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Progress in Hanford's Double-Shell Tank Integrity Project

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ABSTRACT

The U.S. Department of Energy's Office of River Protection has an extensive integrity assessment program for the Hanford Site Double-Shell Tank System. The DOE Orders and environmental protection regulations provide the guidelines for the activities used to inspect and maintain 28 double-shell tanks (DSTs), the waste evaporator, and ancillary equipment that compose this system. This program has been reviewed by oversight and regulatory bodies and found to comply with the established guidelines.

The basis for the DOE Order 435.1-1 for tank integrity comes from the Tank Structural Integrity Panel led by Brookhaven National Laboratory during the late 1990s. These guidelines established criteria for performing Non-Destructive Examination (NDE), for acceptance of the NDE results, for waste chemistry control, and for monitoring the tanks. The environmental regulations mirror these requirements and allow for the tank integrity program to provide compliant storage of the tanks. Both sets of requirements provide additional guidance for the protection of ancillary equipment.

CH2M HILL uses two methods of NDE: visual inspection and Ultrasonic Testing (UT). The visual inspection program examines the primary tank and secondary liner of the DST. The primary tank is examined both on the interior surface above the waste in the tank and on the exterior surface facing the annulus of the DST. The interior surface of the tank liner is examined at the same time as the outer-surface of the primary tank. The UT program examines representative areas of the primary tank and secondary liner by deploying equipment in the annulus of the tank.

Both programs have led to the development of new equipment for remote inspection of the tanks. Compact camera and enhanced lighting systems have been designed and deployed through narrow access ports (called risers) into the tanks. The UT program has designed two generations of crawlers and equipment for deployment through risers into the thermally hot and radioactive environment. Also extensions were developed to allow inspection of the tank's curve upper (haunch) and lower (knuckle) surfaces.

CH2M HILL primarily maintains chemistry control of the DST by ensuring that the concentrations of hydroxide and nitrite ions are favorable with respect to the nitrate ion concentration in the waste. This control program is supported by an extensive sampling program that obtains samples from the supernatant and solid layers in the tank to ensure compliance with the chemical specification. At DOE direction, CH2M HILL has embarked on a waste chemistry optimization program to enhance the protection of the tank surface and the understanding of the parameters that affect general and localized corrosion in the tanks.

Over the past decade, DOE has deployed Electrochemical Noise corrosion probes in the DST to monitor localized corrosion. From the information gathered as part of the chemistry control, new information has been identified about the parameters requiring control to ensure tank integrity. CH2M HILL is deploying

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a series of corrosion probes to test and employ these parameters to provide real time corrosion monitoring of the DSTs.

INTRODUCTION

The mission of the U.S. Department of Energy's River Protection Project (RPP) is to store, retrieve, treat, and dispose of the highly radioactive waste in Hanford Site tanks in an environmentally sound, safe, and cost-effective manner. The RPP mission requires adequate tank capacity for waste storage and waste feed delivery, which is provided by double-shell tank (DST) system. Maintaining the integrity of this system is a key to establishing a functional waste storage and transfer facilities assets.

Concerns related to aging of radioactive waste storage facilities throughout the U. S. Department of Energy (DOE) complex led to the Brookhaven National Laboratory (BNL) developing guidelines for structural integrity programs for tank systems (BNL-52527, *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*). The committee of experts that developed these guidelines is commonly known as the Tank Structural Integrity Panel (TSIP). 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*).

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 TSIP utilized previous work at BNL, which dealt with seismic analysis of the DOE's high-level waste (HLW) 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. Hanford developed site-specific guidelines based on this work.

To implement the Double-Shell Tank Integrity Project (DSTIP), CH2M HILL Hanford Group, Inc. (CH2M HILL) has used applicable regulations, DOE Orders and technical standards, and guidelines developed by expert panels for DOE. The regulations addressing the operation of Hazardous Waste tanks system under the *Resource Conservation and Recovery Act of 1976 (RCRA)* are found in 40 CFR, *Protection of Environment*, which the State of Washington has been authorized to regulate through the Washington Administrative Code (WAC) for *Dangerous Waste Regulation 173-303*.

These regulations require integrity assessments of tank systems that store dangerous waste and determination by an Independent Qualified Registered Professional Engineer (IQRPE) as to whether the tank system is fit for use. Completion of the IQRPE integrity assessments for the DST System is considered by the DOE and the Washington State Department of Ecology (Ecology) to have satisfied the *Hanford Federal Facility Agreement and Consent Order* ("Tri-Party Agreement") (Ecology et al. 1989) Milestone M-48-00 ("Complete Identified Dangerous Waste Tank Corrective Actions, March 31, 2006").

BACKGROUND

The Hanford radioactive waste is contained in 149 single-shell tanks (SSTs) and 28 DSTs. These tanks are supported by ancillary equipment (e.g., transfer piping, valve pits, and one miscellaneous tank), that allows the movement of the waste into, within, and out of the tank system. The SSTs were built in 12

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farms between 1943 and 1964 and were designed to hold between 50,000 and one million gallons of waste. The construction of the DSTs began in 1968 with the sixth farm being completed in 1986. All of the DSTs have a nominal one million-gallon waste capacity.

Stress corrosion cracking (SCC) of the SSTs carbon-steel liners was a factor causing the leakage of waste from the SSTs to the surrounding soil. This leakage led to a decision by the U.S. Atomic Energy Commission (predecessor to the U.S. Energy Research and Development Administration and subsequently the DOE) in the 1960s to initiate construction of DSTs with improved design, materials, and construction. The free liquids from SSTs have been transferred to DSTs as part of the SST interim stabilization program, which was completed in fiscal year (FY) 2005. Eventually, the remaining solids (i.e., sludge and salt cake) and interstitial liquid in the SSTs will also be retrieved and transferred to DSTs for subsequent processing and disposal; after that, the disposition of the SSTs will be take place per the applicable requirements.

At this point, the structural integrity program for SSTs is limited to ensuring that structural adequacy is maintained throughout SST waste retrieval and closure and as such, the SST integrity is not covered as part of the DSTIP. However, since negotiations under the Tri-Party Agreement may extend the use of the SSTs, the DOE may establish a more extensive program for SST integrity.

DESCRIPTION OF THE DOUBLE-SHELL TANK SYSTEM

In addition to the 28 DSTs, the DST System includes the 242-A Evaporator, numerous valve and pump pits to allow transfer line connections, and 89 process lines, with an additional 39 lines required for tank farm operations, for a total of 128 credited lines. There is also one miscellaneous tank, 241-AZ-301, required for tank farm operations.

During DST design and construction, steps were taken to prevent SCC, which included material selection, tank wall thickness, and post-weld heat treatment. Hanford personnel selected higher strength steels to build the DSTs as compared to that used for SST construction. The thicknesses of the primary tank walls were increased over the steel plate used in previous construction, to minimize operational stresses. Finally, 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 590 °C (1100 °F).

Construction History

The DSTs were constructed over a period of roughly 18 years (from 1968 to 1986), with a presumed design life of 20 to 50 years. Table 1 covers the construction dates, year of initial service, and the expected service life at time of construction. The DSTs were designed such that any potential leaks could be detected, the leaking waste would be held in the secondary containment, and corrective action taken long before there could be any release of waste to the environment. To date, none of the 28 of the DSTs has experienced waste leaks, and all the DSTs have been certified by the IQRPE as fit for use.

Table 1. Double-Shell Tank Construction and Age.

Tank Farm	Number of Tanks	Construction Period	Construction Project	Initial Operation	Service Life	Current Age (2008)
241-AY	2	1968 – 1970	IAP-614	1971	40	37

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241-AZ	2	1970 – 1974	HAP-647	1976	20	32
241-SY	3	1974 – 1976	B-101	1977	50	31
241-AW	6	1976 – 1979	B-120	1980	50	28
241-AN	7	1977 – 1980	B-130, B-170	1981	50	27
241-AP	8	1982 – 1986	B-340	1986	50	22

Double-Shell Tank Features

Fig. 1 shows a general schematic of a DST, which consists of a primary steel tank inside of a secondary steel liner enclosed in a reinforced-concrete shell. The primary steel tank rests atop an eight inch insulating concrete slab, separating it from the secondary steel liner, and providing for air circulation/leak detection channels under the primary tank bottom plate. An annular space of 2.5 feet exists between the secondary liner and primary tank, allowing for visual inspection of the tank wall and secondary liner annular surfaces. The annular space also allows for visual and ultrasonic inspections of the primary tank walls and secondary liners.

Each of the DSTs has between 59 and 126 risers penetrating the dome and annulus, providing access for video cameras, ultrasonic inspection devices, waste sampling devices, pumps, and other equipment which requires access to either the primary tank interior or annular space. Above each DST (extending from grade to vary depths) are three to five pits, which house valves and pumps. This equipment allows transfer of waste fluids and sludge from SSTs to DSTs, from DSTs to other DSTs, or from DSTs to other facilities (e.g., 242-A Evaporator).

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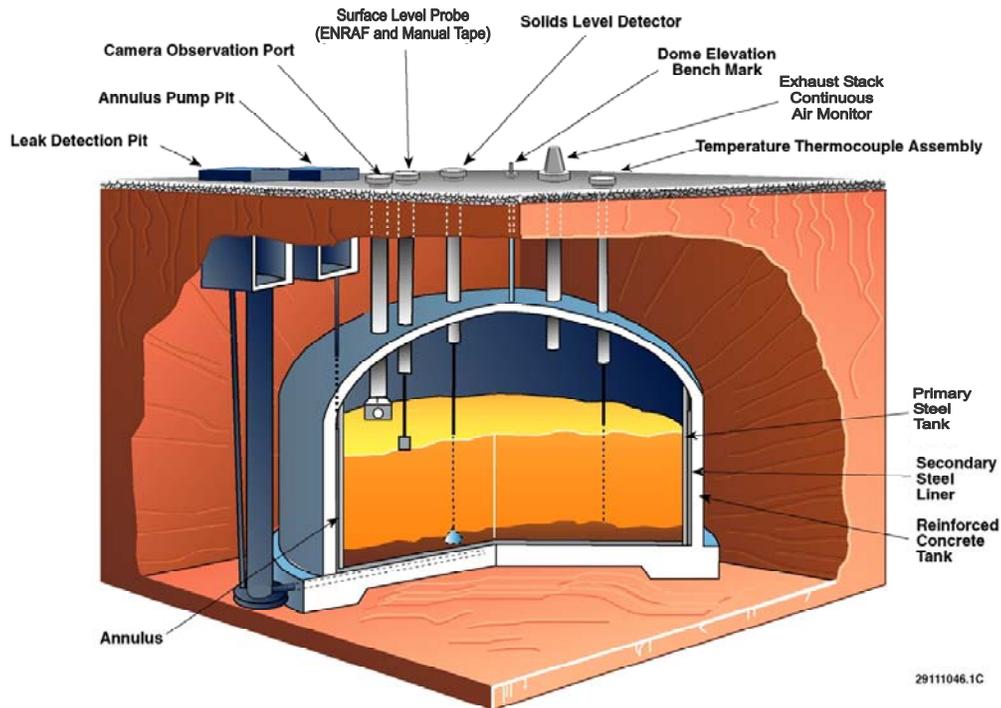


Fig. 1. Double-Shell Tank Construction.

242-A Evaporator

The 242-A Evaporator was built in 1976. It was based on the 242-S Evaporator and incorporated lessons learned from the earlier facility to improve design and operation of the facility. The evaporator is located north of the 241-AW tank farm. The 242-A Evaporator reduces the water content of the waste and then transfers concentrated waste to a number of receiving DSTs.

Waste Transfer System

The waste transfer system consists of a number of double-encased pipelines, pump and valve pits, pumps, jumpers, and valves. The transfer system features were either built in conjunction with the tank farms they serve or as separate construction projects. A key system to maintain the integrity of the transfer system is the cathodic protection system.

PROJECT STRATEGY

The DOE provides requirements for tank integrity in Chapter II, "High Level Waste Requirements" of the Implementation Guide (DOE G 435.1-1) for use with DOE M 435.1-1. The DOE G 435.1-1 states that

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the BNL TSIP document provides the basis for an acceptable program. The BNL TSIP guidelines are the basis for the CH2M HILL program for both structural integrity and corrosion control.

The evaluation of the structural integrity of the DSTs was conducted using modern Finite Element Analysis (FEA) techniques. The DSTIP controls the chemistry of the waste in the DSTs to limit the propensity for corrosion to occur. In addition to this chemistry control program, the DSTIP conducts nondestructive examination (NDE) of the primary tanks and the secondary liners to detect any corrosion that may be occurring. Together these programs provide a robust system for ensuring the continued leak and structural integrity of the DSTs.

In addition to this baseline set of programs, the DSTIP has initiated chemistry optimization testing, along with corrosion monitoring, to fully understand and improve corrosion mitigation in the DSTs. The chemistry optimization studies have built on the years of testing at the Savannah River and Hanford Sites to further identify the chemical composition ranges that minimize the propensity for localized corrosion. The in-tank corrosion monitoring looks for indications of incipient corrosion from in-tank sensors and provides for data correlation between laboratory testing parameters and actual tank chemistry environments.

LOADING CONDITIONS AND STRUCTURAL ANALYSIS FOR THE DOUBLE-SHELL TANKS

The DSTs were designed and constructed to maintain structural stability under a variety of load conditions. These loads include dead weight, 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-specific criteria that specifies the loads required for verification of structural adequacy of tanks. The site-specific design criteria are found in WHC-SD-WM-DGS-003, *Structural Acceptance Criteria for the Evaluation of Existing Double-Shell Waste Storage Tanks Located at the Hanford Site Richland Washington*, and specify many load combinations, and the allowable stresses for each load combination that must be considered.

Finite Element Analysis models (ANSYS and Dytran) are being used to represent structural features and to calculate stresses at representative locations. These models include soil-structure interactions, concrete degradation and creep, and simulated worst-case operational cycling, to provide the DSTIP with ability to verify structural adequacy for purposes of controlling loads on tanks and to estimate the effects of degraded geometry or material properties on tank life expectancy. The DST structural analysis of record for the thermal and operating loads and seismic loads is documented in RPP-RPT-28968, *Hanford Double-Shell Tank Thermal and Seismic Projec – Summary of Combined Thermal and Operating Loads*, which included updated seismic data derived from the latest Waste Treatment and Immobilization Plant (WTP) seismic analysis.

EXPERT ADVICE

Over the course of the DSTIP, advice and direction have been sought from numerous panels of outside experts (see Table 2) brought in to review the various aspects of DST integrity and operations. These panels date back to the BNL TSIP on seismic analysis for HLW tanks.

Table 2. Tank Integrity Expert Panels.

Expert Panel	Reference
Tank Structural Analysis	BNL-52361, <i>Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Tanks and Appurtenances.</i>
Tank Structural Integrity	BNL-52527, <i>Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks.</i>
Double-Shell Tank Life Extension	PNNL-13571, <i>Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension</i>
Electrochemical Noise	RPP-8416, <i>Final Report Technical Review Panel for EN Based Corrosion Monitoring of Hanford Double Shell Tanks.</i>
Double-Shell Tank Level Rise	RPP-19438, <i>Report of Expert Panel Workshop for Hanford Double-Shell Tank Waste Level Increase</i>
Chemistry Optimization	RPP-RPT-22126, <i>Expert Panel Workshop for Hanford Site Double-Shell Tank Chemistry Optimization.</i>
Vapor Space Corrosion	RPP-RPT-31129, <i>Expert Panel Workshop on Double-Shell Tank Vapor Space Corrosion Testing</i>

NONDESTRUCTIVE EXAMINATION OF DOUBLE-SHELL TANK INTEGRITY

The DSTIP uses visual and ultrasonic inspections of the DSTs. Visual inspections provide useful information as to the physical condition of the DSTs. In addition to visual inspection, Ecology's guidance on tank system integrity assessment (Publication 94-114, *Guidance for Assessment and Certifying Tank Systems that Store and Treat Dangerous Waste* [Ecology 1994]) identifies ultrasonic inspection as acceptable volumetric test method. To satisfy as low as reasonably achievable (ALARA) principles in the high-radiation environments, both visual and ultrasonic inspections use robotic equipment and other remotely controlled techniques.

Visual Inspection

Visual inspection of tanks by remote video camera is used to assess tank conditions and to support deployment of remotely operated NDE equipment. Both the inside of the primary tank (above the waste level) and the annulus surfaces of the primary tank and secondary liner are inspected using remote video equipment. Visual inspections occur in conjunction with the tank's ultrasonic inspection when practical. The interval between successive inspections cannot exceed seven years.

The primary tank's interior visual inspection, including the dome space, is performed through one of the primary tank's risers; the primary tank annulus side wall and secondary liner annulus visual inspection is performed via four of the annulus risers selected so that a near 360° visual inspection is conducted. The DST visual inspections, completed in 2006, established the baseline that is used for baseline comparison with future inspections.

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The baseline information is documented in the Tank Integrity Inspection Guide (TIIG). The TIIG contains photographic information of notable indications (areas of interest) and specifies their location on each DST, as well as showing the tank regions examined by UT. Fig. 2 is an example of the inspection map section of the TIIG. Fig. 3 is an illustration of the information in the guide section of a TIIG. Each item of interest has been mapped and is given a unique tank specific photo identification number, which enables the region to be identified, explained in the TIIG, and to be recalled for use in planning for subsequent inspections.

Ultrasonic Testing Inspection of Double-Shell Tanks

The DSTIP uses ultrasonic testing (UT) with remote robotic crawlers to examine the DSTs for thinning, pitting, and cracking. This type of inspection provides a volumetric examination of the metal examined. The inspections are performed using a magnetic crawler that holds the transducers to conduct the examination. The crawler used during Pulse-echo ultrasonic inspection (P-scan) imaging is shown in Fig. 4. The crawler system is deployed through a 24-inch annulus inspection riser. 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

The P-scan¹ system is manufactured by FORCE Technology. It 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.

The P-scan crawler inspects the primary tank vertical walls using one dual-element 0° transducer to detect wall thinning and corrosion pitting, and two 45° shear-wave transducers to detect pitting and cracking transverse to the scanning direction. The inspection setup is illustrated in Fig. 5. The inspection of the welds consists of angle beam inspections. The DSTs were not designed or fabricated for in-service inspection, and therefore the weld crowns were not prepared for inspection (i.e., ground flat). To detect cracks parallel to the weld, a 60°-shear-wave transducer is directed toward the weld and a dual-element 0° transducer is also included to detect wall thinning and corrosion pitting (Fig. 6). The system has a practical detection sensitivity of ± 0.020 inches.

¹ P-scan is a trade name used by FORCE Technology, Brøndby, Denmark.

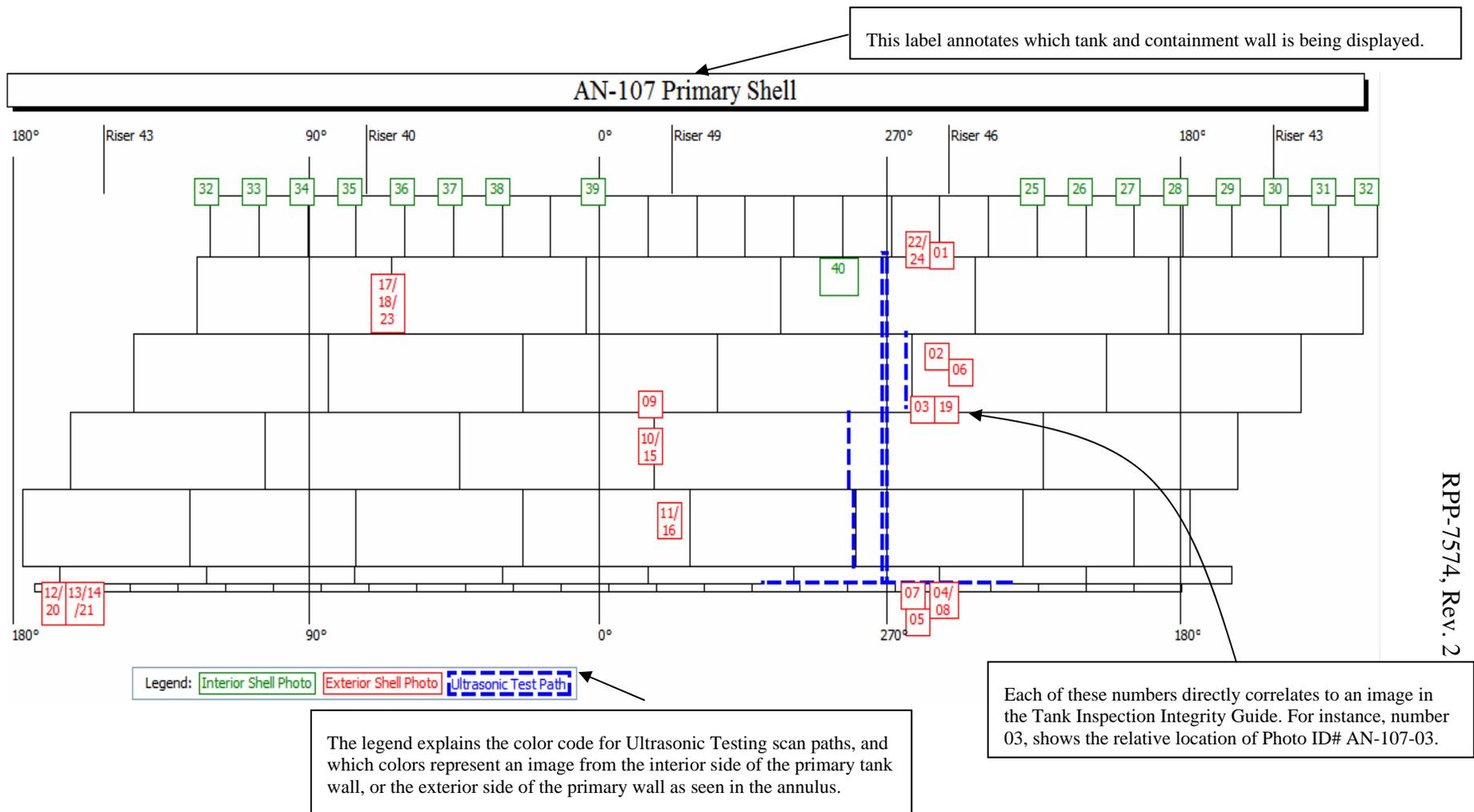


Fig. 2. 241-AN-107 Tank Integrity Inspection Map Example.

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

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.

Date of Inspection lists the date the video inspection was performed.
 Date of Review lists the fiscal year an inspection report commented on this region.

Shipping Mark	Heat #	Ingot & Cut	Nominal Thickness
F7301M2	3G5922	0400C	0.500
F7301M2	3G5922	0600C	0.500



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

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

Color photo of area of interest.

Fig. 3. AN Tank Integrity Inspection Guide Example.

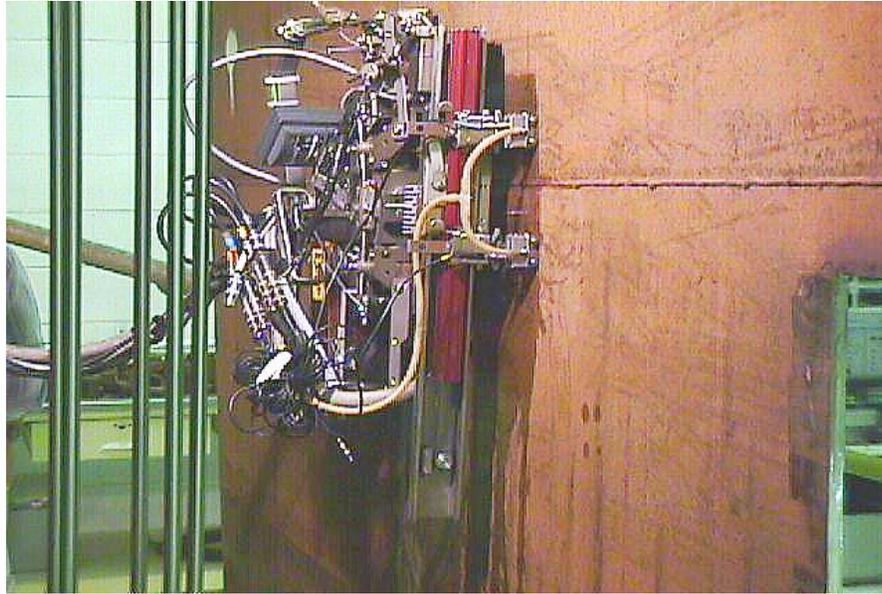
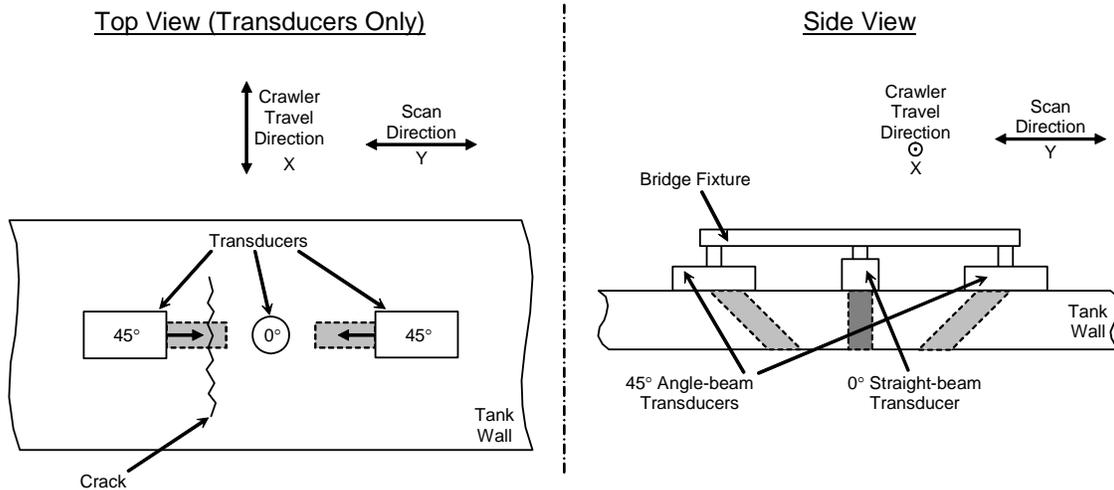
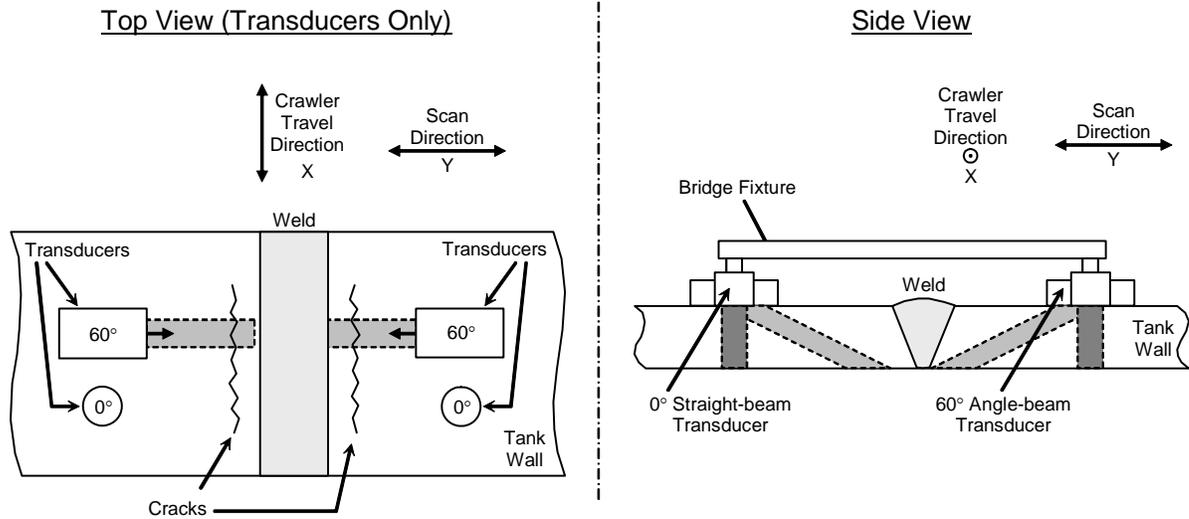


Fig. 4. P-scan Crawler System on Tank Mock-up.



Vertical Wall Scan Inspection Setup – Uses two 45° Transducers and one 0° Transducer
(Inspect for Wall Thinning, Pitting and Axial Cracks)

Fig. 5. Schematic of UT Setup for Vertical Wall Scan Inspections.



First Pass of Vertical and Horizontal Weld Inspection – Uses two 60° Transducers and two 0° Transducers (Inspect for Wall Thinning, Pitting and Heat Affected Zone Cracks Parallel to the Weld)

Fig. 6. Schematic of UT Setup for First Pass of Weld Inspections.

To detect cracks oriented perpendicular to welds, two opposing 45° shear-wave transducers are directed parallel to the weld. Welds are examined from both sides of the weld crown (Fig. 6). Using this inspection technique, a “lack of fusion” between weld passes (i.e., internal to the weld) was identified in tank 241-AP-103 (RPP-13802, *Ultrasonic Inspection Results for Double-Shell Tank 241-AP-103*).

Tandem-Synthetic Aperture Focusing Technique

Structural analysis indicates that the most highly stressed region of the tank – the region most susceptible to stress corrosion cracking – is from the middle to lower part of the knuckle. To accommodate tank wall curvature in this region, a flexible extended arm for the was tested and was deployed in FY 2002. During FY 2003 development was completed for the tandem-synthetic aperture focusing technique (T-SAFT) for lower knuckle inspection. The T-SAFT was successfully deployed, and was used for knuckle inspection starting in December, 2002.

Ultrasonic Testing Inspection Performance

Ultrasonic inspections of the all 28 DSTs were completed in FY 2005 in accordance with the HFFACO Milestone M-48 Series requirements:

- Thirty-inch wide vertical scan of the primary tank wall for all DSTs;
- Twenty-foot length of circumferential weld joining the primary tank vertical wall to the lower knuckle and adjacent heat-affected zone for all DSTs;
- Twenty-foot length of vertical weld joining shell plate courses of the primary tank, extended as necessary to include at least one foot of vertical weld in the nominally thinnest wall plate and adjacent heat-affected zones for all DSTs.

- Twenty-foot long circumferential scan 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 one foot above that liquid/vapor interface for six DSTs;
- Twenty-foot long circumferential scan of the predicted maximum stress region of the primary tank lower knuckle for six DSTs.

The TSIP guidelines provided criteria for thinning, pitting, and cracking, which when detected would require further evaluation of a tank’s integrity by a Tank Inspection Assessment Panel. The DSTIP uses those criteria and have adopted a second set of reportable values, which are half of the TSIP criteria. If the UT results are less than the reportable values, no evaluation/reporting is required as shown in Table 3.

Table 3. Ultrasonic Testing Evaluation Guidelines and Reportable Values.

Parameter	Tank Structural Integrity Panel’s Evaluation Guidelines	Double-Shell Tank Integrity Program Reportable Value
Thinning	20% thickness	10 % thickness
Pitting	50% thickness	25 % thickness
Cracking	>12 inches 20% of thickness ≤12 inches 50% of thickness	Any detectable crack

In addition to this scope, ultrasonic inspections of the secondary tanks were performed on three DSTs, in accordance with the TSIP guidelines. Repeat inspections will be conducted on an interval not to exceed ten years through the operating life of the DSTs.

CHEMISTRY OPTIMIZATION TESTING

The optimization of chemistry control was initiated in FY 2005. This work implements a number of the recommendations from RPP-RPT-22126, *Expert Panel Workshop for Hanford Site Double-Shell Tank Chemistry Optimization*, designed to eliminate the long-term addition of caustic sodium hydroxide to the DSTs, and to improve in-tank corrosion monitoring. To date testing has been concluded on tanks 241-AN-102, 241-AN-107, and 241-AY-102. Testing is ongoing for tank 241-AY-101.

The testing for 241-AN-102 and 241-AN-107 was conducted with laboratory simulants representative of the waste in these two tanks and metal specimens made from material similar to the DST metal walls (RPP-RPT-31680, *Hanford Tanks 241-AN-107 and 241-AN-102 Effect of Chemistry and Other Variables on Corrosion and Stress Corrosion Cracking*). Testing showed that if pH 10 is maintained in the saltcake interstitial liquid, there was a low propensity for SCC. This low propensity for SCC was attributed to the nitrite anion present in the waste.

Testing for 241-AY-102 was conducted in a similar fashion. The results showed a lower propensity for SCC in tank than in either 241-AN-107 or 241-AN-102. In addition, the pitting potential was lower. The decrease in pitting was attributed to the concentration of carbonate ion present in the waste.

VAPOR SPACE CORROSION

Vapor space corrosion (VSC) concerns arose after it was observed in some Savannah River Site tanks. It has been implicated in some Hanford DST wall thinning, and in primary ventilation ductwork cracking and deposits (WHC-SD-WM-TI-478, *Evaluation of Cracking in 241-AZ Tank Farm Ventilation Line*).

This type of corrosion has not had an impact on the DST leak integrity to date. The phenomenon is being investigated to quantify potential dome degradation that could lead to structural issues, and because the VSC – waste chemistry relationship is an important factor in the decision to optimize waste chemistry controls.

Hanford's VSC program includes the following elements:

- Identify vapor components that are causing or contributing to VSC (e.g., ammonium nitrate) and those that may inhibit such corrosion (e.g., ammonia);
- Explore the effects of waste chemistry changes (e.g., pH) on VSC and/or derive experimental or analytical methods to analyze the importance to VSC;
- Explore methods and approaches that might allow accelerated laboratory testing for VSC corrosion.

CORROSION CONTROL

Work performed at the Savannah River Laboratory on Savannah River Site waste (DP-1478, *Prediction of Stress Corrosion of Carbon Steel by Nuclear Process Liquid Waste*,) led to the establishment of present waste chemistry controls to minimize DST corrosion. The DST chemistry controls are specified in terms of nitrate, nitrite, and hydroxide concentration limits. The concentration limits are incorporated into a technical safety requirement that is part of the Tank Farms' safety basis, and specific actions are mandated if the chemistry falls out of specification.

Waste transfers or hydroxide/nitrite additions to DSTs are used to adjust waste chemistry to meet the chemistry limits. However, chemical changes occur during waste storage. Hydroxide concentrations in tank waste are affected by ongoing chemical reactions with organics in the waste and with reaction from carbon dioxide in the vapor space. These reactions generally consume the free hydroxide concentration with time, and are more pronounced at the waste surface. Out-of-specification conditions are corrected by blending with other wastes. Occasionally, caustic addition has been necessary to raise the pH level in DST waste.

CORROSION MONITORING IN DOUBLE-SHELL TANKS

The DSTIP has monitored corrosion in several DSTs using in-tank Electrochemical Noise monitoring that was developed as a DOE technology initiative. Additional sensors that monitor tank corrosion potential (E_{corr}), and general corrosion with Linear Polarization Resistance and Electrical Resistance have been installed in Tank 241-AN-107.

Corrosion Probes

Development and adaptation of in-tank corrosion monitoring technology has been under way at the Hanford Site to provide better understanding of corrosion mechanisms in DSTs and to support more effective control of tank waste chemistry to minimize corrosion. The DSTIP plans to use the following configuration to monitor corrosion in the DSTs:

- **Electrical Resistance** – Electrical resistance (ER) 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.
- **Open Circuit Potential/Free Corrosion Potential** - Laboratory testing shows a significant correlation between the value of the Open Circuit Potential/Free Corrosion Potential (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 would be a key parameter to ensure the long-term integrity of the DSTs. The typical approach to measuring the OCP/ E_{corr} is to monitor potential in a chemical environment versus a reference electrode.

Reference and Surrogate Reference Electrodes

The design of available reference electrodes prevents continuous operation in DSTs for extended periods of time because of the fragile nature of these laboratory instruments. A development program is in place to find robust surrogate reference electrodes to measure the OCP/ E_{corr} in the DSTs. A preliminary screening program identified Cu, Ag, and Ni as potential surrogate electrodes. These will be tested in-tank in the corrosion probe assembly for tank 241-AN-102 scheduled for installation this fiscal year.

Monitoring System Strategy and Deployment

Active tanks subject to relatively frequent changes in chemical conditions require a more robust monitoring program than passive tanks in which the chemical composition remains relatively static.

- **Passive DSTs** – The DSTs with a stagnant chemical composition do not need a variety of corrosion monitoring devices. These DSTs will have an array of stressed and unstressed corrosion coupons. The coupons will be removed from the DST and examined for signs of corrosion at a specified frequency.
- **Active DSTs** – Active DSTs include the evaporator feed DST, and the DSTs that receive SST waste. These DSTs will receive an ER probe and an OCP/ E_{corr} monitoring electrode, along with an array of stressed and unstressed corrosion coupons. Readings from the ER probe and E_{corr} would be taken on a periodic basis. The coupons will be removed from the DST and examined for signs of corrosion either at a specified frequency - or in response to readings taken from the reference electrodes and ER probe.

CONCLUSION

The Double-Shell Tank Integrity Program provides a technically sound, compliant inspection, monitoring, and corrosion control program for Hanford's DSTs. The program elements can identify long-term structural and leak integrity trends in the DSTs, allowing for early response to changes that could impact the DSTs' useful life.