includes Tank Integrity Inspection Guides, which map areas of interest based on previous visual inspection reports, IQRPE tank integrity assessments, and additional findings for the DSTs.

RPP-RPT-39149, 2014, *Double-Shell Tank Integrity Inspection Report for 241-SY Tank Farm*, Revision 2, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report documents the finding of the annulus visual inspections completed for each of the DSTs located in the SY Farm. This report includes Tank Integrity Inspection Guides, which map areas of interest based on previous visual inspection reports, IQRPE tank integrity assessments, and additional findings for the DSTs.

D5.2 ULTRASONIC TESTING INSPECTION OF DOUBLE-SHELL TANKS

RPP-RPT-46306, Ultrasonic Measurement Variation
RPP-RPT-58301, Ultrasonic Testing Summary
RPP-RPT-58473, EMAT Strategy White Paper

Hanford has employed UT since 1996. Tank AW-103 was the first tank inspected using UT in 1996. All of the tanks were inspected using UT by 2006, and the second round of testing was completed in 2015. The WRPS has embarked on the third round of testing of the DSTs. Both integrity assessment of the UT inspections found no findings and recommended that the inspection continue as planned.

RPP-RPT-46306, 2010, *Evaluation of Ultrasonic Measurement Variation in the Double-Shell Tank Integrity Project*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** Since measurement inception in 1997, nine waste tanks were examined twice through FY 2009 and provided UT data to be compared with specific areas. The WRPS contracted with PNNL to assist in understanding variations in UT wall-thickness measurement to determine if such differences could be the result of actual wall thinning occurring on the waste tank walls or because of measurement errors.

RPP-RPT-58301, 2015, *Summary of Initial Two Rounds of Double-Shell Tank Ultrasonic Testing*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report documents and compares two rounds of UT examinations for the DSTs. The first inspections were performed from 1996 to 2006, and the second round occurred from 2006 through the present.

RPP-RPT-58473, 2015, *Implementation Strategy for Electromagnetic Acoustic Transducer System into DST Non-Destructive Examination Program*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** Implementation of a nondestructive testing technique using electromagnetic acoustic transducers (EMAT) into the current DSTIP offers faster scanning of the tank walls per deployment of equipment in the farm. The goal for implementation of EMAT technology within the DSTIP is to become a supplemental technology to the current P-Scan[5] ultrasonic transducer inspections being deployed in the DSTs with the ability to inspect additional plate material. This report speaks to the strategy in which EMAT technology will be integrated into the DSTIP.

RPP-PLAN-60509, 2015, *Task Plan for Ultrasonic Inspection o Hanford Double-Shell Tanks FY 16-19*, Washington River Protection *Solutions*, Revision 0, LLC, Richland, Washington.

> **Abstract:** This task plan provides detail necessary to support periodic assessment of double-shell tanks at Hanford through the performance of ultrasonic examinations. The plan addresses the next 8 years of projected work scope, highlighting the chronological order of inspection, the regions to be inspected, and the fiscal year inspection targets based on required periodicity and prior performance.

D5.3 LEAK DETECTION PIT DRAIN LINE VISUAL INSPECTION

RPP-ASMT-55798, Alternatives Evaluation
RPP-RPT-56464, Leak Detection Pit Drain Line Inspection

As a result of the high decay counts on the pump used in the leak detection pit in June 2013, WRPS developed schemes to evaluate the

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

leak detection pit, air channels under the tanks, and the air supply lines. Only the leak detection pit for AY-102 has been inspected to date.

RPP-ASMT-55798, 2013, *Alternatives Evaluation for Tank 241-AY-102 Robotic Inspection*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** In November 2012, WRPS determined that waste had leaked into the annulus of Tank AY-102. The condition and history of this tank is documented in the Leak Assessment Report (RPP-ASMT-53793). To gain further knowledge of the source of the leak and possible pathways for water intrusion, four vendors were invited to present proposals to identify a robotic means to remotely inspect the following three areas of the tank: (1) refractory air slots in the annulus, (2) 4-in. annulus air supply to the central plenum, and (3) 6-in. leak detection pit drain from the central sump.
>
> A Decision Support Board was convened by WRPS to evaluate the options. This report documents the decision process followed and the recommended technologies to be used for each of the robotic inspections.

RRP-RPT-56464, 2014, *241-AY-102 Leak Detection Pit Drain Line Inspection Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report provides a description of the design components, operational approach, and results from the Tank AY-102 leak detection pit drain piping visual inspection. To perform this inspection, a custom robotic crawler with a deployment device was designed, built, and operated to inspect the 6-in. lead detection pit drain line.

D5.4 241-AZ-301 SECONDARY CONTAINMENT VESSEL CORROSION RATE

RPP-RPT-57887, Corrosion Rate Report

One recommendation from the 2006 integrity assessment was to continue the visual inspection of the AZ-301 catch tank. The WRPS expanded this recommendation to include an evaluation of the interaction of the tank with the Cathodic Protection System and to evaluate other elements of cathodic protection.

RPP-RPT-57887, 2015, *241-AZ-301 Secondary Containment Vessel Corrosion Rate Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The WRPS recently requested a "calculation of the corrosion rate of the external shell of 241-AZ-301 condensate receiver tank secondary containment vessel." Problematically, such a measurement cannot be directly made or calculated. This report provides an estimated range of uniform corrosion rates possible for the AZ-301 condensate receiver tank secondary containment vessel (AZ301-COND-TANK-002). This range was deduced from an analysis of tank design, materials of construction, coatings, and historical literature data regarding the corrosion of buried carbon steel in Hanford Site soils.

D6.0 STRUCTURAL INTEGRITY ASSESSMENT OF THE DOUBLE-SHELL TANKS

The DSTIP assesses the structural integrity of the DSTs using modern finite analysis and by conducting dome surveys to look for elevation changes in dome monuments.

D6.1 STRUCTURAL ANALYSIS

The DSTs were constructed over a 20-year period. As such, different codes of record were used to evaluate the tanks. In addition, analyses of the tanks changed with time and used different input parameters in the analysis. The Office of River Protection commissioned an effort to provide a common analysis of all DSTs using the same code of record, analysis methodology, and input parameters. This work was completed in support of the 2006 integrity assessment and evaluated the tanks for completion in 2028.

RPP-RPT-23308, Thermal & Operating Loads
RPP-RPT-27570, PC2 Surface Spectra
RPP-RPT-28963, Fluid-Structure Interaction
RPP-RPT-28964, Soil-Structure Interaction
RPP-RPT-28966, ANSYS Seismic Analysis
RPP-RPT-28967, Buckling Eval for Primary Tanks
RPP-RPT-28968, Thermal & Operating Loads

RPP-RPT-23308, 2004, *Hanford Double-Shell Tank Thermal and Seismic Project – Thermal and Operating Load Analysis*, Revision 0, Pacific Northwest National Laboratory, Richland, Washington.

> **Abstract:** This report documents the thermal and operating loads analysis prepared by PNNL to evaluate structural integrity of the DSTs.

RPP-RPT-27570, 2006, *Development of PC2 Surface Spectra for Double-Shell Tank Facilities, DOE Hanford Site in Washington State*, Revision 0, Pacific Northwest National Laboratory, Richland, Washington.

> **Abstract:** This report describes the surface response spectra for the DST farm facilities at the DOE Hanford Site.

RPP-RPT-28963, 2009, *Hanford Double Shell Tank Thermal and Seismic Project - Dytran Benchmark Analysis of Seismically Induced Fluid-Structure Interaction in a Hanford Double Shell Primary Tank*, Revision 1, Pacific Northwest National Laboratory, Richland, Washington.

> **Abstract:** The purpose of this study is to demonstrate the capabilities and investigate the limitations of the finite element code MSC.Dytran®2 for performing a dynamic fluid-structure interaction analysis of the primary tank and contained waste. To this end, the Dytran®[6] solutions are benchmarked against theoretical solutions appearing in the Seismic Design and Evaluation Guidelines (BNL-52361, 1995), when such theoretical solutions exist. When theoretical solutions were not available, comparisons were made to theoretical solutions to similar problems and to the results from ANSYS®[7] simulations.

[6] Dytran is a registered trademark of Dytran Instruments, Inc., Chatsworth, California.
[7] ANSYS is a registered trademark of Swanson Analysis Systems, Inc., Canonsburg, Pennsylvania.

RPP-RPT-28964, 2006, *Hanford Double Shell Tank Thermal and Seismic Project - Establishment of Methodology for Time Domain Soil-Structure Interaction Analysis of a Hanford Double Shell Tank*, Revision 0, Pacific Northwest National Laboratory, Richland, Washington.

Abstract: The overall scope of the project is to complete an up-to-date comprehensive analysis of record of the DST System at the Hanford Site. The "Double-Shell Tank (DST) Integrity Project – DST Thermal and Seismic Analysis" in support of TPA Milestone M-48-14.

RPP-RPT-28966, 2008, *Hanford Double Shell Tank Thermal and Seismic Project – ANSYS Seismic Analysis of Hanford Double Shell Tank*, Revision 1, Pacific Northwest National Laboratory, Richland, Washington.

Abstract: The original scope of the project was to complete an up-to-date comprehensive analysis record of the DST System at the Hanford Site in support of TPA Milestone M-48-14. The work described herein was performed in support of the seismic analysis of the DSTs. The thermal and operating loads analysis of the DSTs is documented in PNNL-14706*, DST Primary Tank Settlement Evaluation*. Although TPA Milestone M-48-14 has been met, Revision 1 is being issued to address external review comments with emphasis on changes in the modeling of anchor bolts connecting the concrete dome and the steel primary tank.

RPP-RPT-28967, 2006, *Hanford Double-Shell Tank Thermal and Seismic Project – Buckling Evaluation Methods and Results for the Primary Tanks*, Revision 2, Pacific Northwest National Laboratory, Richland, Washington.

Abstract: After releasing Revision 0 of this report, an independent review of the DST Thermal and Operating Loads Analysis combined with the Seismic Analysis was conducted by Dr. Robert P. Kennedy of RPK Structural Mechanics Consulting and Dr. Anestis S. Veletsos of Rice University. Revision 1 was then issued to address their review comments (included in Appendix D). Additional concerns involving the evaluation of concrete anchor loads and allowables were found during a second review by Drs. Kennedy and Veletsos. Extensive additional analysis was performed on the anchors. The current report (Revision 2) references this recent work, and additional analysis is presented to show that anchor loads do not concentrate significantly in the presence of a local buckle.

RPP-RPT-28968, 2009, *Hanford Double-Shell Tank Thermal and Seismic Project – Summary of Combined Thermal and Operating Loads with Seismic Analysis*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The latest revision of this report documents changes to the anchor bolt evaluation. RPP-RPT-32237, *Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms*, described changes to the anchor bolt modeling and evaluation that were implemented in response to the independent reviewer's comments. Similar changes have been made in the bounding tank analysis and are documented in this report. The conclusions of the previous release of this report remain unchanged.

D6.2 DOME LOADING

RPP-20257, AN Tank Farm Dome Load
RPP-20258, AP Tank Farm Dome Load
RPP-20259, AW Tank Farm Dome Load
RPP-20260, AY Tank Farm Dome Load
RPP-20261, AZ Tank Farm Dome Load
RPP-20262, SY Tank Farm Dome Load
RPP-20473, Design and Dome Load Criteria

RPP-20257, 2004, *241-AN Tank Farm Historic Dome Load Record Data,* Revision 0, COGEMA Engineering Corporation, Richland, Washington.

> **Abstract:** This report provides the historic dome load records (DLRs) for each tank of the AN Farm at the Hanford Site. The DLRs were generated for each tank. To archive the historic DLRs, this report summarizes and releases historic DLRs for the AN Farm tanks using the dome load records summary sheets (DLRSSs). The DLRSSs have been assembled to provide the up-to-date information and to facilitate quick retrieval and usage of dome load data for a specific tank. This up-to-date data can be conveniently used by Operations personnel performing any work on or around the AN Farm, so that the allowable load margin (ALM) limit is not exceeded for any specific tank.

RPP-20258, 2004*, 241-AP Tank Farm Historic Dome Load Record Data*, Rev. 0, COGEMA Engineering Corporation, Richland, Washington.

> **Abstract:** This report provides the historic dome load records (DLRs) for each tank of the AP Tank Farm at the Hanford Site. The DLRs were generated for each tank. To archive the historic DLRs, this report summarizes and releases an historic DLRs for the AP Farm tanks using the dome load records summary sheets (DLRSSs). The DLRSSs have been assembled to provide the up-to-date information and to facilitate quick retrieval and usage of dome load data for a specific tank. This up-to-date data can be conveniently used by Operations personnel performing any work on or around the AN Tank Farm, so that the allowable load margin limit is not exceeded for any specific tank.

RPP-20259, 2004, *241-AW Tank Farm Historic Dome Load Record Data,* Rev. 0, COGEMA Engineering Corporation, Richland, Washington.

> **Abstract:** This report provides the historic dome load records (DLRs) for each tank of the AW Tank Farm at the Hanford Site. The DLRs were generated for each tank. To archive the historic DLRs, this report summarizes and releases an historic DLRs for the AW Farm tanks using the dome load records summary sheets (DLRSSs). The DLRSSs have been assembled to provide the up-to-date information and to facilitate quick retrieval and usage of dome load data for a specific tank. This up-to-date data can be conveniently used by Operations personnel performing any work on or around the AN Tank Farm, so that the allowable load margin limit is not exceeded for any specific tank.

RPP-20260, 2004, *241-AY Tank Farm Historic Dome Load Record Data,* Rev 0, COGEMA Engineering Corporation, Richland, Washington.

> **Abstract:** This report provides the historic dome load records (DLRs) for each tank of the AY Tank Farm at the Hanford Site. The DLRs were generated for

each tank. To archive the historic DLRs, this report summarizes and releases an historic DLRs for the AY Farm tanks using the dome load records summary sheets (DLRSSs). The DLRSSs have been assembled to provide the up-to-date information and to facilitate quick retrieval and usage of dome load data for a specific tank. This up-to-date data can be conveniently used by Operations personnel performing any work on or around the AN Tank Farm, so that the allowable load margin limit is not exceeded for any specific tank.

RPP-20261, 2004, *241-AZ Tank Farm Historic Dome Load Record Data,* Rev 0, COGEMA Engineering Corporation, Richland, Washington.

Abstract: This report provides the historic dome load records (DLRs) for each tank of the AP Tank Farm at the Hanford Site. The DLRs were generated for each tank. To archive the historic DLRs, this report summarizes and releases an historic DLRs for the AP Farm tanks using the dome load records summary sheets (DLRSSs). The DLRSSs have been assembled to provide the up-to-date information and to facilitate quick retrieval and usage of dome load data for a specific tank. This up-to-date data can be conveniently used by Operations personnel performing any work on or around the AN Tank Farm, so that the allowable load margin limit is not exceeded for any specific tank.

RPP-20262, 2004, *241-SY Tank Farm Historic Dome Load Record Data,* Rev 0, COGEMA Engineering Corporation, Richland, Washington.

Abstract: This report provides the historic dome load records (DLRs) for each tank of the SY Tank Farm at the Hanford Site. The DLRs were generated for each tank. To archive the historic DLRs, this report summarizes and releases an historic DLRs for the SY Farm tanks using the dome load records summary sheets (DLRSSs). The DLRSSs have been assembled to provide the up-to-date information and to facilitate quick retrieval and usage of dome load data for a specific tank. This up-to-date data can be conveniently used by Operations personnel performing any work on or around the AN Tank Farm, so that the allowable load margin limit is not exceeded for any specific tank.

RPP-20473, 2007, *Design and Dome Load Criteria for Hanford Waste Storage Tanks*, Revision 1A, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report provides the design load and dome load control and tracking requirements for the Hanford Site underground waste storage tanks. The criteria is based on the extensive review of the Analysis of Record documents, the inherent built in design margins, strength of the structural concrete used for the tanks, the maximum dome loads allowed at the tank surface, and establishing the allowable concentrated load or allowable load margin limits for added factor of safety.

D6.3 AP-FARM INCREASED LIQUID LEVEL HEIGHT

RPP-RPT-32237, Increased Liquid Level Analysis

RPP-RPT-32237, 2009, *Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms*, Revision 1, Washington River Protection Solutions, LLC, Richland, Washington.

> **Abstract:** This report describes changes to the anchor bolt modeling and evaluation that were implemented in response to the independent reviewer's comments. Similar changes have been made in the bounding tank analysis and are documented in RPP-RPT-28968. The conclusions of the previous release of this report remain unchanged.

D7.0 CORROSION CONTROL

The enhancement of the corrosion control program began in 2005. The retrieval of waste from Tank 241-S-112 and 241-S-102 led to the need to add hundreds of tons of sodium to DSTs to comply with hydroxide concentrations required. To support this work, the Expert Panel for Tank Chemistry Optimization form an oversight committee to guide the work.

D7.1 EXPERT PANEL OVERSIGHT COMMITTEE REVIEWS

Letter 0602740, Oct 2006
RPP-ASMT-35619, Nov, 2007
RPP-RPT-35923, Feb, 2008
RPP-ASMT-39508, Jan, 2009
RPP-ASMT-39069, Jan, 2009
RPP-RPT-43115, Sep, 2009
RPP-ASMT-46121, April 2010
RPP-ASMT-47066, Sep, 2010
RPP-ASMT-47754, Jul, 2011
RPP-RPT-50092, Aug, 2011
RPP-RPT-50571, Sept, 2011
RPP-ASMT-51427, Jan, 2012
RPP-ASMT-51875, Mar, 2012
RPP-ASMT-52033, Apr, 2012
RPP-ASMT-52070, July, 2012
RPP-ASMT-53360, Sep, 2012
RPP-ASMT-54634, Feb, 2013
RPP-ASMT-55478, Aug, 2013
RPP-ASMT-55871, Aug, 2013
RPP-ASMT-56781, Feb, 2014
RPP-ASMT-56862 Mar, 2014
RPP-ASMT-57109, Apr, 2014
RPP-ASMT-59979, Aug, 2014
RPP-ASMT-60108, Feb, 2015
RPP-ASMT-60348, Jul, 2015

The Expert Panel Oversight Committee (EPOC) was formed from key members of the Expert Panel for Waste Chemistry Optimization. These panel members guided the corrosion testing for the DOE from 2005 through 2015. The panel member built up considerable knowledge of the parameters that impact corrosion in the DSTs during this work. With formation from the Tank Integrity Expert Panel, WPRS asked the EPOC members to continue their role as part of the Corrosion Subgroup.

D7.1.1 Expert Panel Oversight Committee Review Reports

Letter 0602740, October 2006, "Expert Panel Oversight Committee Assessment of the 241-AN-107 and 241-AN-102 Waste Chemistry Corrosion Testing for Double-Shell Tank Waste Chemistry Optimization," Michael T. Terry, PE to Robert Popielarczyk.

> **Abstract:** This letter presents an assessment of the new results and prior findings regarding the propensity for SCC and pitting corrosion in Tanks AN-102 and AN-107.

RPP-ASMT-35619, 2007, *Expert Panel Oversight Committee Assessment of Fiscal Year 2007 Corrosion and Stress Corrosion Cracking Simulant Testing Program and the Impact on Double-Shell Tank 241-AY-102*, Revision 0, CH2M HILL Hanford Group Inc., Richland, Washington.

Abstract: The EPOC for Chemistry Optimization reviewed the testing performed on waste simulants for the carbonate-rich and nitrate waste layers in Tank AY-102. Both of the waste types were found to not have a propensity for either pitting or SCC. Both waste simulants were actually more benign than the simulants tested for Tank AN-107.

RPP-RPT-35923, 2008, *Hanford Tank AY-101: Effect of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking*, Revision 0, CH2M HILL Hanford Group Inc., Richland, Washington.

Abstract: Laboratory testing was performed to develop a comprehensive understanding of the corrosivity of the tank wastes stored in Tank AY-101. This test program placed particular emphasis on defining the range of tank waste chemistries necessary to prevent the onset of localized forms of corrosion, particularly pitting and SCC. This report summarized the key finding of the research program.

RPP-ASMT-39508, 2009, *Expert Panel Oversight Committee Assessment of Fiscal Year 2008 Corrosion and Stress Corrosion Cracking Simulant Testing Program*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC provided oversight for the implementation of selected parts of Recommendation III of RPP-RPT-22126, *Expert Panel Workshop on Tank Chemistry Optimization – Status of Oxygen Generation and Depletion Modeling*. Recommendation III provided four specific requirements for Panel approval of a proposal to revise the chemistry control limits for DSTs. One of the more significant requirements was successful performance of an accelerated SCC experimental program. This testing program has evaluated optimization of the chemistry controls to prevent corrosion in the interstitial liquid and supernatant regions of the DSTs.

RPP-ASMT-39069, 2009, *Summary and Recommendations of the Expert Panel Oversight Committee Meeting on double-Shell Tank Corrosion Monitoring and Testing Help August 4 and 5, 2008*, Revision 0, CH2M HILL Hanford Group Inc., Richland, Washington.

Abstract: The EPOC met on August 4 and 5, 2008 to discuss various aspects of DST corrosion monitoring and testing including FY 2009 planning. Formal presentations were made to update the EPOC on these subjects.

RPP-RPT-43115, 2009, *Summary and Recommendations of the Expert Panel Oversight Committee Meeting on Double-Shell Tank Corrosion Monitoring and Testing Help June 1-3, 2009*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC has held biweekly telephone conferences and met at Watts Hall on the Ohio State University campus from June 1-3, 2009 to discuss various

aspects of corrosion Monitoring and Testing including FY 2010 planning. Formal presentations were made to update the EPOC.

RPP-ASMT-46121, 2010, *Corrosion Propensity Assessment of Tank 241-AN-106 Waste*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC on DST Corrosion Monitoring and Testing has been asked to prove an assessment of the propensity for pitting and SCC of the tank steel in contract with the interstitial liquid and supernatant layers of Tank AN-106. We examined the results of ongoing and previous testing programs and conclude the following:

- The risk of SCC in the supernatant layer in Tank AN-106 is very low. The risk of SCC in the solid layer in the tank is also probably low, but this risk will be quantified in the near future once the ongoing statistical investigation of the Savannah River Site and corrosion potential tests being performed at Det Norske Veritas (U.S.A.), Inc. (DNV, Inc.) is completed.
- The risk for pitting in the supernatant and solid waste layers in Tank AN-106 is low.

RPP-ASMT-47066, 2010 *Need for Sampling of Double-Shell tanks 241-AN-103, 241-AN-104, 241-AZ-101 and 241-SY-102*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The technical basis for corrosion monitoring that is employed by WRPS, has identified six DSTs that formally require core samples in FY 2011. Decisions about the need for core sampling of two of these tanks have already been reached on the basis of existing procedures. The Technical Lead for tank integrity asked the DST Corrosion Monitoring EPOC for its recommendations regarding the need to sample the other four tanks: AN-103, AN-104, SY-102 and AZ-101.

RPP-ASMT-47754, 2011, *The Double-Shell Tank Corrosion Monitoring and Testing Expert Panel Oversight Committee Meeting Held august 17 & 18, 2010*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC reviewed presentations on the current status of the tanks; the latest information on the Multi-Probe Corrosion Monitoring System; investigations into the mechanisms of liquid-air interface (LAI) corrosion at Savannah River Nation Laboratory (SRNL), Ohio State University, and DNV Columbus, Inc., Dublin, Ohio; vapor space corrosion studies at PNNL and at SRNL; and the status of corrosion testing at DNV Columbus, Inc. This report summarizes the most significant EPOC discussions from that meeting.

RPP-RPT-50092, 2011, *The Double-Shell Tank Corrosion Monitoring and Testing Expert Panel Oversight Committee Meeting Held May 18-20, 2011*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC reviewed presentations on the current status of the tanks; the latest information on the data from the Multi-Probe Corrosion Monitoring System; investigation into the mechanisms of LAI corrosion at SRNL, Ohio State University, and DNV, Inc.; vapor space corrosion studies at DNV, Inc. and at SRNL; the status of corrosion testing at DNV, Inc.; and an approach to a revised probe design. This report summarized the most significant EPOC Discussion from that meeting.

RPP-ASMT-50571, 2011, *The Propensity for Pitting and Stress Corrosion Cracking in Present and Future Tank 241-AN-106 Wastes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: On July 15, 2011 the DST Corrosion Monitoring and Testing EPOC was asked by WRPS for their opinion regarding the propensity for pitting and SCC of Tank AN-106. Waste from Tank C-110 was transferred to Tank AN-106, changing the composition of the liquid supernatant layer and the interstitial liquids in the solid layers. Further changes in the composition of the waste layers in Tank AN-106 are anticipated as a result of transfer of wastes from Tanks C-105 and C-107. Completed corrosion testing supports the conclusion that the risk of SCC in the solid layer is low. The risk of pitting can be reduced by maintaining a solid layer pH of at least 12 and a temperature of 55 °C or below.

RPP-ASMT-51427, 2012, *Assessment of Fiscal Year 2011 Corrosion Monitoring and Testing*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The DST Corrosion Monitoring and Testing EPOC provided oversight of corrosion testing and monitoring and the implementation of procedures designed to minimize the risk of corrosion-related failures of the DSTs. The chemistry within the waste tanks changes as a result of chemical interactions within the waste and the waste transfer operations.

These changes impact the potential for corrosion-related degradation of the waste tanks. Three laboratories are currently involved in providing corrosion testing service for the Hanford DSTIP: DNV, Inc., SRNL, and the 222-S Laboratory. The Panel was asked by WRPS for their opinion regarding the corrosion testing performed for the Hanford Site waste tanks in FY 2011 and the testing needs for FY 2012.

RPP-ASMT-51875, 2012, *Assessment of Double-Shell Tank 241-AZ-102 Linear Indication*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC was asked to evaluate a linear indication that was observed on the lower knuckle of the primary steel liner of Tank AZ-102 via video camera located in the annulus. The EPOC concluded that the indication is not a crack in the tank.

RPP-ASMT-52033, 2012, *Assessment report on Electrochemical Corrosion Testing for tank 241-AN-106 Grab Samples in Support of Corrosion Mitigation Tank 241-C-107 Retrieval (LAB-RPT-12-00003, Rev 0)*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC was asked by WRPS to evaluate the *Report on Electrochemical Corrosion Testing for Tank 241-AN-106 Grab Samples in Support of Corrosion Mitigation Tank 241-C-107 Retrieval* (LAB-RPT-12-00003 R0).

RPP-ASMT-52070, 2012, *Evaluation of Proposed Use of a Retractable Corrosion Monitoring Probe in Double-Shell Tanks*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The DST Corrosion Monitoring and Testing EPOC has been overseeing corrosion testing and monitoring and the implementation of procedures designed to minimize the risk of corrosion related failures of the DSTs. The EPOC was asked by WRPS to evaluate conceptual design information on the use of a new retractable corrosion monitoring probe (RCMP) in place of a Multi-Probe Corrosion Monitoring System (MPCMS). For the last several years, MPCMSs have been installed and operated with varying degrees of success in several DSTs. Data on the proposed RCMP is limited to presentation materials and conversations among individuals from the EPOC, ARES Corporation, and WRPS. The EPOC was also asked to provide a recommendation on whether or not to proceed with design development.

In general, the goal of the RCMP design is to create a system that is more flexible, more serviceable, and less expensive than the previous MPCMS design. The RCMP assembly will consist of a permanently installed above-riser housing unit (with spray ring) and a replaceable probe head and cable assembly that can be raised and lowered in the tank depending on monitoring needs. Monitoring head components will be determined on a tank-by-tank basis, but the design will facilitate easy replacement of the monitoring head and cable should sensor or cable failure occur, or if monitoring changes are needed after installation. Typically, monitoring heads will be relatively small in size and contain primary reference electrodes, secondary reference electrodes, tank material electrodes and/or electrical resistance sensors. Installation of other components may be considered in the future.

RPP-ASMT-53360, 2012, *Assessment Double-Shell Tank 241-AN-102 Propensity for Pitting Under Current Waste Chemistry Composition*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC was asked to review the currently out-of-specification waste chemistry in Tank AN-102 with respect to its propensity to pitting and recommend whether a caustic addition is necessary based on corrosion testing of a tank steel at DNV, Inc. The EPOC recommended that the pH in Tank AN-102 be increased to 13.5 by addition of caustic (sodium hydroxide).

RPP-ASMT-54634, 2013, *Propensity For Corrosion In the 241-AY-102 Annulus*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report documents the evaluation by the EPOC for the propensity for corrosion by the waste found in the Tank AY-102 annulus.

RPP-ASMT-55478, 2013, *Expert Panel Oversight Committee Review of Laboratory Comparison Data*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC conducted a third-party review of the electrochemistry testing from three laboratories used by WRPS to compare results. The EPOC found the three laboratories were indistinguishable from one another.

RPP-ASMT-55871, 2013, *Propensity for Corrosion in the 241-AY-102 Annulus*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The EPOC provided advice to WRPS on corrosion testing, monitoring, and the implementation of procedures designed to minimize the risk of corrosion-related failures of the DSTs. In February 2013, the EPOC provided recommendations (RPP-ASMT-54634) on corrosion analyses and testing to determine if leaked waste in the annulus of Tank AY-102 might compromise the integrity of the secondary liner. Recent sampling of the Tank AY-102 leak detection pit (LDP) raised concerns that the external surface of the secondary liner may be exposed to water and/or waste. As a result, WRPS requested the EPOC to update RPP-ASMT-54634 with additional testing recommendations to determine if the secondary liner and LDP could be at risk from this external exposure.

RPP-ASMT-56781, 2014, *Outcomes From the August 2013 Expert Panel Oversight Committee Meeting*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This letter report summarizes the August 2013 EPOC meeting outcomes related to development of a cyclic potentiodynamic polarization (CPP) pitting protocol, LAI corrosion testing, and finite/boundary element analysis of DSTs.

RPP-ASMT-56862, 2014, *Expert Panel Oversight Committee Fiscal Year 2013 Chemistry Testing Review*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The DST Corrosion Monitoring and Testing EPOC provided advice to WRPS on corrosion testing, monitoring, and the implementation of procedures designed to minimize the risk of corrosion-related failures of the DSTs. This letter

outlines the EPOC's opinions regarding corrosion testing performed in 2013 and provide input on testing needs for 2014.

RPP-ASMT-57109, 2014, *Expert Panel Oversight Committee March 2014 Meeting Outcomes,* Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The DST Corrosion Monitoring and Testing EPOC provided advice to WRPS on corrosion testing, monitoring, and the implementation of procedures designed to minimize the risk of corrosion-related failures of the DSTs. This letter report documents the EPOC bi-annual meeting on March 13 and 14, 2014.

RPP-ASMT-59979, 2014, *Expert Panel Oversight Committee August 2014 Meeting Outcomes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The DST Corrosion Monitoring and Testing EPOC provided advice to WRPS on corrosion testing, monitoring, and the implementation of procedures designed to minimize the risk of corrosion-related failures of the DSTs. This letter report documents the EPOC bi-annual meeting on August 11 and 12, 2014.

RPP-ASMT-60108, 2015, *Approaches to Probabilistic Assessment of Radioactive Waste Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The integrity of the underground radioactive waste tanks at the Hanford Site is managed through a variety of engineering assessments, laboratory testing, and field monitoring. Much of this assessment is deterministic in nature. However, the many uncertainties surrounding the historical tank conditions, waste chemistries, and the relationship between waste chemistry and corrosion demand a probabilistic approach to tank integrity. In this paper, several approaches are identified for such probabilistic assessment. The paper is conceptual in nature with some illustrative examples. It does not attempt to predict the probability of failure of any given tank. Recommendations are made for improving the probabilistic assessments and the experimental data needed.

RPP-ASMT-60348, 2015, *Expert Panel Oversight Committee March 2015 Meeting Outcomes*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** At the March 19 semi-annual meeting, the EPOC focused on 2014 testing outcomes and completed their review of the chemistry control program technical basis. Vapor space corrosion, pitting protocol, integrated specification development, and corrosion probe outcomes were topics discussed at the meetings. The outcome is documented herein.

D7.1.2 Corrosion Test Reports

The DSTIP has conducted corrosion testing to optimize the chemistry control in the DSTs. This testing has been guided by the EPOC. The DSTIP has used three laboratories to support this work DNV Columbus, Inc.; SRNL; and 222-S Laboratory at the Hanford Site.

D7.1.3 Det Norske Veritas, Inc. Testing

The predecessor to DNV Columbus, Inc. was selected as the prime laboratory to conduct testing because of its reputation and capabilities. Their initial work was with tank-specific analysis to support recovery plans. The work expanded to develop a new specification for the prevention of stress corrosion cracking at temperatures below 50 °C. The more recent work has been associated with the prevention of localized corrosion and investigating Tank AY-102 annulus corrosion.

RPP-RPT-28063, Nov 2005
RPP-RPT-31680, Oct 2006
RPP-RPT-33284, Sept 2007
RPP-RPT-35923, Feb 2008
RPP-RPT-37505, Nov 2008
RPP-RPT-42703, Sept 2009
RPP-47176, September 2010
RPP-47895, FY 2011 Test Report
RPP-RPT-56141, FY 2013 Test Report
RPP-RPT-58300, FY 2014 Test Report

RPP-RPT-28063, 2005, *Investigation of Chemistry Factors Influencing Stress Corrosion Cracking Susceptibility of High-Level Waste in Double-Shell Tank 241-AN-107*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

> **Abstract:** This report discusses research performed to assist in characterizing the corrosivity of the off-normal waste solution stored in Tank AN-107. The objective of this work was to specifically characterize the propensity of the supernatant in the interstitial solution of the saltcake to cause pitting corrosion and SCC in the steel of Tank AN-107.

RPP-RPT-31680, 2006, *Hanford Tanks 241-AN-107 and 241-AN-102 Effect of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

> **Abstract:** A series of CPP, potentiostatic polarization, slow-strain rate, and constant load crack growth rate tests were performed on Tanks AN-102 and AN-107. The key findings of these tests are included in this report.

RPP-RPT-33284, 2007, *Hanford Tanks AY102 and AP101: Effect of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

> **Abstract:** Laboratory testing was performed to develop a comprehensive understanding of the corrosivity of the tank wastes stored in Tanks AY-102, AP-101, and AY-101. This test program placed particular emphasis on defining the range of tank waste chemistries necessary to prevent the onset of localized forms of corrosion, particularly pitting and SCC. This report summarizes the key findings of the research program.

RPP-RPT-35923, 2008, *Hanford Tanks AY10: Effect of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

> **Abstract:** Laboratory testing was performed to develop a comprehensive understanding of the corrosivity of the tank wastes stored in Tank AY-101. This test program placed particular emphasis on defining the range of tank waste chemistries necessary to prevent the onset of localized forms of corrosion,

particularly pitting and SCC. This report summarizes the key findings of the research program.

RPP-RPT-37505, 2008, *Effects of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking in Hanford Double-Shell Tanks*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: Laboratory testing was performed to develop a comprehensive understanding of the corrosivity of the tank wastes stored in DSTs using simulants primarily from Tanks AP-105, SY-103, and AW-105. Additional tests were conducted using simulants of the waste stored in Tanks AZ-102, SY-101, AN-107, and AY-101.

This test program placed particular emphasis on defining the range of tank waste chemistries that do not induce the onset of localized forms of corrosion, particularly pitting and SCC. This report summarizes the key findings of the research program conducted in FY 2008.

RPP-RPT-42703, 2009, *Effect of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking of Hanford Tanks*, Revision A, DNV Columbus, Inc. Dublin, Ohio.

Abstract: Laboratory testing was performed to develop a comprehensive understanding of the corrosivity of the tank wastes stored in DSTs. This test program placed particular emphasis on defining the range of tank waste chemistries that do not induce the onset of localized forms of corrosion, particularly pitting and SCC. This report summarizes the key findings of the research program conducted in FY 2009.

RPP-47176, 2010, *Final Report: Effects of Various Species in Nitrate Based Double-Shell Tank Waste Simulants on OCP, SCC, and LAI Corrosion of Tank Steel*, Revision 0, Det Norske Veritas Columbus, Inc. for Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: Laboratory testing was performed to try to develop a comprehensive understanding of the corrosivity of the tank wastes stored in DSTs. This test program placed particular emphasis on defining the range of tank waste chemistries that do not induce the onset of localized forms of corrosion, particularly pitting and SCC. This report summarizes the key findings of the research program conducted in FY 2010.

RPP-47895, 2012, *FY 2011 DNV DST Corrosion and Stress Corrosion Cracking Testing Report*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The Hanford reservation contains several million gallons of liquid legacy radioactive wastes from Cold War weapons production that are stored in 177 underground storage tanks. Because of various chemical reactions taking place inside the tanks, the waste chemistries will tend to change over time. Although the changes occur slowly, the chemical reactions will modify the compositions of the wastes, especially given the currently estimated 2025+ possible time horizon anticipated for tank storage of existing wastes.

In FY 2011, testing and evaluating the threat of localized corrosion, SCC, and LAI corrosion continued. These testing efforts were focused primarily on four principal activities: (1) examining the effects of adding waste from different tanks to Tank AN-106 on the propensity for pitting and SCC of the tank steel, (2) examining the long-term, open circuit potential in laboratory tests to provide a basis for comparison with field observations and to compare newly produced steel with vintage tank steel, (3) evaluating the SCC propensity of tank steel in different simulants that do not pass the current specification at 50 °C, with an actual in-service temperature less than 35 °C, and (4) developing a reliable, robust method to determine susceptibility to LAI corrosion.

RPP-RPT-56141, 2014, *FY2013 DNV DST and SST Corrosion and Stress Corrosion Cracking Testing Report*, Revision 0, Det Norske Veritas (USA) Inc. for Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report summarizes the FY 2013 activities at DNV, Inc. to support the recommendations of the DST Corrosion Monitoring and Testing EPOC for WRPS tank integrity maintenance activities. The activities focused on the corrosion and SCC of tank steel in DST waste simulants to determine the window of adequate performance.

A test protocol established for pitting corrosion was evaluated. The LAI corrosion was evaluated for different simulant chemistries. The corrosion and SCC of steel in various simulants that could contact the secondary shell was also evaluated.

The SCC and localized corrosion tests were conducted on selected SST waste simulants to ensure that the evolving tank chemistries and temperatures do not change the corrosion behavior of the tank steel. Boundary and finite element analyses were performed to evaluate the distribution of potentials in selected tanks.

RPP-RPT-58300, 2015, *FY2014 DST and SST Chemistry Testing Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides a summary of FY 2014 activities at DNV Columbus, Inc. to support the recommendations of the DST Corrosion Monitoring and Testing EPOC for the WRPS tank integrity maintenance activities. The activities primarily focused on the corrosion and SCC of tank steel in DST waste simulants to determine the window of adequate performance. An important focus of the testing was to evaluate the integrity of the secondary liner of Tank AY-102. The chemistry of material and fluid accumulated in the annular space between the primary and secondary liners was simulated in a number of ways. The approximate metallurgical condition of the secondary liner, especially for the field welds of Tank AY-102, was simulated. The SCC and localized corrosion tests were conducted under these conditions. New metallurgies of tank steel were identified for possible future tank construction and these were tested. The SCC and localized corrosion tests were also conducted on selected SST waste simulants to ensure that the evolving tank chemistries and temperatures do not

change the corrosion behavior of the tank steel. Boundary analyses and finite element analyses were performed to evaluate the distribution of potentials in Tank AY-102.

D7.1.4 Savannah River National Laboratory Testing

DP-1478, Prediction of Stress Corrosion of CS
SRNL-STI-2010-00509, Corrosion Testing Simulants
SRNL-STI-2011-00494, LAI Corrosion
SRNL-STI-2013-00739, Vapor Space Corrosion
SRNL-STI-2013-00743, LAI Corrosion
SRNL-STI-2014-00616, DST Corrosion Studies

The Savannah River Site has waste similar to the waste stored in the DSTs. In fact, the chemistry specification for the DSTs have the basis in work performed at Savannah River to establish their specifications. These specifications were established to prevent stress corrosion cracking in non-post weld heat treated tanks. The SRNL originally performed work to confirm the original testing. Since then, the laboratory has done work to extend the knowledge of localized corrosion based on work originally performed for late wash processing of the feed to the Defense Waste Processing Facility.

DP-1478, 1978, *Prediction of Stress Corrosion of Carbon Steel by Nuclear Process Liquid Wastes*, Revision 0, E. I. du Pont de Nemours & Co., Savannah River National Laboratory, Aiken, South Carolina.

> **Abstract:** Radioactive liquid wastes are stored in mild steel waste tanks, some of which have developed cracks from stress corrosion. A laboratory test was developed to determine the relative aggressiveness of the wastes for SCC of mild steel. Tensile samples were strained to fracture in synthetic waste solution in an electrochemical cell with the sample as the anode. The electrochemical tensile test was subsequently used as one of the bases for establishing limits on the composition of the stored wastes.

SRNL-STI-2010-00509, 2010, *Corrosion Testing in Simulated Tank Solutions*, Revision 0, Savannah River National Laboratory, Aiken, South Carolina.

> **Abstract:** Three simulated waste solutions representing wastes from Tanks SY-102 (high nitrate, modified to exceed guidance limits), AN-107, and AY-102 were supplied by PNNL. Out of the three solutions tested, both optical and electrochemical results show that carbon-steel samples corroded much faster in Tank SY-102 (high nitrate) than in the other two solutions with lower ratios of nitrate to nitrite. The effect of the surface preparation was not as strong as the effect of solution chemistry.
>
> In areas with pristine mill-scale surface, no corrosion occurred even in the Tank SY-102 (high nitrate) solution; however, corrosion occurred in the areas where the mill-scale was damaged or flaked off because of machining.

SRNL-STI-2011-00494, 2011, *Testing Vapor space and Liquid-Air Interface Corrosion in Simulated Environments of Hanford Double-Shelled Tanks*, Revision 0, Savannah River National Laboratory, Aiken, South Carolina.

Abstract: Electrochemical coupon testing was performed on six Hanford Site tank solution simulants and corresponding condensate simulants to evaluate the susceptibility of vapor space and LAI corrosion. Partial-immersion coupon testing was also performed on the six tank solution simulants to complement the accelerated electrochemical testing. Overall, the testing suggests that the Tank SY-102 high nitrate solution is the most aggressive of the six solution simulants evaluated. Alternatively, the most passive solution, based on both electrochemical testing and coupon testing, was the Tank AY-102 solution.

SRNL-STI-2013-00739, 2013, *Vapor Space Corrosion Testing Simulating the Environment of Hanford Double-Shell Tanks*, Revision 0, Savannah River National Laboratory, Aiken, South Carolina.

Abstract: As part of an integrated program to better understand corrosion in the high-level waste tanks, the Hanford Site investigated corrosion at the LAI and at higher areas in the tank vapor space. This research evaluated localized corrosion in the vapor space over Hanford Site DST simulants to assess the impact of ammonia and new minimum nitrite concentration limits, which are part of the broader corrosion chemistry limits. The findings from this study showed that the presence of ammonia gas (550 parts per million) in the vapor space is sufficient to reduce corrosion over the short-term (i.e., four months) for a Hanford Site waste chemistry (Tank SY-102 high nitrate). These findings are in agreement with previous studies at both the Hanford Site and Savannah River Site that showed ammonia gas in the vapor space to be inhibitive.

SRNL-STI-2013-00743, 2013, *Liquid-Air Interface Corrosion Testing Simulating the Environment of Hanford Double-Shell Tanks*, Revision 0, Savannah River National Laboratory, Aiken, South Carolina.

Abstract: Coupon tests on A537 carbon-steel materials were conducted to evaluate the LAI corrosion susceptibility in a series of solutions designed to simulate conditions in the radioactive waste tanks located at the Hanford Site. The new SCC requirements and the impact of ammonia on LAI corrosion were the primary focus.

SRNL-STI-2014-00616, 2014, *Hanford Double Shell Waste Tank Corrosion Studies – Final Report FY 2014*, Revision 0, Savannah River National Laboratory, Aiken, South Carolina.

Abstract: The SRNL tasks for FY 2014 included studies to evaluate the susceptibility of carbon steel to vapor space corrosion, LAI corrosion, and pitting corrosion. The SRNL also evaluated the susceptibility of carbon steel to pitting corrosion under buffered waste conditions, with the objective of determining the adequate amount of inhibitor (e.g., nitrite) necessary to mitigate pitting corrosion.

Other CPP experiments were performed in historical waste simulants, and the results were compared to previously gathered results. The results of these activities were used to assess the robustness of the standardized CPP protocol.

D7.1.5 Hanford Site 222-S Laboratory Testing

The DSTIP has been conducting corrosion testing of tank waste to better quantify the risk of waste storage. These test support the ongoing optimization testing by allowing comparison to simulant testing with actual tank waste. The high cost of these tests and the limited sample size don't allow for the optimization testing to be conducted solely with tank waste.

RPP-12077, AY-102 Sludge
FH-0300284, AN-107 Sludge
LAB-RPT-10-00011, AN-107 Noise Probe
LAB-RPT-12-00003, AN-106 Corrosion Testing
LAB-RPT-12-00009, AN-102 Corrosion Testing
LAB-RPT-12-00010, AY-102 Annulus Sample
LAB-RPT-13-00004, SY-102 Corrosion Testing
LAB-RPT-14-00010, Comparison of CPP
LAB-RPT-15-00002, AY-102 LDP Water
LAB-RPT-15-00004, AY-102 Supernatant
RPP-RPT-52537, AN-101 versus Testing
RPP-RPT-53488, AY-101 Multi-Probe
RPP-RPT-54241, AN-102 Multi-Probe
RPP-RPT-56410, AY-102 Corrosion Probe
WRPS-1302964, AY-102 LDP Solids
WRPS-1305306, AY-102A LDP Pipe Crawler
WRPS-1400194, 2AN & 7AN Grab Samples

RPP-12077, *Electrochemistry Corrosion Study for Tank 241-AY-102 Sludge*, Revision 0, CH2M HILL Hanford Group, Richland, Washington.

> **Abstract:** The report described the analyses performed on core samples from the sludge region of the waste in Tank 241-AY-102 to determine the electrochemical corrosion potential.

FH-0300284, 2003, *Electrochemical Corrosion Testing of A537 Class 1 Carbon Steel in 241-AN-107 Sludge*, Revision 0, Fluor Hanford, Inc., Richland Washington.

> **Abstract:** Tank AN-107 segments 21R1A and 21R2A were extruded under anaerobic conditions. The segments were subjected to electrochemical testing using CPP from minus 0.300 mV versus free corrosion potential to 1.6 mV.

LAB-RPT-10-00011, 2010, *Results of the Examination of Electrochemical Noise Probe specimens Removed from Tank 241-AN-107*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** An integrated multifunction corrosion probe was installed in Tank AN-107 on September 20, 2006. A portion of the probe was retrieved on June 8, 2010, and the sections holding the detectors were delivered to the 222-S Laboratory for analysis. The examination and disassembly of the probe sections encountered a number of challenges. However, disassembly and relevant analyses were successfully completed.

LAB-RPT-12-00003, 2012, *Report on Electrochemical Corrosion Testing for Tank 241-AN-106 Grab Samples in Support of Corrosion Mitigation Tank 241-C-107 Retrieval*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: Tank AN-106 supernatant was used to retrieve sludge from Tank C-107 by sluicing, and the retrieved waste was then transferred back to Tank AN-106. Sampling was required to ensure that the waste remains in compliance with Section 1.5, "Corrosion Mitigation," of OSD-T-151-00007, *Operating Specifications for the Double-Shell Storage Tanks.*

LAB-RPT-12-00009, 2012, *Report on Corrosion Potential Testing of Tank 241-AN-102 Grab Samples in Support of Corrosion Mitigation for Fiscal Year 2012*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: Grab samples from Tank AN-102 were tested using CPP tests at 30 °C, 40 °C, and 50 °C. The samples showed no signs of localized corrosion in the testing or under scanning electron microscopic investigation. The corrosion rates were calculated from the CPP tests performed and were found to have a maximum of 0.14 mil/yr, which is below the corrosion rate specification of 1 mil/yr for the DSTs.

LAB-RPT-12-00010, 2012, *Solid Phase Characterization of Tank 241-AY-102 Annulus Space Particulate*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The Special Analytical Studies Group at the 222-S Laboratory examined the particulate recovered from a series of samples from the annular space of Tank AY-102 using solid phase characterization methods.

LAB-RPT-13-00004, 2013, *Report on Electrochemical Corrosion Testing of 241-SY-102 Grab Samples from the 2012 Grab Sampling Campaign*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report describes the results of the electrochemical testing performed on Tank SY-102 grab samples that were collected in support of corrosion mitigation under RPP-PLAN-51499, *Tank 241-SY-102 Grab Sampling and Analysis Plan for Waste Chemistry Control.* The objective of the work presented was to determine corrosion resistance of Tank SY-102 to the grab samples collected using electrochemical methods up to 50 °C and to satisfy the data quality objectives in RPP-8532, *Double-Shell Tanks Chemistry Control Data Quality Objectives.*

LAB-RPT-14-00010, 2014, *Summary of the 222-S Laboratory Results in the Inter-Laboratory Comparison of Cyclic Potentiodynamic Polarization Analyses*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report summarizes the results obtained at the Hanford Site 222-S Laboratory used in an inter-laboratory study to compare CPP analyses. The DOE Occurrence Reporting Program recommended an inter-laboratory comparison study to improve the quality assurance/quality control of the electrochemistry program at the 222-S Laboratory. To accomplish this, the same three samples were analyzed at three separate laboratories (222-S Laboratory, SRNL, and DNV Columbus, Inc.) to obtain an analysis protocol that would provide similar results independent of analysis location. The final round of testing determined that when

all three laboratories used the same testing protocol and materials, the same conclusions would be derived from the same samples. The results also provided the foundation for the EPOC to create a universal CPP protocol for all laboratories to follow to ensure future data is comparable between laboratories.

LAB-RPT-15-00002, 2015, *Final Report for the Corrosion Potential Investigation of Leak Detection Pit Water from Tank 241-AY-102*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The corrosion potential of water collected in the LDP of Tank AY-102 was tested in hot cell 11A3 of the 222-S Laboratory using electrochemical impedance spectroscopy and a long-term coupon exposure technique. The metal used in the tests represented the carbon steel of the outer liner for the DST. The corrosion rate for metal submerged in the grab samples was found to be approximately 5.4 and 7.0 mil/yr for temperatures of 40 and 50 °C, respectively.

LAB-RPT-15-00004, 2015, *Report on the Corrosion Potential Testing of Archived Supernatant Samples from Tank 241-AN-102*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The corrosion potential of archived supernatant grab samples from Tank AN-102 was tested in hot cell 11A3 of the 222-S Laboratory using CPP. This work was a re-investigation of waste grab samples from this tank using a new experimental protocol recently approved by the EPOC.

RPP-RPT-52537, 2012, *Report on Electrochemical Corrosion Testing of 241-AN-101 Grab Samples from 241-C-112 Midpoint Sampling Campaign*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report describes the results of the electrochemical testing performed on Tank AN-101 grab samples that were collected in support of corrosion mitigation under RPP-PLAN-50985, *Tank 241-AN-101 Grab Sampling and Analysis Plan at the Midpoint of Tank 241-C-112 Retrieval*.

RPP-RPT-53488, 2012, *Report on the Examination of Tank 241-AY-101 Multi-Probe Corrosion Monitoring System*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report describes the analysis and forensic findings of the examination of the first removable section of the MPCMS that was retrieved from Tank AY-101 on May 20, 2012, after about three years of deployment.

RPP-RPT-54241, 2013, *Report on the Examination of Tank 241-AN-102 Multi-Probe Corrosion Monitoring System*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The first passive, removable section of the MPCMS was analyzed to determine the susceptibility of Tank AN-102 to corrosion. The probe section contained coupons from different levels of the tank, including the vapor space, LAI, supernatant region, and sludge region. Round weight loss coupons and

precracked C-rings were deployed in all the regions except the LAI. A bar coupon was deployed at the LAI to determine the effect in that region.

RPP-RPT-56410, 2014, *Report on the Examination of Tank 241-AY-102 Removable Corrosion Probe Extracted in September 2013 from the Multi-Probe Corrosion Monitoring System*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The 19 passive corrosion coupons from the first removable probe assembly of the MPCMS from Tank AY-102 were analyzed for the presence, type, and amount of corrosion. All the coupons examined showed a small amount of pitting. There was no evidence of SCC on the precracked C-ring coupons, and no corrosion due exclusively to the LAI was observed. However, one C-ring coupon located below the sludge-supernatant interface was observed to have pits approximately 2.0 mil (50 µm) deep and displayed more corrosion than neighboring coupons.

Page, J. S., Pestovich, J. A., and Cooke, G. A., 2013, "Final Report for the SEM and XRD Analysis of Solids Recovered On and In the Tank 241-AY-102 Leak Detection Pit (LDP) Pump," (Memorandum WRPS-1302964 to J. H. Rasmussen, July 25), Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The attachment to this memorandum constitutes the final report for the special studies on the scanning electron microscopy and X-ray diffraction analysis of the solids recovered from the Tank AY-102 LDP pump.

Cooke, G. A., 2013 "Solids Recovery and Solid Phase Characterization from the 241-AY-102A Leak Detection Pit Robotic Pipe Crawler," (Memorandum WRPS-1305306 to J. G. Reynolds, December 27), Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: Characterization tests on solids recovered from the robotic pipe crawler that had been deployed in the Tank AY-102 LDP were conducted at the 222-S Laboratory. The majority of the solids were composed of rust and scale. Minor amounts of silicate soil minerals and a calcium-rich phase were also found. The calcium-rich phase is probably derived from cement or groundwater precipitation. Traces of a phase consistent with graphite were also observed. None of the particulate examined had characteristics consistent with tank waste.

Cooke, G. A., 2014, "Corrosion Testing Results of 2AN-09 and 7AN-10 Grab Samples," (Memorandum WRPS-1400194 to R. B. Wyrwas, January 28), Washington River Protection Solutions, LLC, Richland, Washington.

Abstract: The attachment to this letter contains the CPP results from corrosion testing performed on grab samples from the Tank AN-102 and Tank AN-107 grab sampling campaigns. None of the CPP curves had characteristics of pitting or aggressive corrosion. The coupons did not display pitting or aggressive corrosion when observed in the hot cell after testing.

D7.1.6 Pacific Northwest National Laboratory Testing

PNNL-19767, Vapor Phase Corrosion

PNNL-19767, 2010, *Chemical Species in the Vapor Phase of Hanford Double-Shell Tanks: Potential Impacts on Waste Tank Corrosion Processes*, Pacific Northwest National Laboratory, Richland, Washington.

> **Abstract:** The overall objective of this research program was to determine the changes in supernatant or condensate chemistry that could occur on the surface of waste tank steels as the solutions dried and exchanged gases with the vapor phase. The potential impacts such changes could have on the corrosion of DST steels in the tank headspace were identified.

D7.1.7 Secondary Liner Assessments

The leak of tank on to the annulus floor of Tank AY-102 caused concern for increase corrosion of the liner material by either the waste or the waste reacted with the refractory concrete. This work was guided by the EPOC, which developed the test ranges and conditions.

RPP-RPT-54099, AY-102
RPP-RPT-57774, AY-102
RPP-ASMT-60109, AY-102

RPP-RPT-54099, 2012, *Evaluation of the Corrosion Threat of the Waste in the Tank 241-AY-102 Annulus*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** Waste has leaked from the primary tank into the annulus of Tank AY-102. The propensity for corrosion of this waste was evaluated to determine if it is corrosive enough and must be promptly removed, or if the material is benign and can remain in the annulus. Uncertainties in the waste composition, temperature, and character of the steel tank complicate the corrosion assessment. The available analytical data and the information about the temperature of the waste in contact with the secondary liner were concluded to not be sufficient to determine the corrosion threat to the secondary liner with the desired degree of confidence. Recommendations for further testing and analytical data were developed in collaboration with the EPOC.

RRP-RPT-57774, 2015, *Evaluation of Tank 241-AY-102 Secondary Containment System*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report describes ongoing evaluations of the secondary containment system of Tank AY-102 by WRPS and includes details of secondary containment integrity inspections and testing to assess the propensity for corrosion. Corrosion testing results provide confidence that the secondary liner will maintain its integrity until the tank waste is retrieved.

RPP-ASMT-60109, 2015, *Effects of Metallurgical Factors and Waste Chemistry on Localized Corrosion and SCC of Hanford Radioactive Waste Tank 241-AY-102*, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This paper presents the results of ongoing studies on the effects of various waste chemistries on localized corrosion and SCC of one of the Tank AY-102. The chemistries of the waste in the annular space of Tank AY-102 were simulated using various scenarios of evaporation and equilibration with atmospheric C02. Additionally, the metallurgical treatments undergone by the tank during its installation were simulated. The resultant simulant chemistries and thermal treatments were used in localized corrosion and SCC tests. A combination of CPP and potential staircase methods indicate that the secondary tank liner is not likely to suffer from localized corrosion in simulants representing the waste present in the annular space. Similarly, crack growth rate tests do not indicate an immediate threat of SCC to the secondary tank liner.

D7.2 IN-TANK CORROSION MONITORING

The EPOC directed that corrosion monitoring be conducted in seven selected DSTs to provide a correlation between laboratory measurements and actual tank waste conditions.

D7.2.1 Corrosion Probes and Coupons

RPP-RPT-51766, Quarterly Report
RPP-RPT-56410, AY-102 MPCMS
RPP-RPT-53488, AY-101 MPCMS
RPP-RPT-53427, AY-101 MPCMS
RPP-RPT-54241, AN-102 MPCMS

RPP-RPT-51766, 2014, *Corrosion Probe Monitoring Systems: July, August, & September 2014 Quarterly Report*, Revision 10, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** Updated quarterly, this report provides status on the operation of and data from the MPCMS.

RPP-RPT-56410, 2014, *Report on the Examination of Tank 241-AY-102 Removable Corrosion Probe Extracted in September 2013 from the Multi-Probe Corrosion Monitoring System*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The 19 passive corrosion coupons from the first removable probe assembly of the MPCMS from Tank AY-102 were analyzed for the presence, type, and amount of corrosion. All of the coupons examined showed a small amount of pitting. There was no evidence of SCC on the precracked C-ring coupons, and no corrosion due exclusively to the LAI was observed. However, one C-ring coupon located below the sludge-supernatant interface was observed to have pits approximately 2.0 mil (50 μm) deep and displayed more corrosion than neighboring coupons.

RPP-RPT-53488, 2012, *Report on the Examination of Tank 241-AY-101 Multi-Probe Corrosion Monitoring System*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report describes the analysis and forensic findings from the examination of the first removable section of MPCMS that was retrieved from Tank AY-101 on May 20, 2012, after about three years of deployment.

RPP-RPT-53427, 2014, *Tank 241-AY-101 Multi-Probe Corrosion Monitoring System Data Comparison Report*, Revision. 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report provides a comparison between the MPCMS in-tank probe data and the data from the first periodic removal of a coupon rack. The MPCMS was installed in Tank AY-101 on April 30, 2009. The first removable probe was retrieved from Tank AY 101 on May 20, 2012, about three years after its installation.

RPP-RPT-54241, 2013, *Report on the Examination of Tank 241-AN-102 Multi-Probe Corrosion Monitoring System*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** The first passive, removable section of the MPCMS was analyzed to determine the susceptibility of Tank AN-102 to corrosion. The probe section contained coupons from different levels of the tank: vapor space, LAI, supernatant region, and the sludge region. Round weight loss coupons and precracked C-rings were deployed in all of the regions except the LAI. A bar coupon was deployed at the LAI to determine the effect in that region.

D7.2.2 Coupon Testing

RPP-RPT-53428, 2014, *Tank 241-AN-102 Multi-Probe Corrosion Monitoring System Data and Coupon Data Comparison Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

> **Abstract:** This report provides a comparison between MPCMS in-tank probe data and the data from the first periodic removal of a coupon rack. The MPCMS was installed in Tank AN-102 on May 1, 2008. The first removable probe was retrieved from Tank AN-102 on July 10, 2012, about four years after its installation. The coupons from the removable probe showed minimal corrosion, which supports the data obtained from the MPCMS installed in Tank AN-102.

D8.0 WASTE TRANSFER SYSTEM PIPING

The DSTs are connected through a number of transfer lines and pits. The pits contain jumpers, which provide connection amongst the transfer lines that terminate at the pits. In response to concerns about the degradation of these systems, the DSTIP developed a fitness-for-service (FFS) program using the American Petroleum Institute guidelines.

RPP-RPT-52788, FFS Implementation
RPP-RPT-52790, Annual Status Report
RPP-RPT-52791, FFS Erosion/Corrosion
RPP-RPT-58233, SL-164 Const Review

RPP-PLAN-52788, 2014, *Waste Transfer System Fitness-for-Service Implementation Plan*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides the implementation plan for determining the FFS of the Waste Transfer System (WTS) piping and components. The FFS program provides a means to determine WTS component projection life and allow for management of aging WTS components. Through implementation of the FFS program, WRPS is provided with a means to prevent leaks and failures in the tank farms WTS. The data collected to understand, analyze, and trend damage mechanisms, or to evaluate transient overloads, is then used to make run-or-replace decision, and if necessary, modify system design, maintenance, or operating procedures.

RPP-RPT-52790, 2015, *Tank Farm Waste Transfer System Fitness-for-Service Annual Status Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The annual status of the WTS FFS work is summarized in this report as accomplishments and future activities for each of the FFS functions. The basis for estimating the integrity of the piping system is addressed, and the estimated remaining useful life for the WTS components within the FFS scope is included.

RPP-RPT-52791, 2015, *Tank Farm Waste Transfer System Fitness-for-Service Erosion and Corrosion Basis*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: This report provides UT measurements to assess the erosion and corrosion wear rates for a representative range of jumper fittings, piping, and encasements, and to determine the FFS of the WTS piping and components. These wear rates are also to be used for design allowances in new piping and component design. There is little evidence of corrosion based on the UT pipe wall thickness measurements and laboratory forensics.

RRP-RPT-58233, 2015, *Slurry Line SL-164 Construction Review*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: As a follow-up to the discovered failure of slurry line SL-164, WRPS conducted an investigation to identify construction issues or events that may have contributed to the slurry lines premature failure. Efforts of this review serve to inform cause analysis efforts and support further development of potential actions to investigate the location of line failure.

D9.0 OTHER INTEGRITY ASSESSMENTS

Not part of the DSTIP. The integrity project has performed other assessments to support the tank waste mission.

RPP-RPT-33306, 242-A Evaporator Assessment Report
RPP-RPT-33307, 242-A Evaporator Integrity Report
RRP-RPT-58161, AZ-301 Catch Tank NDE and Inspection Report

RPP-RPT-33306, 2007, *IQRPE Integrity Assessment Report for the 242-A Evaporator Tank System,* Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report is the assessment by an IQRPE of the 242-A Evaporator Unit. The report recommends that the 242-A Evaporator Unit be re-assessed by an IQRPE in 10 years.

RPP-RPT-33307, 2007, *IQRPE Integrity Assessment Report for the 242-A PC-5000 Transfer Pipeline*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

Abstract: This report documents the assessment by an IQRPE of the process condensate waste transfer line (PC-5000) from the 242-A Evaporator Facility to the Liquid Effluent Retention Facility. This assessment is required by RCRA Permit WA7890008967, *Permit for Dangerous and or Mixed Waste Research, Development, and Demonstration* and the "Dangerous Waste Regulations" (WAC 173-303-640[2], "Assessment of Existing Tank System's Integrity"). The report recommends that the PC-5000 line be reassessed by an IQRPE in 10 years.

RRP-RPT-58161, 2014, *241-AZ-301 Non Destructive Examination and Inspection Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Abstract: The 2006 IQRPE assessment resulted in recommendations to conduct NDE of the AZ-301 primary tank and secondary containment vessel. This report provides the results of the UT and visual inspection of the AZ-301 catch tank.

D10.0 REFERENCES

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.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement,* 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia,

RCRA Permit No.: WA 7890008967, 2004, *Permit for Dangerous and or Mixed Waste Research, Development, and Demonstration*, Washington State Department of Ecology, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

RPP-8532, 2009, *Double-Shell Tanks Chemistry Control Data Quality Objectives*, Revision 10, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-PLAN-50985, 2014, *Tank 241-AN-101 Grab Sampling and Analysis Plan at the Midpoint of Tank 241-C-112 Retrieval*, Revision 0A, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-PLAN-51499, 2013, *Tank 241-SY-102 Grab Sampling and Analysis Plan for Waste Chemistry Control*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

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

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

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

WAC 173-303-640(2), "Assessment of Existing Tank System's Integrity," *Washington Administrative Code*, as amended.

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APPENDIX E

2006 DOUBLE-SHELL TANK INTEGRITY ASSESSMENT RECOMMENDATION DISPOSITIONS

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E1.0 DOUBLE-SHELL TANK INTEGRITY ASSESSMENT RECOMMENDATION DISPOSITIONS E-1

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E1.0 DOUBLE-SHELL TANK INTEGRITY ASSESSMENT RECOMMENDATION DISPOSITIONS

A Double-Shell Tank System Integrity Assessment Report was completed in March 2006, as required by the *Washington Administrative Code* (WAC) 173-303-640(2) and the Tri-Party Agreement (TPA) Milestone M-48-14 (Ecology et al 1989). The integrity assessment comprises seven volumes that individually address the double-shell tanks, waste compatibility, waste transfer system, and cathodic protection system. RPP-RPT-50440, *2006 Double-Shell Tank Integrity Assessment Recommendation Dispositions*, collectively summarizes the dispositions of actions taken to close the recommendations.

Most of the actions were completed and the recommendations closed. However, 15 of the closed recommendations have follow-up activities that were included in this revision of the Double-Shell Tank Integrity Project Plan. Seven of the 15 recommendations are restatements of other recommendations. Table E-1 summarizes how those recommendations were incorporated into this report.

E2.0 REFERENCES

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order – Tri-Party Agreement,* 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

RPP-RPT-50440, 2013, *Double-Shell Tank Integrity Assessment Recommendation Dispositions*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

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

WAC 173-303-640(2), "Assessment of Existing Tank System's Integrity," *Washington Administrative Code*, as amended.

Table E-1. Double-Shell Tank System Integrity Assessment Recommendation Dispositions included in RPP-7574. (3 pages)

Recommendation	Disposition	Location in RPP-7574 (Rev. 4)
R7	The Tank Operations Contractor should perform periodic self-assessments on the dome load monitoring program to track compliance with the dome load procedures and errors, if any, with the dome load limit. It is further recommended that the periodicity of these self-assessments be a minimum of once per year.	The annual self-assessment recommendation was not adopted. Section 5.0 discusses the biennial elevation surveys.
R15	Any DST piping (especially carbon steel primary piping) and other ancillary equipment that is removed from service for the next several years should be examined for erosion and/or corrosion. The history of the transfers through that piping should be reviewed so that the average corrosion/erosion rate for Hanford DST piping can be determined.	RPP-PLAN-52788[a] describes the use of forensics on strategic jumpers to establish the remaining useful life.
R16	Comparison of historical to current visual inspections should be performed, looking for growth and changes to the corrosion patches and discoloration. Similarly, coordination between the visual and UT examinations should occur to provide quantification for better understanding.	Section 4.0 gives a description of the generation and use of tank integrity inspection guides used to compare visual inspections. An enhanced visual inspection has been developed in response to the Tank AY-102 leak. RPP-ASMT-53793[b] provides assessment of the discovered Tank AY-102 leak.
R23	Document, trend, and analyze data from bi-monthly rectifier inspection and annual polarization surveys.	Section 4.0 contains a description of the annual surveys and the bi-monthly rectifier inspections. At the time of this writing, this action is on hold with intent to resume, pending review.
R26	Measure all anode outputs in the DST areas to establish the baseline for modeling the cathodic protection system.	Section 4.0 includes the action to complete the anode measurements. At the time of this writing, this action is on hold with intent to resume, pending review.
R28	Measure and document anode current outputs.	Section 4.0 includes the action to complete the anode measurements. At the time of this writing, this action is on hold with intent to resume, pending review.
R29	Perform internal inspections of the secondary liner of catch tank AZ-301 every 10 years.	Section 4.0 discusses the visual inspection of catch tank AZ-301.

Table E-1. Double-Shell Tank System Integrity Assessment Recommendation Dispositions included in RPP-7574. (3 pages)

Recommendation	Disposition	Location in RPP-7574 (Rev. 4)
R38	Develop and adopt a DST System waste transfer line encasement future integrity assessment inspection schedule for implementation.	RPP-PLAN-52788[a] describes the plan for encasement pressure testing.
R40	Performance of a detailed laboratory examination of any DST System waste transfer line encasements that are removed permanently from service for coating defects, and internal and external corrosion.	RPP-PLAN-52788[a] describes the use of forensics on encasements.
R45	A formal integrity assessment should be performed on all DST System waste transfer, drain, and process waste lines 8 years after the issuance of this integrity assessment.	Integrity assessments of the drain lines are not performed. Pressure testing of the transfer pipelines encasements is covered in RPP-PLAN-52788.[a] The fitness-for-service program has identified the 75 lines maintained for routine transfers within RPP-RPT-52206.[c]
R49	Any statistically representative samples of DST pipelines removed from service should be unearthed and examined in a laboratory for corrosion/erosion, and failure mode as necessary. Provide copies of the associated reports, if available, that describe the actions that have been taken, or are currently planned to address the IQRPE recommendations for the primary piping system.	RPP-PLAN-52788[a] describes the use of forensics on strategic jumpers to establish the remaining useful life. RPP-7574 (Rev. 3) contained the 21 IQRPE recommendations disposition and incorporated the elements from technical reports that address the IQRPE recommendations.
R55	Assessment frequencies for DST components (e.g., ancillary equipment) should be provided.	Section 8.0 addresses the inspection of ancillary equipment.
R61	Pits must be cleaned and have their coatings re-inspected by a qualified NACE International coating inspector.	The necessary periodicities for pit cleaning and re-inspection are included in Section 4.0.
R64	The catch tank 241-AZ-301 should be assessed again by an IQRPE in 10 years. This assessment should include visual inspection and UT examination of both the primary and secondary tank.	Section 4.0 discusses when the next inspection will take place.

Table E-1. Double-Shell Tank System Integrity Assessment Recommendation Dispositions included in RPP-7574. (3 pages)

Recommendation	Disposition	Location in RPP-7574 (Rev. 4)
R66	UT examinations are not considered to be an adequate means of monitoring both low corrosion rates and rapid onset events (e.g., SCC), and need to be augmented by in-tank corrosion monitors. However, UT examinations are still needed to quantify the general condition of the tank wall.	Section 5.0 discusses the new corrosion probe design.

[a]RPP-PLAN-52788, 2014, *Waste Transfer System Fitness-for-Service Implementation Plan*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

[b]RPP-ASMT-53793, 2012, *Tank 241-AY-102 Leak Assessment Report*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

[c]RPP-RPT-52206, 2012, *Tank Farms Waste Transfer System Fitness-for-Service Requirements and Recommendations*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

DST = double-shell tank.
IQRPE = Independent Qualified Registered Professional Engineer.
SCC = stress corrosion cracking.
UT = ultrasonic testing.

APPENDIX F

DOUBLE-SHELL TANK ULTRASONIC TESTING FINDINGS AND STATUS

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E1.0 DOUBLE-SHELL TANK INTEGRITY ASSESSMENT RECOMMENDATION DISPOSITIONS E-1

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F1.0 DOUBLE-SHELL TANK ULTRASONIC TESTING FINDINGS AND STATUS

The ultrasonic testing (UT) measurement results have been summarized in RPP-RPT-58301, *Summary of Initial Two Rounds of Double-Shell Tank Ultrasonic Testing*. This report documents and compares the first two rounds of UT inspections for the Hanford Site double-shell tanks (DST). The first inspections were performed from 1996 to 2006. The second round occurred from 2007 through the present. These examinations are performed for the purpose of detecting, reporting, and comparing plate-thinning areas, pitting areas, and linear indications. The DST Integrity Project (DSTIP) uses guidance from BNL-52527/UC-406, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*.

The UT data for the primary tank walls show no significant loss of wall thickness, and the walls are more than adequate to support their structural function. The average wall thickness values are still above the nominal plate thickness values specified in the original design for primary tank wall thicknesses. The measured values between the first and second inspections in the primary tank wall data are within the accuracy of the equipment. In addition, none of the tanks have pits that exceed 25 percent of the wall thickness, and there are no reportable linear indications.

Table F-1 addresses the key areas of interest that have been found. Table F-2 lists the year of each UT inspection and provides the reference to the most recent UT Test Report.

F2.0 REFERENCES

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.

RPP-7018, 2001, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-101*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-8698, 2001, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-102*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-11169, 2003, *Supplemental Inspection Results for Double-Shell Tank 241-AY-101*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-11581, 2003, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-102*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-13546, 2003, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-101 – FY 2003*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-15765, 2003, *Ultrasonic Inspection Results for Double-Shell Tank 241-AZ-102 – FY 2003*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RRP-18444, 2006, *Ultrasonic Inspection Results for Double-Shell Tank 241-SY-101, FY 2004 and FY 2006*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-23205, 2005, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-106 – FY 2005*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-23573, 2005, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-102 – FY 2005*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-24379, 2005, *Supplemental Ultrasonic Inspection Results for Double-Shell Tank 241-AP-104 – FY 2005*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-24476, 2006, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-103– FY 2005 and FY 2006*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-26254, 2006, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-104 – FY 2005 and FY 2006*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-27467, 2006, *Supplemental Ultrasonic Inspection Results for Double-Shell Tank 241-AN-105 – FY 2005*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-30804, 2007, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-103 – FY 2006*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-32137, 2007, *Ultrasonic Inspection Results for Double-Shell Tank 241-AY-102 – FY 2007*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-32344, 2008, *Ultrasonic Inspection Results for Double-Shell Tank 241-AY-101 – FY 2007*, Revision 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-34107, 2007, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-106 – FY 2007*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-34264, 2007, *Ultrasonic Inspection Results for Double-Shell Tank 241-AZ-101 – FY 2007*, Revision 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-35741, 2008, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-107 – FY 2008*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-36722, 2008, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-108 – FY 2008*, Revision 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-RPT-38778, 2008, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-102 – FY 2008*, Revision 0A, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-39716, 2009, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-101 – FY 2009*, Revision 0/0A, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-40887, 2009, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-105 – FY 2009*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-41840, 2009, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-106 – FY 2009*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-43609, 2010, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-102 – FY 2010*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-45110, 2010, *Ultrasonic Inspection Results for Double-Shell Tank 241-AW-104 – FY 2010*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-46567, 2010, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-103 – FY 2010*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-47563, 2010, *Ultrasonic Inspection Results for the Liquid/Air Interface Region of Double-Shell Tank 241 -AY-101-FY 2010*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-48427, 2011, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-107 – FY 2011*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-49494, 2011, *Ultrasonic Inspection Results for Double-Shell Tank 241-AN-101 – FY 2011*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-51020, 2012, *Ultrasonic Inspection Results for Double-Shell Tank 241-AZ-102 – FY 2012*, Revision 1, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-51735, 2012, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-105 – FY 2012*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-52572, 2012, *Ultrasonic Inspection Results for Double-Shell Tank 241-SY-101 – FY 2012*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-53884, 2013, *Ultrasonic Inspection Results for Double-Shell Tank 241-SY-103 – FY 2013*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54594, 2013, *Ultrasonic Inspection Results for Double-Shell Tank 241-SY-102 – FY 2013*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-54818, 2013, 2*41-AZ Tank Farm Construction Extent of Condition Review for Tank Integrity*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

RPP-RPT-58301, 2015, *Summary of Initial Two Rounds of Double-Shell Tank Ultrasonic Testing*, Revision 0, Washington River Protection *Solutions*, LLC, Richland, Washington.

Table F-1. Double-Shell Tanks with Areas of Interest. (3 pages)

Tank	Document no./ date[a]	Comments
AN-102	RPP-8698, 2001 RPP-RPT-38778, 2008	Waste surface was constant at approximately 400-in. level for 20 years leading to waterline corrosion. Pits of 59 mil and 89 mil were observed between 0-59.28 cm (0-23.34 in.) from top of Plate 1 at this historical LAI. In FY 2001, one small area of reportable wall thinning was found on Plate 1. Its size was 0.174 in. by 0.270 in., with a minimum thickness of 0.445 in. However, in FY 2008, no area of reportable wall thinning was noted on Plate 1. This is due to improved evaluation criteria by the Level III UT inspectors. The FY 2001 data for the indication was reevaluated, and the indication in question was determined as not being called wall thinning today, but rather transducer liftoff or some other anomaly.
AN-105	HNF-4816, 1999 RPP-RPT-27467, 2005	The UT values taken in 1999 incorrectly indicated primary tank thinning on Plates 1 and 2. The walls were scanned again in 2002 and did not show thinning. PER-2002-5448 documents an equipment malfunction: *The ultrasonic testing (UT) equipment is designed to allow the sensor to ride above the irregular tank surface in a track-like fixture. For this specific tank, the sensor was improperly adjusted, allowing the sensor to contact the tank wall. The sensor began to wear as it moved along the wall. This sensor wear was then misinterpreted to indicate tank wall thinning.*
AP-103	RPP-RPT-46567, 2010 No new data	Two anomalies: a gouge on the outside surface of Plate 4 just above the Plate 5 to Plate 4 horizontal weld, and an area of incomplete fusion in the HAZ of Plate 5 vertical weld. Both were reexamined in 2010 and found to have no change in size.
AP-108	RPP-RPT-36722, 2008 No new data	A linear indication was discovered in Plate 4 in FY 2000 that measured 6 in. long and 0.142 in. deep. It had not grown in length or depth as of 2008.
AW-101	RPP-7018, 2001 RPP-RPT-39716, 2009	The waste level was constant at approximately 400-in. level for 19 years. Horizontal weld scan of Plate 1 indicated 48 mil of pitting. The 2009 UT data show that the primary tank wall thickness is comparable to that specified in the design documents. This UT evaluation did not identify any corrosion or pitting that affects the structure of the tank or requires any operational restrictions beyond those currently in place on DST AW-101.
AW-102	RPP-11581, 2003 RPP-RPT-43609, 2010	The waste level at 375 to 380 in. for 5 years. The measured minimum of 0.49 in. at 382.6-in. level. Re-inspection of Tank AW-102 was reported in RPP-RPT-43609.[a] The results of the Tank AW-102 UT inspection indicated no reportable wall thinning, no pit-like indications that exceeded 10% of wall thickness, and no reportable crack-like indications in the area examined.

Table F-1. Double-Shell Tanks with Areas of Interest. (3 pages)

Tank	Document no./ date[a]	Comments
AY-101	RPP-11169, 2002	The waste level was constant at 343 in. for at least 8.5 years. At the time of UT examination, the minimum average thickness was 0.51 in. with a maximum pit depth of 101 mil.
	RPP-RPT-32344, 2007	In the areas scanned both in FY 2001 and FY 2007, the number of reportable wall thinning indications increased from 15 to 35. RPP-RPT-32344[a] concluded, "one area of reportable wall thinning identified exceeds the acceptance criteria of 20% wall thinning. Since the only credible failure mechanism is tank wall perforation, and all pitting and thinning to date is small compared to plate thickness, there is no threat to tank integrity nor is there any need for operational restrictions on DST AY-101."
AY-102	RPP-RPT-32137, 2007 No new data	The waste level had significant height fluctuations. There were three reportable thinning areas at the Plate 4 level.
AZ-101	RPP-RPT-54818, 2013	In the primary tank sidewall of Tank AZ-101, a square groove from grinding was discovered after heat treatment and allowed to remain without repair. The groove is approximately 5.5 in. long by 3/16 in. wide by 3/32 in. deep. The groove is in the weld where the lower knuckle is joined to course one (Seam E-1 between weld footage 127 ft-0 in. to 127 ft-6 in. with north assigned as zero). Liquid penetrant testing revealed that there was no crack emanating from the base of the groove and, as a matter of practicality, any repair attempted could impart additional stresses that would not have been relieved since post-weld stress relieving had already occurred.
AZ-102	RPP-15765, 2003	The waste level was between 330 in. and 370 in. for at least 17 years. Wall thinning of Plate 2 observed in this range of heights. Exceeded 10% criterion for the minimum measured 367 to 379-in. levels exceeded 10% criterion.
	RPP-RPT-51020, 2012	Nine areas of reportable wall thinning were identified in FY 2003, while only three areas of reportable wall thinning were identified in 2012. In FY 2003, the tank walls and weld HAZs were not cleaned before they were scanned. The cleaning appears to have given a better view of the tank wall, allowing better differentiation between wall thinning and pits. Also, improved analysis techniques and additional experience have been acquired since FY 2003.

Table F-1. Double-Shell Tanks with Areas of Interest. (3 pages)

Tank	Document no./ date[a]	Comments
SY-101	RPP-18444, 2006	These reportable indications in Plate 1 have been attributed to waterline corrosion near the previous waste surface, which was fairly constant (at an average level of 407 in.) from 1981 to 1996.
	RPP-RPT-52572, 2012	The 2012 UT data show that the primary tank wall thickness is comparable to that specified in the design documents. This UT evaluation did not identify any corrosion or pitting that affects the structure of the tank or requires any operational restrictions beyond those that may currently be in place on Tank SY-101.

Note: No clear evidence of LAI corrosion was observed in the remaining DSTs examined ultrasonically.

[a]Full references are provided in Section F2.0.

DST = double-shell tank.
FY = fiscal year.
HAZ = heat-affected zone.
LAI = liquid-air interface.
UT = ultrasonic testing.

Table F-2. Ultrasonic Test Reports.

Farm	Tank	Year of visual inspection	Most recent ultrasonic testing reports[a]
AN Farm	AN-101	1992, 2002, 2005, 2011	RPP-RPT-49494, 2011
	AN-102	1992, 2002, 2008	RPP-RPT-38778, 2008
	AN-103	1992, 2002, 2009	RPP-RPT-24476, 2005
	AN-104	1992, 2002, 2009	RPP-RPT-26254, 2005
	AN-105	1992, 2006, 2009	RPP-RPT-27467, 2005
	AN-106	1992, 2002, 2007, 2011	RPP-RPT-34107, 2007
	AN-107	1992, 2002, 2006, 2011	RPP-RPT-48427, 2011
AP Farm	AP-101	1992, 2002, 2005	RPP-13546, 2003
	AP-102	1992, 2002, 2004, 2006, 2009	RPP-RPT-23573, 2005
	AP-103	1992, 2005, 2006, 2010	RPP-RPT-46567, 2010
	AP-104	1992, 1997, 2005, 2006, 2009	RPP-RPT-24379, 2005
	AP-105	1992, 2006, 2012	RPP-RPT-51735, 2012
	AP-106	1992, 2004, 2006, 2009	RPP-RPT-23205, 2005
	AP-107	1992, 2002, 2007, 2008	RPP-RPT-35741, 2008
	AP-108	1992, 2002, 2008, 2012	RPP-RPT-36722, 2008
AW Farm	AW-101	1991, 2001, 2008, 2009, 2012	RPP-RPT-39716, 2009
	AW-102	1991, 2001	RPP-RPT-43609, 2010
	AW-103	1991, 2002, 2006, 2007, 2011	RPP-RPT-30804, 2006
	AW-104	1991, 2001, 2009, 2010	RPP-RPT-45110, 2010
	AW-105	1991, 2001, 2008, 2009	RPP-RPT-40887, 2009
	AW-106	1991, 2001, 2009	RPP-RPT-41840, 2009
AY Farm	AY-101	1992, 2001, 2007, 2008, 2009	RPP-RPT-47563, 2010
	AY-102	1992, 2001, 2003, 2006, 2012	RPP-RPT-32137, 2007
AZ Farm	AZ-101	1993, 2001, 2007	RPP-RPT-34264, 2007
	AZ-102	1993, 2001, 2007	RPP-15765, 2003
SY Farm	SY-101	1993, 2000, 2003, 2008	RPP-RPT-52572, 2012
	SY-102	1993, 2003, 2008, 2009	RPP-RPT-54594 2013
	SY-103	1993, 2003, 2009	RPP-RPT-53884, 2013

[a]Full references provided in Section F2.0.

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