Hanford Double-Shell Tank Ultrasonic Test Examinations – 15287

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ABSTRACT

Washington River Protection Solutions, LLC (WRPS) under contact from the US DOE is responsible for assessing the condition of the double-shell tanks (DSTs) of the Hanford Nuclear Site. WRPS contracted AVERA Federal Services, LLC to perform the ultrasonic testing inspections of the primary tank wall in 28 DSTs to access the condition of the tanks, judge the effects of past corrosion control practices, and satisfy a regulatory requirement to periodically (eight to ten year frequency) assess the integrity of the tanks per Brookhaven National Laboratory (BNL) guidelines for structural integrity programs for tank systems [1].

The major requirements for the Ultrasonic Testing (UT) of each tank are to detect, characterize (identify, size and locate), and record measurements made of any wall thinning, pitting or cracks that might be present in the wall 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 through two 24-inch diameter risers approximately 180° apart.

From 1996 to 2006 the first-round of ultrasonic test inspections for all DSTs were completed utilizing a Pulse-Echo (P-Scan) system. The second round of ultrasonic test inspections have continued since 2007 and are complete for 26 of 28 tanks. The two remaining tanks will receive the second inspections during fiscal year 2015. Currently, the ultrasonic testing comparison results between the first and second rounds of inspection have identified no structural integrity concerns at action levels specified in the BNL guidelines [1].

INTRODUCTION

Concerns related to aging radioactive waste tank storage facilities throughout the US DOE complex led to Brookhaven National Laboratory (BNL) developing guidelines for structural integrity programs for tank systems [1]. The committee of experts who developed these guidelines is commonly known as the Tank Structural Integrity Panel (TSIP). The US DOE has subsequently adopted these guidelines, and requires site operators to have a program consistent with them [2]. The contractual agreement with the Tank Operating Contractor includes a requirement to maintain the tank Structural Integrity Program as described in the Double-Shell Tank (DST) Integrity Project Plan [3]. Non-destructive examination of the primary tank stems from these requirements. The structural integrity programs at Savannah River Site and Hanford were summarized in 2010 [4].

The TSIP guideline criteria for thinning, pitting, and cracking, and DST Integrity Project (DSTIP) reporting criteria are provided in Table I. The criteria provide the level at which degradation mechanisms would require additional action (e.g. increased monitoring). The TSIP recommended examination of 10% of the tanks. The DSTIP examines all of the tanks on an inspection frequency is 8-10 years.

TABLE I. Ultrasonic Testing Evaluation Guidelines and Reportable Values

Parameter	**Structural Integrity Panel Acceptance Criteria BNL-52527**	**Tank Integrity Project Reportable Value RPP-7574**
Thinning	20% thickness	10 % thickness
Pitting	50% thickness	25 % thickness
Cracking	>30 cm (12 in) 20% of thickness ≤30 cm (12 in) 50% of thickness	Any Linear Indication greater than 15 cm (6 in) in length and 0.25 cm (0.1 in) in depth.

DESCRIPTION OF DOUBLE-SHELL TANKS

The carbon steel tanks (see Fig. 1) vary somewhat with respect to plate thickness as shown in Fig. 2. The primary tank is 23 m (75 ft) in diameter and measures approximately 14 m (45.75 ft) in height at the dome center. 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 bottom knuckle is an inwardly curved section of plate that transitions up to the tank wall.

In the 241-AY, 241-AZ, and 241-SY farms, the wall consists of three plates that are approximately 10 ft in height; followed by a "top transition plate" that is approximately 1 m (3 ft) in height. In the 241-AW, 241-AN, and 241-AP farms, there are four plates that are approximately 2.5 m (8 ft) in height. Finally, an inwardly curved section referred to as the top knuckle joins the vertical wall with the roof section of the tank. Fig. 2, below, depicts the course layout for each tank farm.

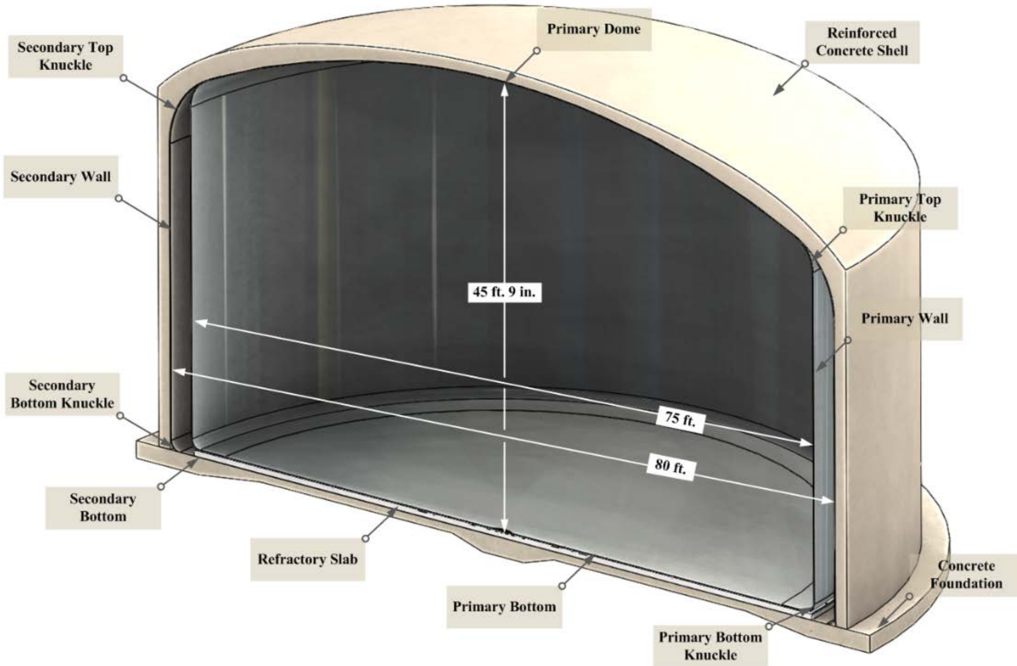

Fig. 1. Double-Shell Tank Components.

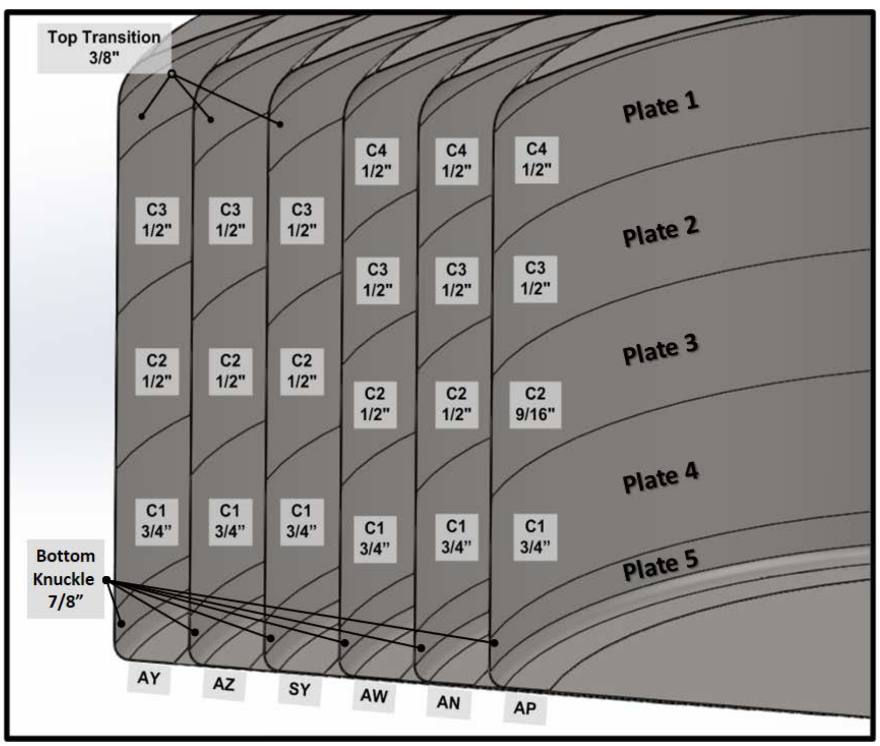

Fig. 2. Primary Tank Wall Course Layout.

INSPECTION APPROACH

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

- Entrance to the annulus is made through two 61 cm (24 in) risers and the same two risers are revisited every cycle to allow comparison and accurate wall loss estimates.
- Four 38 cm (15 in) wide vertical scans of the primary tank wall for all tanks. Two scans are done side-by-side in each riser inspected.
- Twenty-foot length of circumferential weld joining the primary tank vertical wall to the lower knuckle and adjacent heat-affected zone for all tanks.
- Six meter (20 ft) 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 tanks.
- Six meter (20 ft) 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 5-year period, extending at least 30 cm (1 ft) above that liquid/vapor interface for six tanks.
- Six meter (20 ft) long circumferential scan of the predicted maximum stress region of the primary tank lower knuckle for six tanks

The P-scan System 4 scanners shown in Fig. 3 are deployed through two 61 cm (24 in) diameter annulus inspection risers on opposite sides of the tank. One riser on the east side of each DST for examinations of the primary tank wall, the vertical and horizontal weld in the heat affected zone, the upper knuckle, and the secondary tank lower knuckle. The second riser on west side of the tank is utilized to examine the primary tank wall. All tank welds in the heat affected zones examined were in the “as-welded” condition.

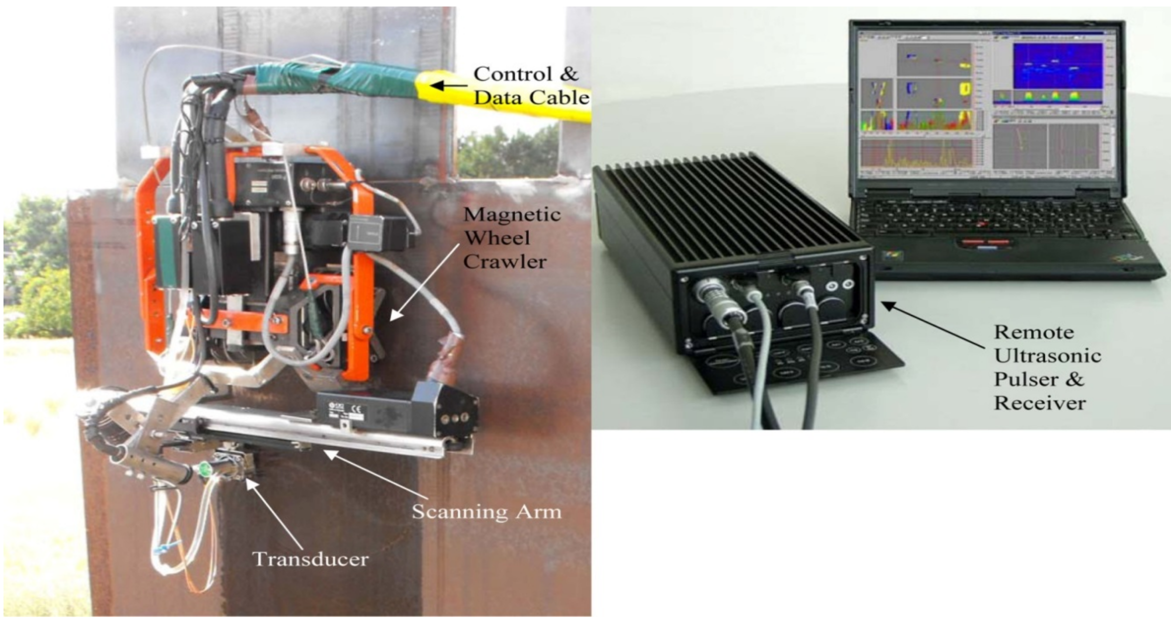

Fig. 3. P-scan Crawler System on Tank Mock-Up.

Typical scan paths are shown in Fig. 4. The vertical wall scans are performed from the plate top to the plate bottom with the scanner backing down the wall.

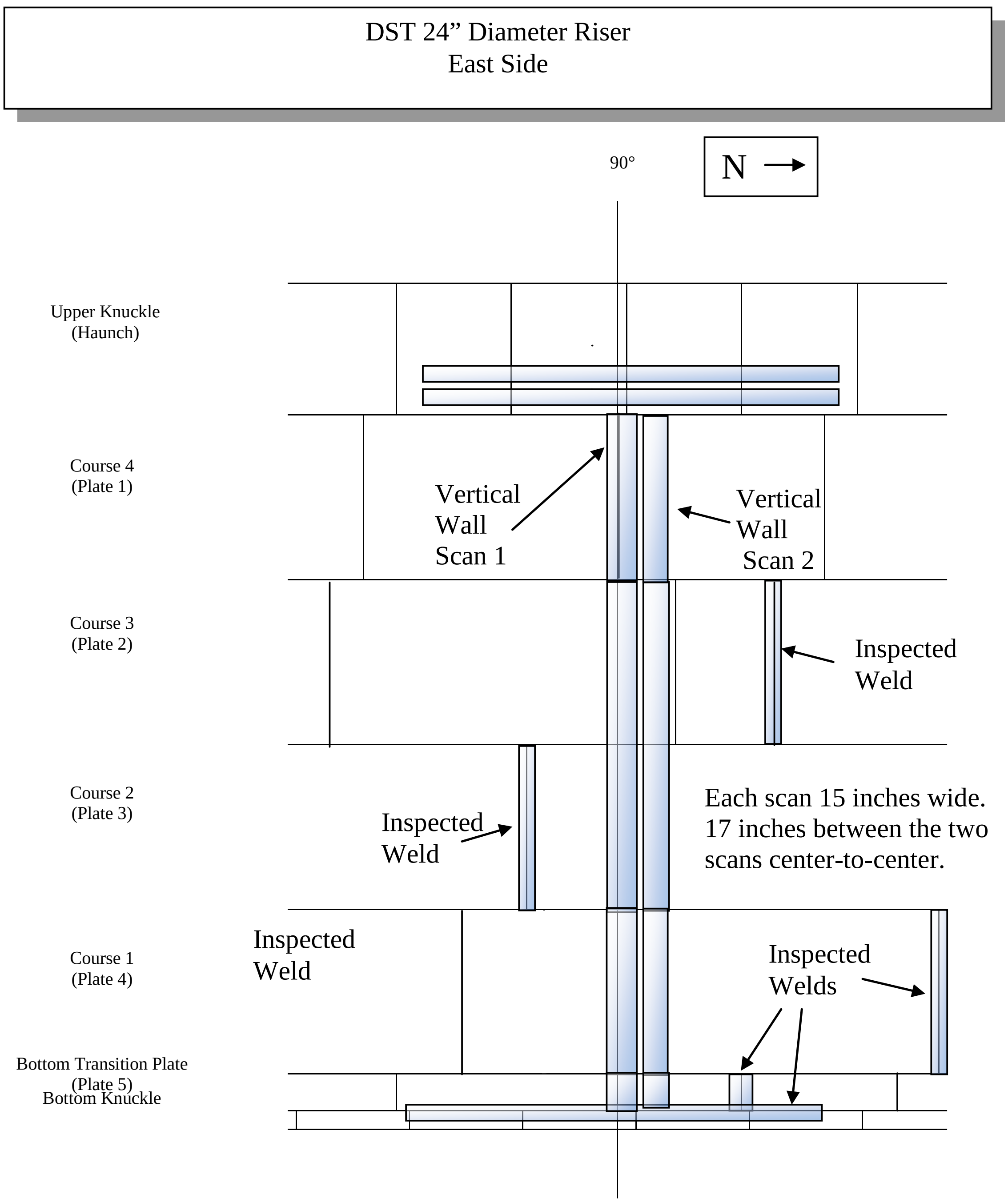

Fig. 4. Typical Ultrasonic Testing Scan Paths on East Side of Double-Shell Tank Primary Wall.

Ultrasonic Testing Technology

An ultrasonic test may be used to measure the thickness of a material or to examine the internal structure of the material for possible discontinuities such as voids and/or cracks. Ultrasonic testing is performed by deploying an ultrasonic transducer to the outer surface of the primary tank wall via a remotely operated magnetic crawler. Acoustic waves generated by high-frequency vibrations act and react in a similar fashion to light beams. When the acoustic wave strikes an interrupting object, such as a discontinuity in the material, most of the sound beam energy is reflected. Reflections can then be pickup up by a second, or, in most cases, by the same piezo crystal (transducer). Within the crystal, the mechanical energy is transformed into electrical energy which is then amplified and presented to the UT technician in the form of a horizontal trace. Ultrasonic testing does not give direct information about the exact nature of the discontinuity. It is up to the certified technician to interpret the ultrasonic data.

The repeatability and accuracy of the UT measurements were assessed in 2009 [5] and variability in the data has been improved since. Measurement results are repeatable with in a two-sigma range to about ±0.127 mm (5 mils). The results in the field prior to 2009 are closer to ±0.254-0.381 mm (10-15 mils) with environmental factors, such as temperature, calibration and plate conditions, equipment evolutions, and differences in taking and translating the data between certified technicians. The UT inspection device evolved from an analog system, beginning in 1997, to a digital platform through several iterations of scanner improvements. The data show positive and negative plate thickness variations consistent with the expected field variability. At least seven of the tanks show plate thickness increases between the first and second scan over a 10 year period.

The first UT scanner mounting platform used on a DST was performed with a Force Institute P-Scan™ ultrasonic test instrument and a Force Institute AWS-5D remote-controlled magnetic-wheel crawler. As of fiscal year 2015 the inspection system used to collect data is still a Force Institute P-Scan™ system. Improvements in magnetic crawler design have resulted in a transition from the AWS-5D to the AGS-1 and now currently the AGS-2 crawler (see Fig. 5).

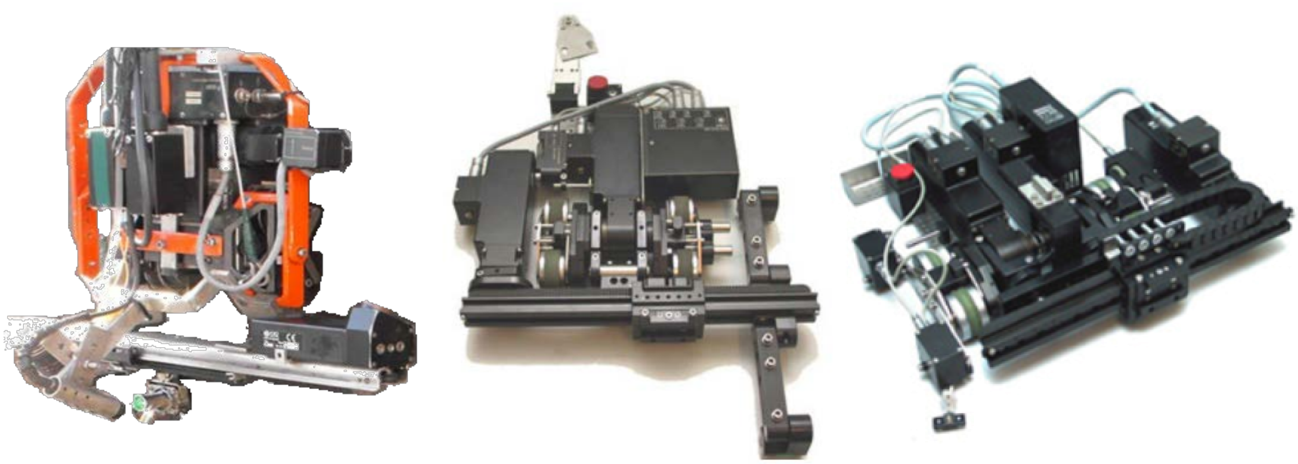

Fig. 5. Force Institute AWS-5D, AGS-1 and AGS-2 Magnetic Wheeled Crawlers.

OBSERVATIONS FROM INSPECTIONS

The raw data is shown in Table II. These values are extracted from 60 documents which report the individual scan results for each tank. All but two of the tanks have at least two scans.

These values are minimums from multiple measurements on each plate and each of the two scans for the original and newest UT tank measurements. Average thickness values are also shown for the scans (original and newest). The data used for this summary were compiled under the following guidelines:

- Original and new values were compared for the same riser.
- Minimum values are the minimum from two scans from the same riser for each round.
- Minimums associated with pitting are highlighted in red in Table II.

TABLE II. Ultrasonic Testing Scan Data

		Minimum Thickness Data Comparison									
		Round 1					Round 2				
		Plate 5 (BK)	Plate 4 (C1)	Plate 3 (C2)	Plate 2 (C3)	Plate 1 (C4)	Plate 5 (BK)	Plate 4 (C1)	Plate 3 (C2)	Plate 2 (C3)	Plate 1 (C4)
		Nominal Thickness					Nominal Thickness				
AY/AZ/SY ->		0.875	0.750	0.500	0.500	0.375	0.875	0.750	0.500	0.500	0.375
AW/AN ->		0.875	0.750	0.500	0.500	0.500	0.875	0.750	0.500	0.500	0.500
AP ->		0.875	0.750	0.563	0.500	0.500	0.875	0.750	0.563	0.500	0.500
Reportable Pit		0.219	0.188	0.125	0.125	0.094	0.219	0.188	0.125	0.125	0.094
0.250		0.219	0.188	0.125	0.125	0.125	0.219	0.188	0.125	0.125	0.125
		0.219	0.188	0.141	0.125	0.125	0.219	0.188	0.141	0.125	0.125
AY-101	1	0.857	0.683	0.409	0.501	0.385	0.857	0.667	0.430	0.434	0.326
AY-102	2	0.775	0.734	0.485	0.485	0.383	0.775	0.672	0.441	0.470	0.347
AZ-101	3	0.860	0.718	0.460	0.443	0.350	0.862	0.728	0.469	0.460	0.355
AZ-102	4	0.874	0.752	0.487	0.412	0.338	0.852	0.754	0.493	0.402	0.346
SY-101	5	0.897	0.713	0.485	0.463	0.306	0.912	0.734	0.488	0.476	0.330
SY-102	6	0.835	0.722	0.477	0.486	0.328	0.864	0.740	0.483	0.486	0.334
SY-103	7	0.890	0.708	0.461	0.486	0.327	0.895	0.717	0.457	0.497	0.323
AW-101	8	0.850	0.724	0.420	0.488	0.469	0.834	0.714	0.481	0.475	0.463
AW-102	9	0.852	0.740	0.507	0.511	0.487	0.855	0.732	0.501	0.495	0.491
AW-103	10	0.855	0.748	0.500	0.508	0.500	0.848	0.732	0.497	0.496	0.465
AW-104	11	0.873	0.763	0.523	0.528	0.516	0.865	0.757	0.485	0.508	0.488
AW-105	12	0.872	0.722	0.484	0.472	0.509	0.852	0.721	0.476	0.463	0.498
AW-106	13	0.868	0.707	0.498	0.499	0.465	0.873	0.725	0.497	0.490	0.489
AN-101	14	0.847	0.720	0.469	0.480	0.486	0.848	0.708	0.461	0.480	0.477
AN-102	15	0.856	0.715	0.457	0.469	0.445	0.856	0.720	0.482	0.496	0.474
AN-103	16	0.846	0.721	0.470	0.496	0.486	0.846	0.721	0.470	0.496	0.486
AN-104	17	0.857	0.743	0.489	0.499	0.480	0.857	0.743	0.489	0.499	0.480
AN-105	18	0.874	0.729	0.480	0.400	0.452	0.851	0.718	0.482	0.464	0.486
AN-106	19	0.857	0.703	0.485	0.473	0.493	0.849	0.727	0.471	0.469	0.485
AN-107	20	0.859	0.754	0.476	0.469	0.510	0.851	0.749	0.490	0.473	0.504
AP-101	21	0.860	0.741	0.539	0.498	0.492	0.861	0.743	0.567	0.500	0.444
AP-102	22	0.790	0.684	0.489	0.416	0.428	0.782	0.685	0.512	0.440	0.444
AP-103	23	0.866	0.737	0.550	0.471	0.486	0.855	0.733	0.558	0.481	0.484
AP-104	24	0.861	0.747	0.570	0.497	0.458	0.848	0.745	0.548	0.481	0.411
AP-105	25	0.856	0.724	0.554	0.484	0.479	0.861	0.734	0.563	0.462	0.480
AP-106	26	0.854	0.747	0.539	0.489	0.455	0.854	0.755	0.539	0.499	0.466
AP-107	27	0.879	0.735	0.568	0.496	0.499	0.856	0.706	0.526	0.464	0.479
AP-108	28	0.871	0.748	0.560	0.462	0.528	0.856	0.714	0.528	0.427	0.508

		Average Thickness Data Comparison									
		Round 1					Round 2				
		Plate 5 (BK)	Plate 4 (C1)	Plate 3 (C2)	Plate 2 (C3)	Plate 1 (C4)	Plate 5 (BK)	Plate 4 (C1)	Plate 3 (C2)	Plate 2 (C3)	Plate 1 (C4)
		Nominal Thickness					Nominal Thickness				
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AW/AN ->		0.875	0.750	0.500	0.500	0.500	0.875	0.750	0.500	0.500	0.500
AP ->		0.875	0.750	0.563	0.500	0.500	0.875	0.750	0.563	0.500	0.500
Reportable Pit		0.219	0.188	0.125	0.125	0.094	0.219	0.188	0.125	0.125	0.094
0.250		0.219	0.188	0.125	0.125	0.125	0.219	0.188	0.125	0.125	0.125
		0.219	0.188	0.141	0.125	0.125	0.219	0.188	0.141	0.125	0.125
AY-101	1	0.875	0.774	0.525	0.532	0.410	0.875	0.750	0.484	0.500	0.385
AY-102	2	0.882	0.766	0.521	0.522	0.411	0.882	0.737	0.500	0.493	0.387
AZ-101	3	0.900	0.753	0.503	0.498	0.383	0.896	0.759	0.508	0.498	0.376
AZ-102	4	0.906	0.772	0.510	0.502	0.389	0.914	0.775	0.512	0.506	0.390
SY-101	5	0.938	0.753	0.516	0.512	0.357	0.946	0.773	0.520	0.519	0.375
SY-102	6	0.883	0.770	0.513	0.522	0.367	0.904	0.781	0.526	0.529	0.377
SY-103	7	0.921	0.755	0.514	0.521	0.359	0.924	0.757	0.517	0.530	0.374
AW-101	8	0.889	0.770	0.531	0.528	0.518	0.877	0.766	0.525	0.522	0.508
AW-102	9	0.896	0.777	0.553	0.552	0.550	0.902	0.777	0.538	0.540	0.544
AW-103	10	0.907	0.766	0.530	0.534	0.525	0.880	0.761	0.535	0.531	0.528
AW-104	11	0.909	0.803	0.556	0.573	0.548	0.901	0.794	0.534	0.558	0.531
AW-105	12	0.904	0.763	0.520	0.505	0.543	0.890	0.764	0.522	0.508	0.536
AW-106	13	0.900	0.757	0.532	0.540	0.514	0.910	0.767	0.542	0.548	0.536
AN-101	14	0.890	0.765	0.517	0.520	0.521	0.897	0.773	0.519	0.520	0.520
AN-102	15	0.904	0.770	0.527	0.535	0.533	0.896	0.758	0.517	0.528	0.508
AN-103	16	0.884	0.755	0.516	0.523	0.539	0.884	0.755	0.516	0.523	0.539
AN-104	17	0.889	0.770	0.524	0.525	0.529	0.889	0.770	0.524	0.525	0.559
AN-105	18	0.910	0.771	0.543	0.468	0.510	0.900	0.755	0.513	0.512	0.516
AN-106	19	0.897	0.760	0.516	0.520	0.553	0.878	0.759	0.499	0.505	0.515
AN-107	20	0.884	0.779	0.517	0.500	0.534	0.882	0.785	0.523	0.503	0.538
AP-101	21	0.875	0.762	0.586	0.521	0.517	0.875	0.767	0.585	0.526	0.526
AP-102	22	0.858	0.739	0.564	0.492	0.502	0.874	0.773	0.586	0.512	0.515
AP-103	23	0.876	0.768	0.583	0.496	0.510	0.872	0.764	0.585	0.503	0.515
AP-104	24	0.878	0.779	0.587	0.522	0.522	0.867	0.772	0.575	0.512	0.512
AP-105	25	0.872	0.760	0.575	0.510	0.516	0.874	0.755	0.580	0.517	0.520
AP-106	26	0.874	0.769	0.568	0.518	0.523	0.878	0.786	0.579	0.524	0.525
AP-107	27	0.902	0.780	0.581	0.520	0.530	0.887	0.752	0.560	0.492	0.512
AP-108	28	0.890	0.779	0.587	0.512	0.548	0.868	0.753	0.564	0.490	0.526

Legend	
	Waiting for 2nd inspection
Red	indicates pits
	No original scan data

Fig. 6 shows the minimum thickness values for both the previous (original) and most recent for each plate and each tank. The average values actually show thickness above nominal values because steel plate is typically fabricated in thickness slightly above the nominal value.

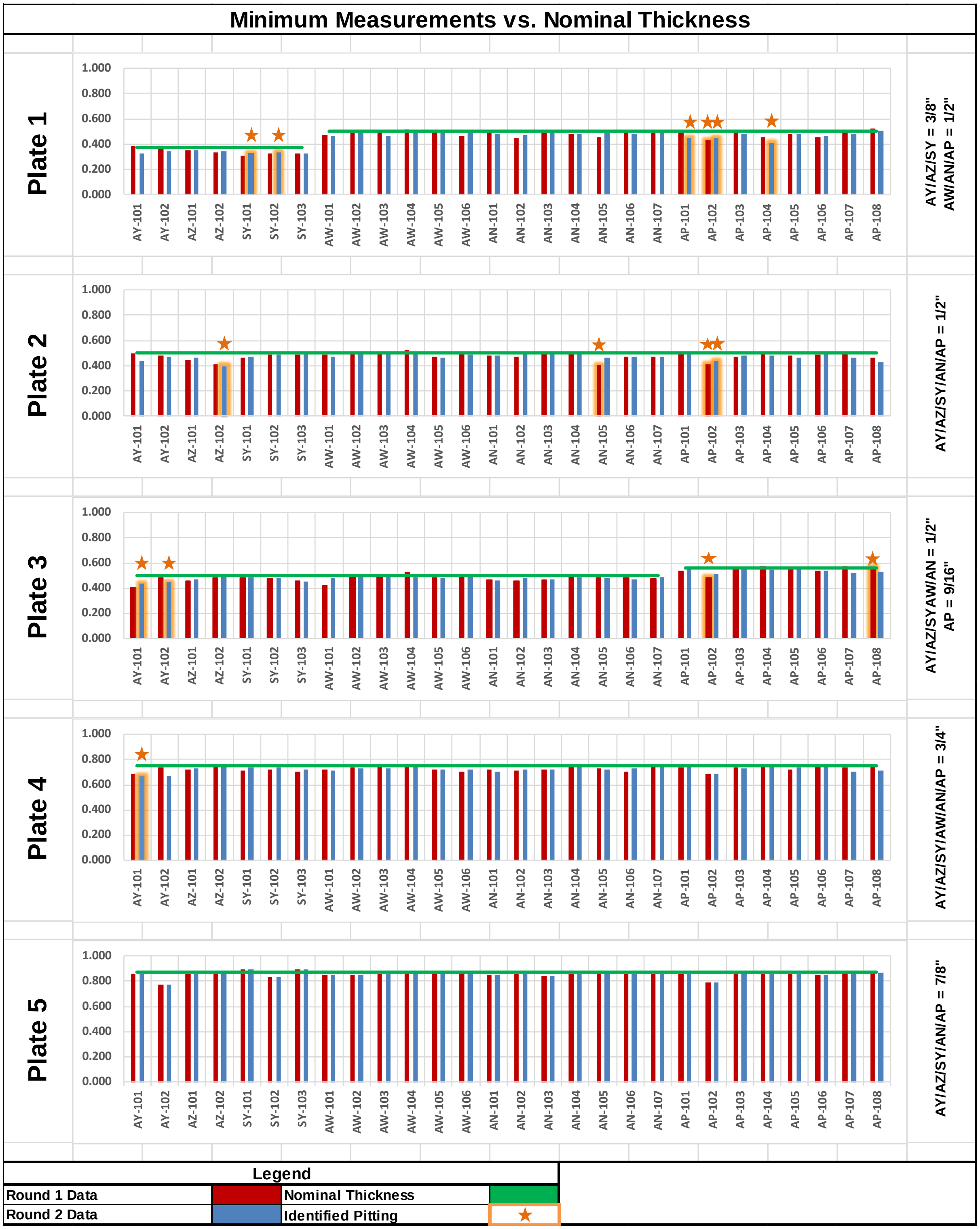

Fig. 6. Minimum Thickness Values (Primary Tank).

Fig. 7 shows the average measurements relative to nominal plate thickness.

Fig. 7. Average Thickness Values (Primary Tank).

The average values for the measurements are shown in Fig. 8 in a bar chart as a fraction of the reportable values (10%). It should be noted that many of the values show no thinning as a consequence of the original plate material exceeding the minimum thickness specification. Of the 140 possible average values (28 tanks with 5 plates), only 21 values are below the nominal thickness. The four highest average thinning measurements are 20 to 30% of the reportable value (10% of the plate thickness).

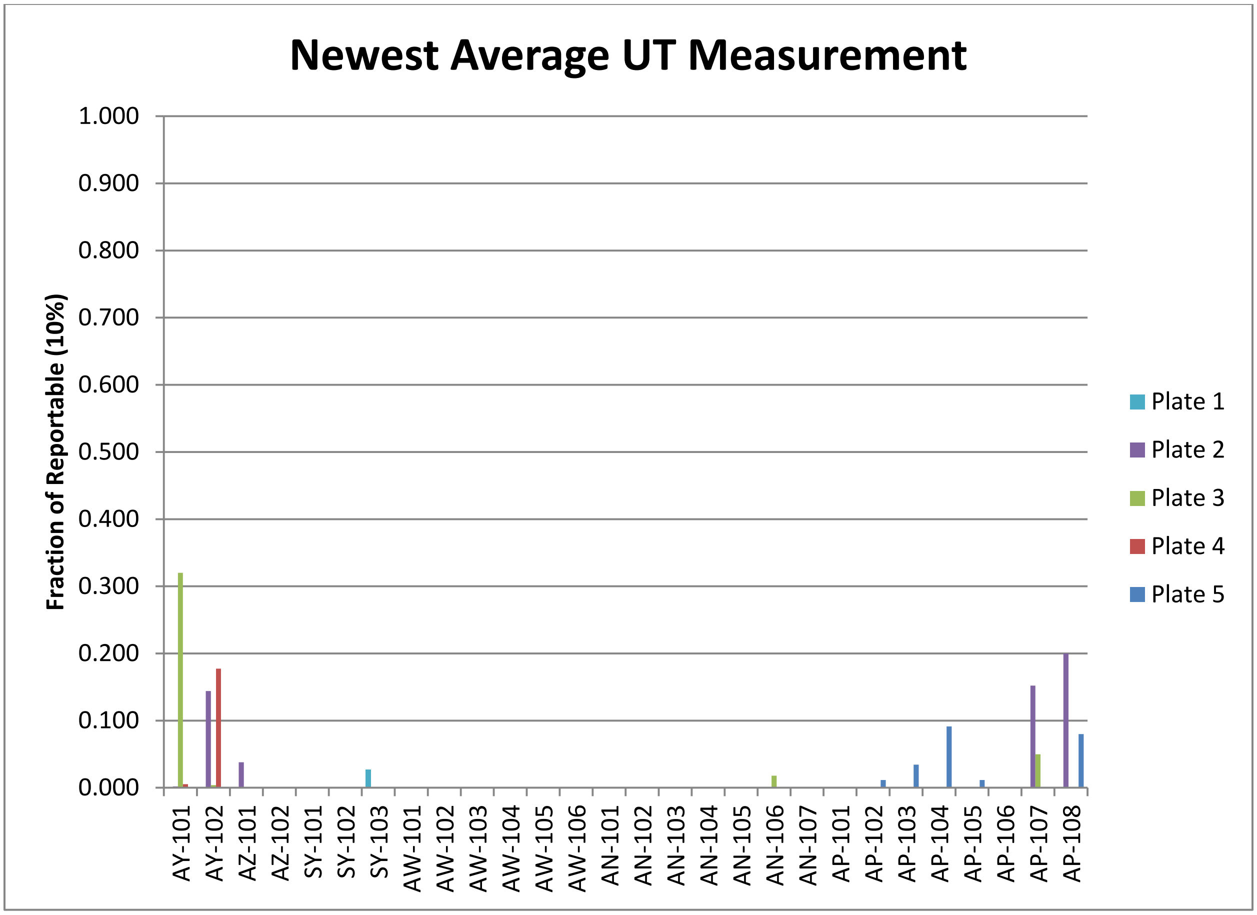

Fig. 8. Average Thickness Measurements (Round 2).

The minimum thickness values are shown as a fraction of the action level (20% for thinning and 50% for pitting) in Fig. 9. These extreme values are within about 70% of the requirement as shown in Fig. 9. Six of the extreme values are above the reportable limit thinning.

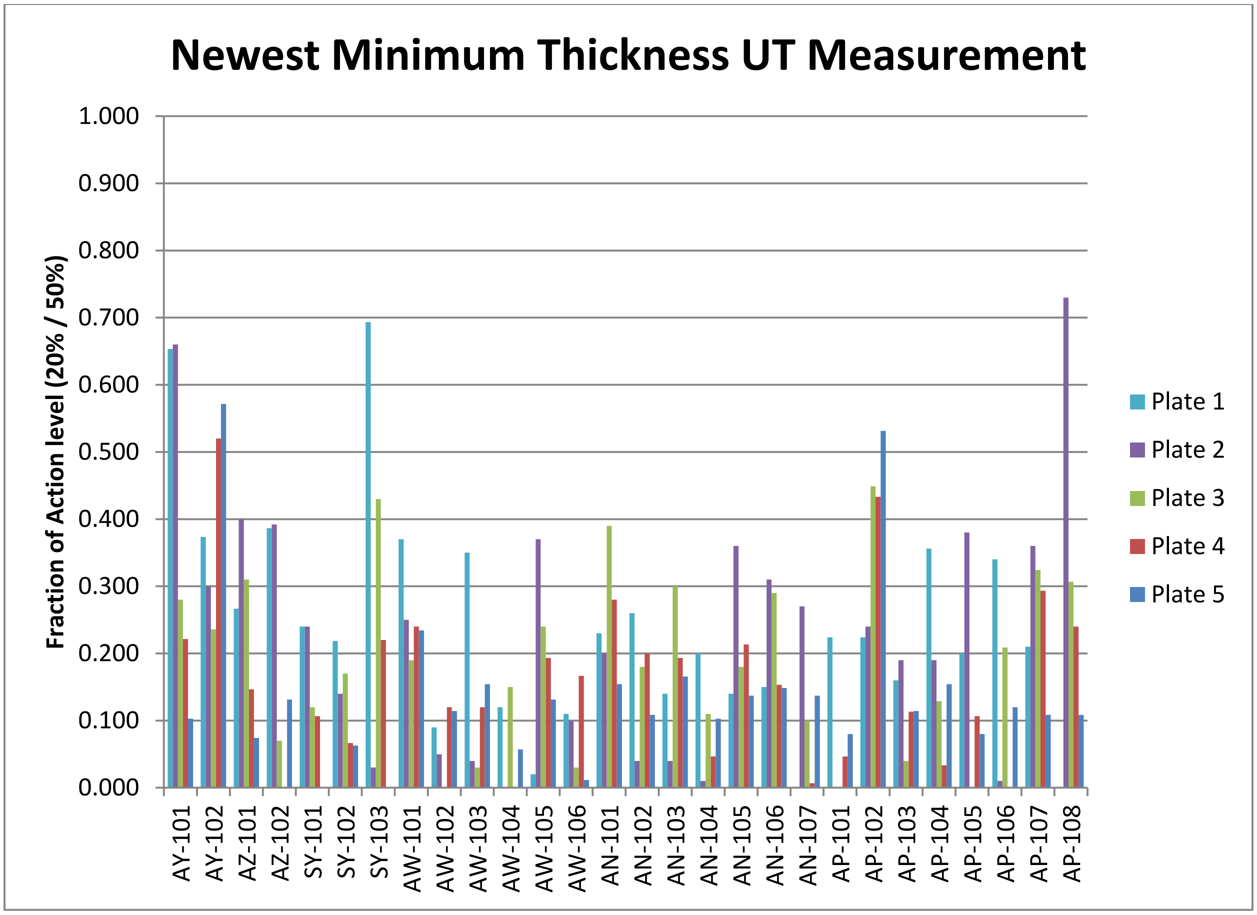

Fig. 9. Minimum Thickness measurements (Round 2).

Other observations with respect to tank integrity include:

1. The annulus ventilation in the AY tanks was turned off for about 10 years. The humidity in the annulus resulted in more rust on the outside wall of the primary tank (annulus side).
2. Tank AP-103 contains two anomalies that were identified during the fiscal year 2003 inspection: an area of incomplete fusion and a gouge. The small area of incomplete fusion, located in the heat-affected zone of the Plate 5 vertical weld, was reexamined and was found to have no change in size. The small gouge on the outside surface of the tank, located on Plate 4 just above the Plate 5-to-Plate 4 horizontal weld, was also reexamined and found to have no change in size.
3. Recently, annulus floor scans in tank AP-102 showed measureable thinning and pitting. The Riser-031 secondary liner floor scan yielded an overall average wall thickness value of 103.1% of nominal. The average minimum wall thickness value was 85.8% of nominal. Of the 12-inch long secondary liner floor scans yielding minimum thicknesses falling below the nominal values, the greatest deviation was 70.2% below nominal. Two areas of reportable wall thinning, no non-reportable pits, and multiple reportable pits were found through Riser-031. Table III below lists the eight areas of reportable plate thinning.

TABLE III. Secondary Floor Reportable Indications

Scan File Name	Indication Boundary Size	Minimum Thickness	Nominal Thickness (inches)	Percent Thinning
Secondary Floor/0/R31 South	37.4x34.7 cm (14.73 x 13.66 in)	0.378 cm (0.149 in)	1.27 cm (0.500 in)	70.2%
Secondary Floor/0/R31 North	24.6 x 23.0 cm (9.86 x 9.07 in)	0.968 cm (0.381 in)	1.27 cm (0.500 in)	23.8%

4. A structural analysis was conducted on the primary tank steel to determine if wall thinning impacted structural integrity [6]. As shown in Fig. 10, the additional wall thinning necessary to challenge structural integrity is far below reportable and action levels.

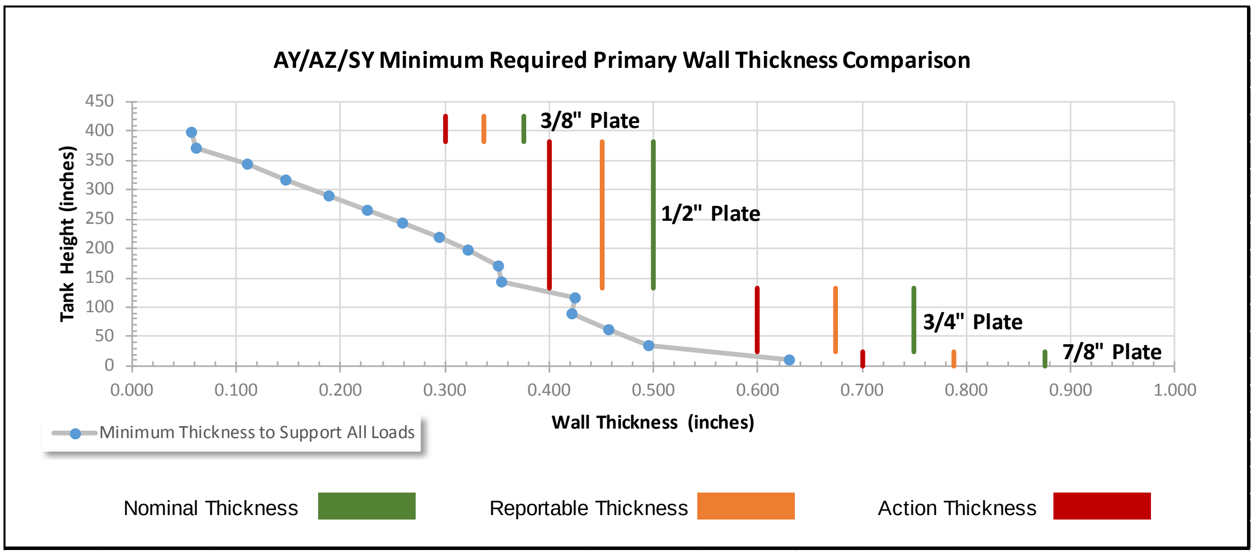

Fig. 10. Minimum Wall Thickness Required for Structural Integrity.

CONCLUSIONS

The UT data for the primary tank walls shows the tanks are in good condition. There is no observable trend in the data and nothing to suggest the remaining useful life of the tanks is compromised. Average values which are lower over the 8-10 year period between measurements are typically 0.254-0.508 mm (10-20 mils) lower, but usually still above nominal plate thickness values. Plate steel is typically fabricated in thicknesses which exceed the nominal values. Normal corrosion rates for carbon steel are 0.0254-0.0508 mm/yr (1-2 mils/yr) and the accuracy of the UT scans are ±0.127 mm (5 mils). At least seven of the tanks show increases in thickness from the first scan to the second over a 10 year period, indicating variability in the scanning conditions and the accuracy of the equipment.

Primary Tank Walls

Seventeen tanks show no areas of wall thinning greater than 10%. As shown in Table IV, 11 tanks show reportable areas of thinning greater than 10% but less than 20%. Four DSTs have pit-like findings which are below the reportable level.

TABLE IV. Summary of Tanks with Findings From Primary Wall Inspections

Tank	Reportable Thinning	Pitting	Linear Indication
AY-101	14		
AY-102	4	18<25%	
AZ-102	3		
SY-101	12	6<25%	
SY-102		4<25%	
SY-103	1		
AW-101	1		
AN-101	1		
AN-102	2		
AP-102	2	13 <25%	
AP-103			P5 - Incomplete fusion, P4 - small gouge
AP-108	4		1 - P4, 15cm (6 in) L x 0.36 cm (0.142 in) D

Welds

Selected weld seams are scanned in the vicinity of the riser chosen for each tank. This data shows the welds are in good condition. However this data is not uniform to be of value in reporting trends relative to the nominal plate thickness.

Bottom Plate

Portions of the bottom knuckle are included in the plate 5 measurements summarized in the primary tank wall data. There is no data on the primary tank bottom because it is not accessible with present technology.

Future Work

Since the initiation of the inspection Program, further enhancements involve the development of a Tandem-Synthetic Aperture Focusing Technique (T-SAFT) Single and Dual Y-Arm System and planned implementation of Electromagnetic Acoustic Transducer (EMAT) System. The T-SAFT was tested and successfully deployed from 1999 to 2003 to inspect the most highly stressed region in the tank, the lower knuckle region. The EMAT system will enable faster material interrogation rates as compared to the standard UT methods currently used for inspecting DSTs. The EMAT system will be evaluated as an enhancement to the DST non-destructive examination program.

REFERENCES

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