PNNL-16646 Rev.0

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Ultrasonic Examination of Double-Shell Tank 241-AY-101 Examination Completed March 2007

AF Pardini
DR Weier

June 2007

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

AREVA NC Inc., under a contract from CH2M Hill Hanford Group, has performed an ultrasonic examination of selected portions of Double-Shell Tank 241-AY-101. The purpose of this examination was to provide information that could be used to evaluate the integrity of the wall of the primary tank. The requirements for the ultrasonic examination of Tank 241-AY-101 were 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. Any measurements that exceed the requirements set forth in the Engineering Task Plan, RPP-Plan-27202 (Jensen 2005) and summarized on page 1 of this document, are to be reported to CH2M Hill Hanford Group and the Pacific Northwest National Laboratory for further evaluation. Under the contract with CH2M Hill Hanford Group, all data is to be recorded on electronic media and paper copies of all measurements are provided to Pacific Northwest National Laboratory for third-party evaluation. Pacific Northwest National Laboratory is responsible for preparing a report(s) that describes the results of the AREVA NC Inc. ultrasonic examinations.

Examination Results

The results of the examination of Tank 241-AY-101 have been evaluated by Pacific Northwest National Laboratory personnel. The primary tank ultrasonic examination consisted of one vertical 15-in.-wide scan path over the entire height of the tank, the heat-affected zone of five vertical welds and one horizontal weld from Riser 88 and one vertical 15-in.-wide scan path over the entire height of the tank from Riser 89. Additionally, three horizontal scans were performed at the liquid-air interface region from riser 88. The examinations were performed to detect any wall thinning, pitting, or cracking in the primary tank wall.

Primary Tank Wall Vertical Scan Paths

One 15-in.-wide vertical scan path was performed on Plates #1, #2, #3, #4, and #5 from Riser 88. The plates were examined for wall thinning, pitting, and cracks oriented vertically on the primary tank wall.

- Plate #1 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #1.
- Plate #2 results indicate one area with minimum thickness of 0.434-in. exceeds the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #2.
- Plate #3 results indicate seven areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these seven areas (with remaining ligament of 0.430-in., 0.439-in., 0.440-in., 0.442-in., 0.444-in., 0.444-in., and 0.444-in.) were analyzed by the ultrasonic testing (UT) Level III and were considered pit-like and therefore do not exceed the reportable pitting level of 25% of the nominal thickness. No vertical crack-like indications were detected in Plate #3.

- Plate #4 results indicate two areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these two areas (with remaining ligament of 0.667-in., and 0.670-in.) were analyzed by the Ultrasonic Level III and were considered pit-like and therefore do not exceed the reportable pitting level of 25% of the nominal thickness. No vertical crack-like indications were detected in Plate #4.
- Plate #5 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #5.

One 15-in.-wide vertical scan path was performed on Plates #1, #2, #3, #4, and #5 from Riser 89. The plates were examined for wall thinning, pitting, and cracks oriented vertically on the primary tank wall.

- Plate #1 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #1.
- Plate #2 results indicate two areas with minimum thickness of 0.397-in. and 0.444-in. that exceed the minimum thinning reportable level of 10% of the nominal thickness. The 0.397-in. area exceeded the acceptance criteria of 20% and will require the tank owner to take special action. No pitting or vertical crack-like indications were detected in Plate #2.
- Plate #3 results indicate eight areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these eight areas (with remaining ligament of 0.431-in., 0.437-in., 0.437-in., 0.439-in., 0.439-in., 0.446-in., 0.446-in., and 0.448-in.) were analyzed by the Ultrasonic Level III and were considered pit-like and therefore do not exceed the reportable pitting level of 25% of the nominal thickness. No vertical crack-like indications were detected in Plate #3.
- Plate #4 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #4.
- Plate #5 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #5.

Primary Tank Wall Horizontal Scan Paths

Three 15-in.-wide horizontal scan paths were performed in the liquid-air interface region on Plate #2 from Riser 88. The plates were examined for wall thinning, pitting, and cracks oriented in a circumferential direction on the primary tank wall.

- Liquid-air interface scan #1 results indicated six areas (with remaining ligament of 0.423-in., 0.431-in., 0.438-in., 0.440-in., 0.445-in., and 0.446-in. exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or circumferentially oriented crack-like indications were detected in liquid-air interface scan #1.
- Liquid-air interface scan #2 results indicated nine areas (with remaining ligament of 0.388-in., 0.419-in., 0.430-in., 0.430-in., 0.439-in., 0.440-in., 0.444-in., 0.445-in., and 0.448-in. exceed the minimum thinning reportable level of 10% of the nominal thickness. However, one of these areas (0.388-in.) was analyzed by the Ultrasonic Level III and was considered pit-like and therefore does not exceed the reportable pitting level of 25% of the nominal thickness. No circumferentially oriented crack-like indications were detected in liquid-air interface scan #2.

- Liquid-air interface scan #3 results indicated two areas (with remaining ligament of 0.436-in., and 0.446-in. exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or circumferentially oriented crack-like indications were detected in liquid-air interface scan #3.

Primary Tank Wall Weld Scan Paths

The heat-affected zone of vertical welds in Plates #1, #2, #3, #4, and #5 from Riser 88 were examined for wall thinning, pitting and cracks oriented either perpendicular or parallel to the weld.

- Plate #1 indicates one area with a minimum thickness of 0.329-in. that exceeded the minimum thinning reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #1.
- Plate #2 indicates two areas with a minimum thickness of 0.434-in. and 0.443-in. that exceeded the minimum thinning reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #2.
- Plate #3 indicates no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #3.
- Plate #4 indicates no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #4.
- Plate #5 indicates no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #5.

The heat-affected zone of the horizontal weld between Plate #3 and Plate #4 from Riser 88 was examined for wall thinning, pitting and cracks oriented either perpendicular or parallel to the weld. The results indicated no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas on Plate #3 side or on Plate #4 side of the horizontal weld.

Extreme Value Analysis

Extreme value measured wall thickness losses were estimated. Since current remaining wall thickness typically still exceeds drawing nominal, thereby generating negative losses, ultrasonic image maximum values were instead used to determine estimated nominal wall thickness per plate/riser combination. These thicknesses tended to run up to about 0.020-in. greater than drawing nominal. They in turn were used with each ultrasonic image minimum value to determine estimated wall thickness losses, which were then combined for a plate course over the two risers, with a single ultrasonic measurement path per riser.

Three parameter Weibull distributions were fit to combinations of plate course measurements as well as to the measurements for the liquid-air interface region. Plates #1& #2 combined generate a worst case measured wall thickness loss of 0.054-in. that might be expected if the entire surface area of the tank wall in these plates, but outside the liquid-air interface region in Plate #2, were ultrasonic inspected. A 95% confidence bound is computed based on the uncertainty in the Weibull parameters caused by the relatively minimal amounts of data for distribution fitting and the quality of the Weibull fit; this 95% bound on measured wall thickness loss is 0.067-in. Note that such losses should be considered relative to the larger "estimated" nominal wall thicknesses and not the drawing nominal.

The corresponding estimated worst case loss and bound for Plates #3, #4, & #5 are respectively 0.122-in. and 0.149-in. These larger values result from generally larger measured losses, their greater variability, and a rather poor Weibull distribution fit. Even larger measured liquid-air interface region losses, with some outlying values as well, give the corresponding loss and bound values for the liquid-air interface region as 0.148-in. and 0.192-in.

Contents

Figures

1.0 Introduction

AREVA NC Inc. (AREVA), under a contract from CH2M Hill Hanford Group (CH2M Hill), has performed an ultrasonic (UT) examination of selected portions of Double-Shell Tank (DST) 241-AY-101. The purpose of this examination was to provide information that could be used to evaluate the integrity of the DST. The requirements for the ultrasonic examination of Tank 241-AY-101 were 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. Any measurements that exceed the requirements set forth in the Engineering Task Plan (ETP), RPP-Plan-27202 (Jensen 2005), are to be reported to CH2M Hill and the Pacific Northwest National Laboratory (PNNL) for further evaluation. Specific measurements that are reported include the following:

- Wall thinning that exceeds 10% of the nominal thickness of the plate.
- Pits with depths that exceed 25% of the nominal plate thickness.
- Stress-corrosion cracks (SCC) that exceed 0.10 in. (through-wall) and are detected in the inner wall of the tank, the heat-affected-zone (HAZ) of welds, or in the tank knuckle.

The accuracy requirements for ultrasonic measurements for the different types of defects are as follows:

- Wall thinning – measure thickness within ±0.020 in.
- Pits – size depths within ±0.050 in.
- Cracks – size the depth of cracks on the inner wall surfaces within ±0.1 in.
- Location – locate all reportable indications within ±1.0 in.

Under the contract with CH2M Hill, all data is to be recorded on electronic media and paper copies of all measurements are provided to PNNL for third-party evaluation. PNNL is responsible for preparing a report(s) that describes the results of the AREVA UT.

2.0 Qualified Personnel, Procedures, and Equipment

Under contract from CH2M Hill, qualification of personnel participating in the DST inspection program, the UT equipment (instrument and mechanical scanning fixture), and the UT procedure that will be used in the examination of the current DST is required. Personnel participating in the examinations are to be certified in accordance with American Society for Nondestructive Testing (ASNT) Recommended Practice SNT-TC-1A, 1992 Edition, and associated documentation is to be provided. The capability of the UT system is to be validated through a performance demonstration test (PDT) on a mock-up simulating the actual DST. The current procedure for the UT is to be based on requirements listed in the American Society for Mechanical Engineers (ASME), Boiler and Pressure Vessel Code Section V, Article 4, *Ultrasonic Examination Methods for Inservice Inspection*.

2.1 Personnel Qualifications

The following individuals were qualified and certified to perform UT of the Hanford DST 241-AY-101:

- **Mr. Wesley Nelson**, ASNT Level III (#LM-1874) in UT, has been identified as AREVA's UT Level III authority for this project. Mr. Nelson has been certified by AREVA as a UT Level III in accordance with AREVA procedure COGEMA-SVCP-PRC-014, latest revision which conforms to the requirements of ASNT SNT-TC-1A, 1992. Further documentation has been provided to establish his qualifications (Pardini 2000).

- **Mr. James B. Elder**, ASNT Level III (#JM-1891) in UT, has been contracted by AREVA to provide peer review of all DST UT data. Mr. Elder has been certified by JBNDT as a UT Level III in accordance with JBNDT written practice JBNDT-WP-1, latest revision. Further documentation has been provided to establish his qualifications (Posakony and Pardini 1998).

- **Mr. William D. Purdy**, AREVA UT Level II limited (for P-Scan data acquisition only). Mr. Purdy has been certified in accordance with AREVA procedure COGEMA-SVCP-PRC-014, latest revision. Further documentation has been provided to establish his qualifications (Posakony 2001).

- **Mr. Jeffery S. Pintler**, AREVA UT Level II limited (for P-Scan data acquisition only). Mr. Pintler has been certified in accordance with AREVA procedure COGEMA-SVCP-PRC-014, latest revision. Further documentation has been provided to establish his qualifications (Pardini 2006).

The following individual participated in this examination and is a trainee and therefore not qualified or certified to perform independent UT of the Hanford DST 241-AY-102:

- **Ms. Laura A. Sepich**, AREVA UT trainee in accordance with AREVA procedure COGEMA-SVCP-PRC-014, latest revision.

2.2 Ultrasonic Examination Equipment

CH2M Hill has provided the UT equipment for the examination of Tank 241-AY-101. This equipment consists of a Force Technology P-Scan ultrasonic test instrument and Force Technology AWS-5D remote-controlled, magnetic-wheel crawler for examining the primary tank wall. Ultrasonic transducers used for the examinations are commercially available. The P-Scan ultrasonic system has been qualified through a PDT administered by PNNL. (Posakony and Pardini 1998)

2.3 Ultrasonic Examination Procedure

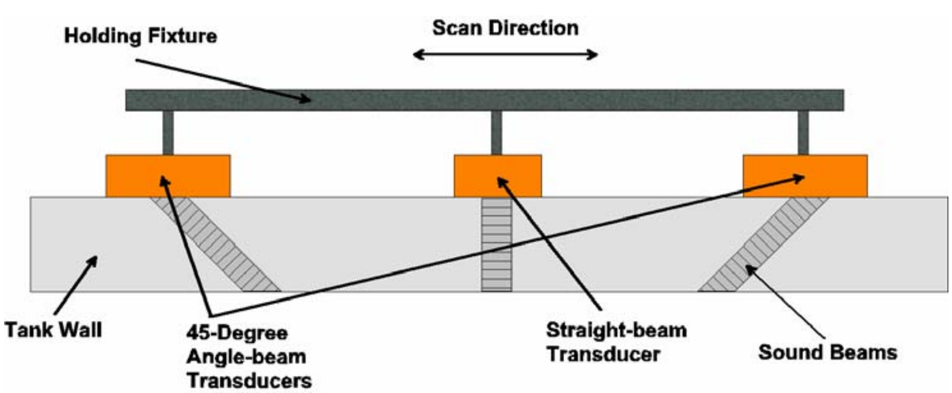
AREVA has provided the UT procedure for the examination of Tank 241-AY-101. This procedure, COGEMA-SVUT-INS-007.3, Revision 3, outlines the type of UT and mechanical equipment that are to be used as well as the types of transducers. Both straight-beam and angle-beam transducers are used for the examination of the primary tank wall. The examination procedures include full documentation on methods for calibration, examination, and reporting. Hard copies of the T-Scan (thickness) and P-Scan (projection or angle beam) views of all areas scanned are made available for analysis. The UT procedure requires the use of specific UT transducers for the different examinations. A calibration performed before and after the examinations identifies the specific transducers used and the sensitivity adjustments needed to perform the inspection. The AREVA UT procedure has been qualified through a PDT (Posakony and Pardini 1998).

3.0 Ultrasonic Examination Configuration

AREVA is required to inspect selected portions of the DSTs which may include the primary and secondary tank walls, the HAZ of the primary tank vertical and horizontal welds, and the tank knuckle and bottoms. The P-Scan system has been configured to perform these examinations and has been performance tested. The examination of Tank 241-AY-101 included UT of the primary tank wall and the HAZ of selected welds in the primary tank wall.

3.1 Primary Tank Wall Transducer Configuration

Figure 3.1 provides an example of the scanning configuration generally used during an examination of the primary tank wall. However, other configurations can be used at the discretion of the AREVA UT Level III (i.e., 45-degree transducers can be removed for simple wall thickness measurements). The functional diagram in Figure 3.1 shows one straight-beam and two angle-beam transducers ganged together for examining the primary tank wall. The straight beam is designed to detect and record wall thinning and pits, and the angle beams are designed to detect and record any cracking that may be present. These transducers are attached to the scanning bridge and they all move together. Information is captured every 0.035-in. (or as set by the UT inspector) as the assembly is scanned across a line. At the end of each scan line the fixture is indexed 0.035-in. (or as set by the UT inspector) and the scan is repeated. The mechanical scanning fixture is designed to scan a maximum of approximately 15-in. and then index for the next scan. The hard copy provides a permanent record that is used for the subsequent analysis.



Transducer Specifications:

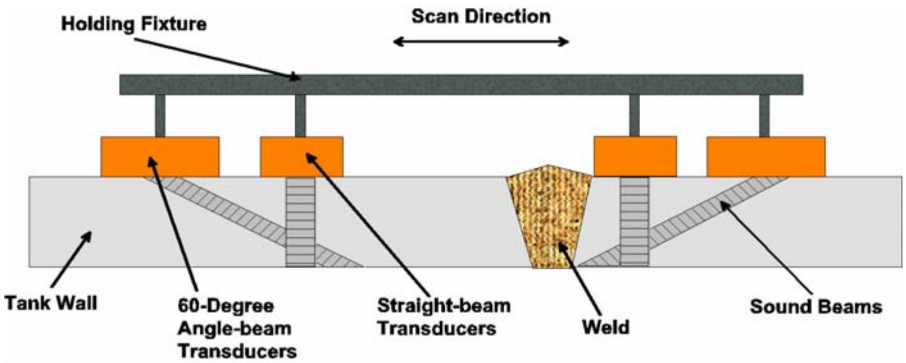
Angle-Beam
Type: MWB-45 04E
Frequency: 4 MHz
Size: 8 X 9 mm
Manufacturer: Krautkramer

Straight-Beam
Type: MSEB 5B
Frequency: 5 MHz
Size: Dual - 9 X 2 mm
Manufacturer: Krautkramer

Figure 3.1. Transducer Configuration for Examining the Primary Tank Wall

3.2 Weld Zone Transducer Configuration

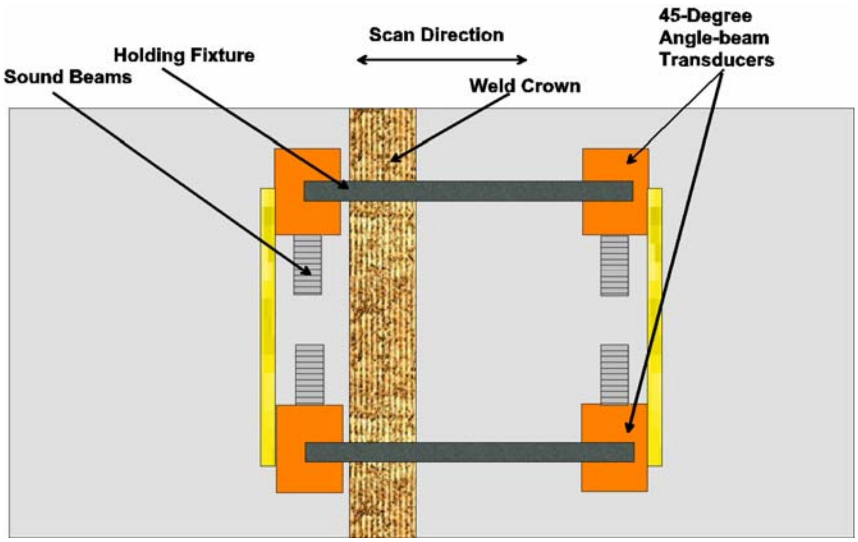
Figure 3.2 is a functional sketch that shows the configurations for examination of the weld zone. The area of interest (HAZ of the weld) is shown as lying adjacent to the weld. Both cracks and pitting may occur in this region. The "A" portion of this sketch shows the 60-degree angle-beam transducers used for detecting cracks parallel to the weld. The straight-beam transducers in this sketch are used for detecting and recording any pitting or wall thinning that may be present. All transducers are ganged together. The scanning distance traveled is limited to a total of approximately 5.0-in. The sketch titled "B" shows the arrangement for detecting cracks that may lie perpendicular to the weld. Four 45-degree, angle-beam transducers are used for this inspection. Again the transducers are ganged together but the scan is limited to a total of approximately 4.0-in. The weld zone requirements are shown in Figure 3.3. The scan protocol, data capture, and index parameters are the same for examining other weld areas in the tank.



A. Configuration for pitting and cracks parallel to weld

Transducer Specifications:
Angle-Beam
Type: MWB-60 04E
Frequency: 4 MHz
Size: 8 X 9 mm
Manufacturer: Krautkramer

Straight-Beam
Type: MSEB 5B
Frequency: 5 MHz
Size: Dual - 9 X 2 mm
Manufacturer: Krautkramer

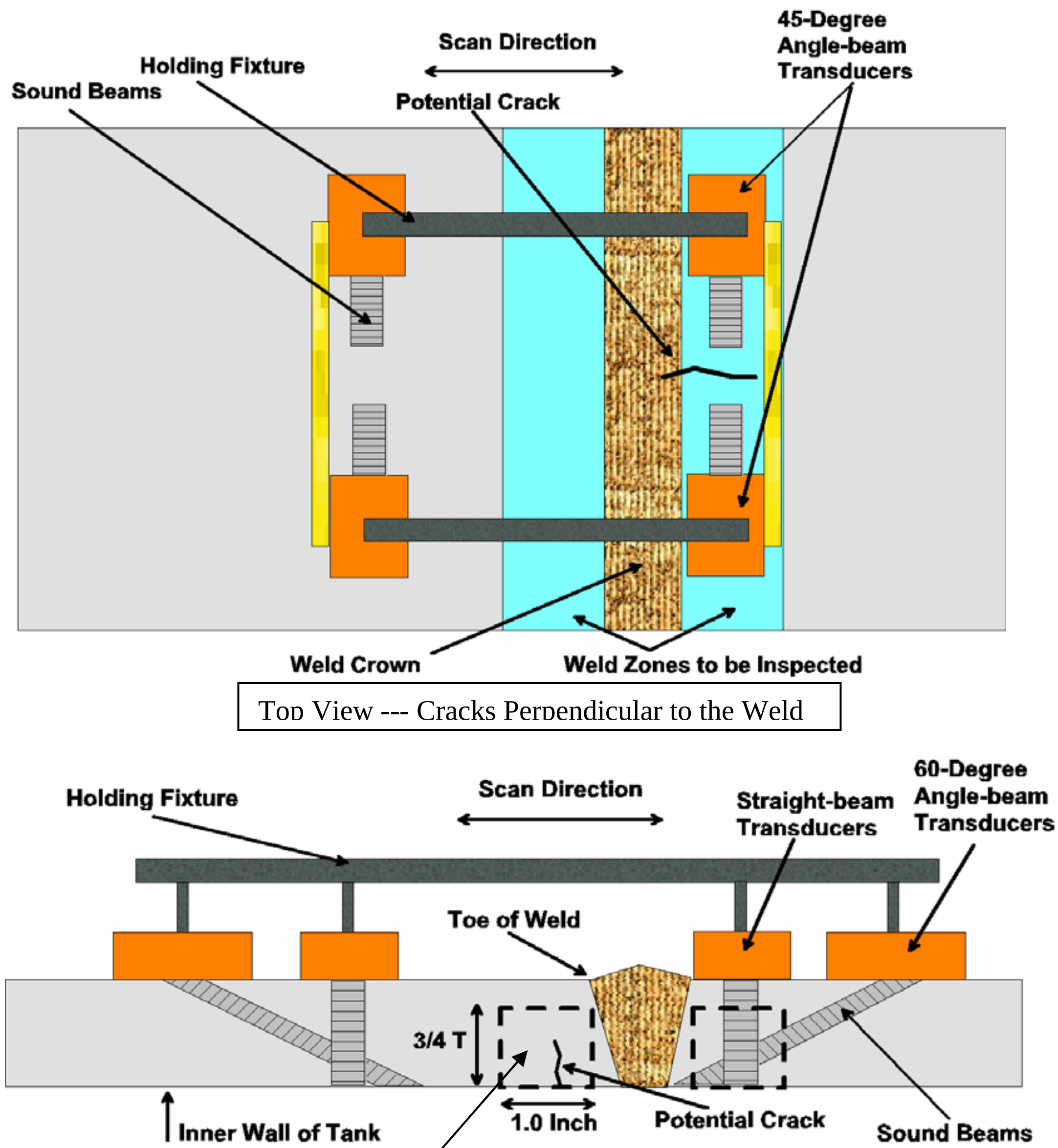


B. Configuration for cracks perpendicular to weld

Transducer Specifications:
Angle-Beam
Type: MWB-45 04E
Frequency: 4 MHz
Size: 8 X 9 mm
Manufacturer: Krautkramer

Figure 3.2. Transducer Configurations for Examination of Weld Zone in the Primary Tank Wall

In the HAZ, the requirement for characterizing cracks that lie perpendicular or parallel to welds in the primary tank wall is described in Figure 3.3. The HAZs are located on either side of the weld and defined as being within 1-in. of the toe of the weld and on the inner three-quarters of the thickness (3/4T) of the plate. These zones are considered most likely to experience stress-corrosion cracking.



A zone ¾ T from the inner surface and 1.0-in. from the toe of the weld is to be ultrasonically examined for cracking, corrosion or pitting. Examinations are to be made on both sides of the weld.

End View --- Cracks Parallel to the Weld

Figure 3.3. Views of the Weld Zone to be Ultrasonically Examined in the Primary Tank Wall

4.0 Ultrasonic Examination Location

Tank 241-AY-101 is located in the Hanford 200 East area in AY Tank Farm. The crawler and associated scanner that hold the transducers were lowered into the 24-in. risers located on the east side (Riser 88) and on the west side (Riser 89) of 241-AY-101. Figure 4.1 provides a graphic of the location of the risers.

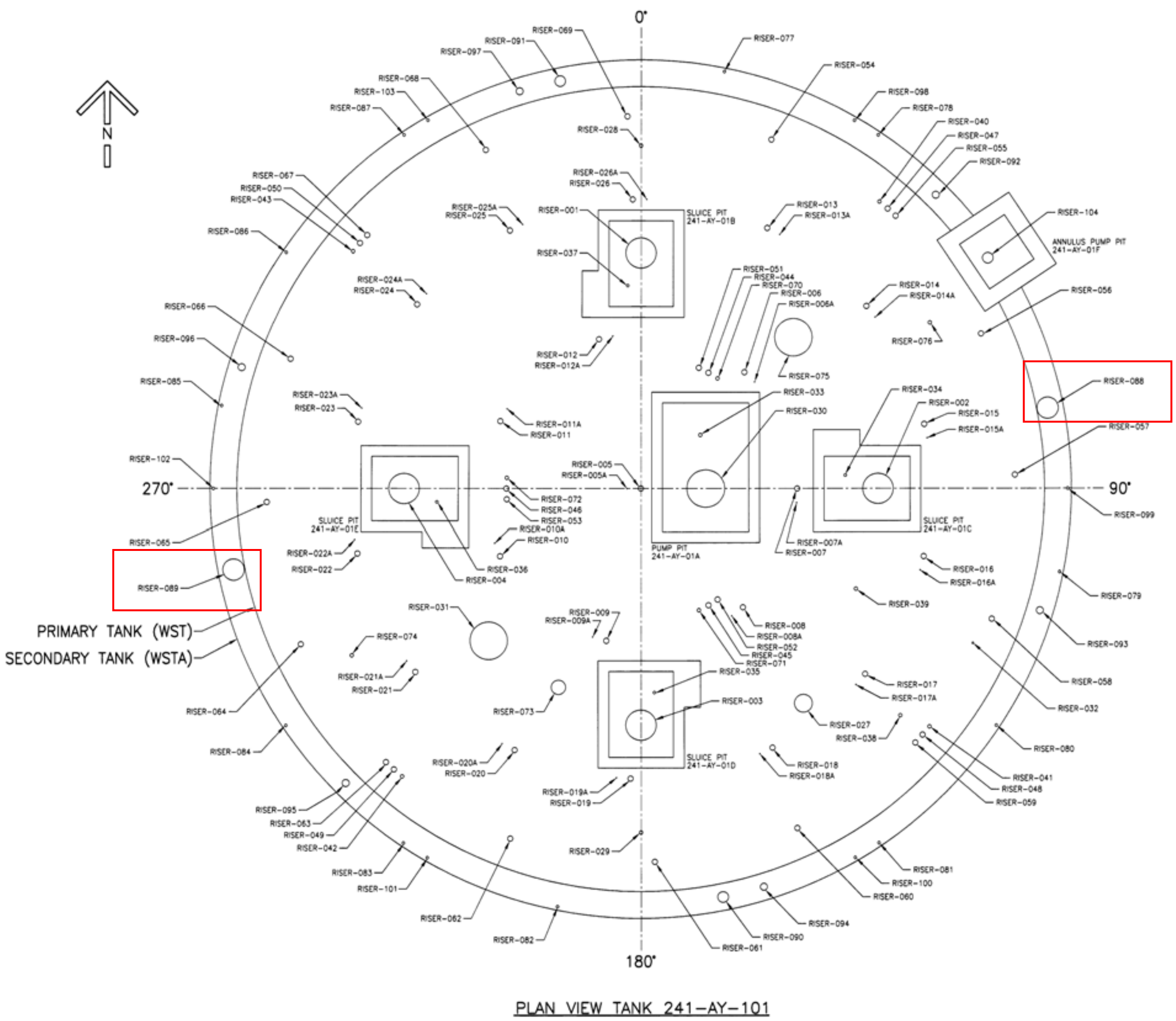


Figure 4.1. UT of Tank 241-AY-101 Riser 88 and Riser 89

Figure 4.2 describes the areas on the primary wall of Tank 241-AY-101 that were ultrasonically examined from Riser 88 located on the east side of the tank. One 15-in.-wide vertical scan path was performed on Plates #1, #2, #3, #4, and #5 below the entrance to Riser 88. Vertical weld HAZ examinations were done on Plates #1, #2, #3, #4, and #5, and the horizontal weld HAZ examination was done between Plate #3 and Plate #4. Additionally three 15-in.-wide horizontal scans were performed in the liquid-air interface (LA) region on Plate #2.

Figure 4.3 describes the areas on the primary wall of Tank 241-AY-101 that were ultrasonically examined from Riser 89 located on the west side of the tank. One 15-in.-wide vertical scan path was performed on Plates #1, #2, #3, #4, and #5 below the entrance to Riser 89.

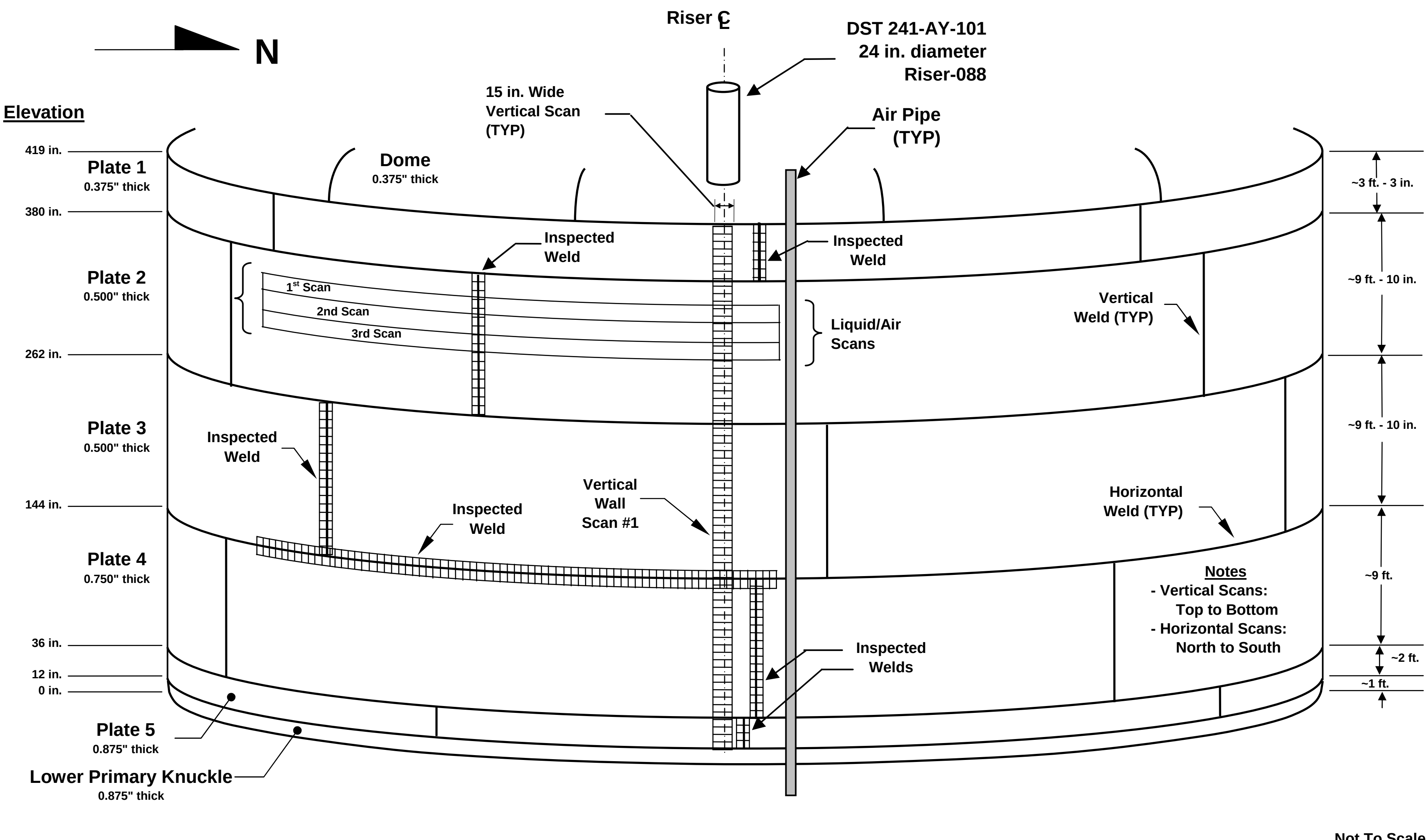


Figure 4.2. Sketch of Scan Paths on 241-AY-101 Primary Tank from Riser 88

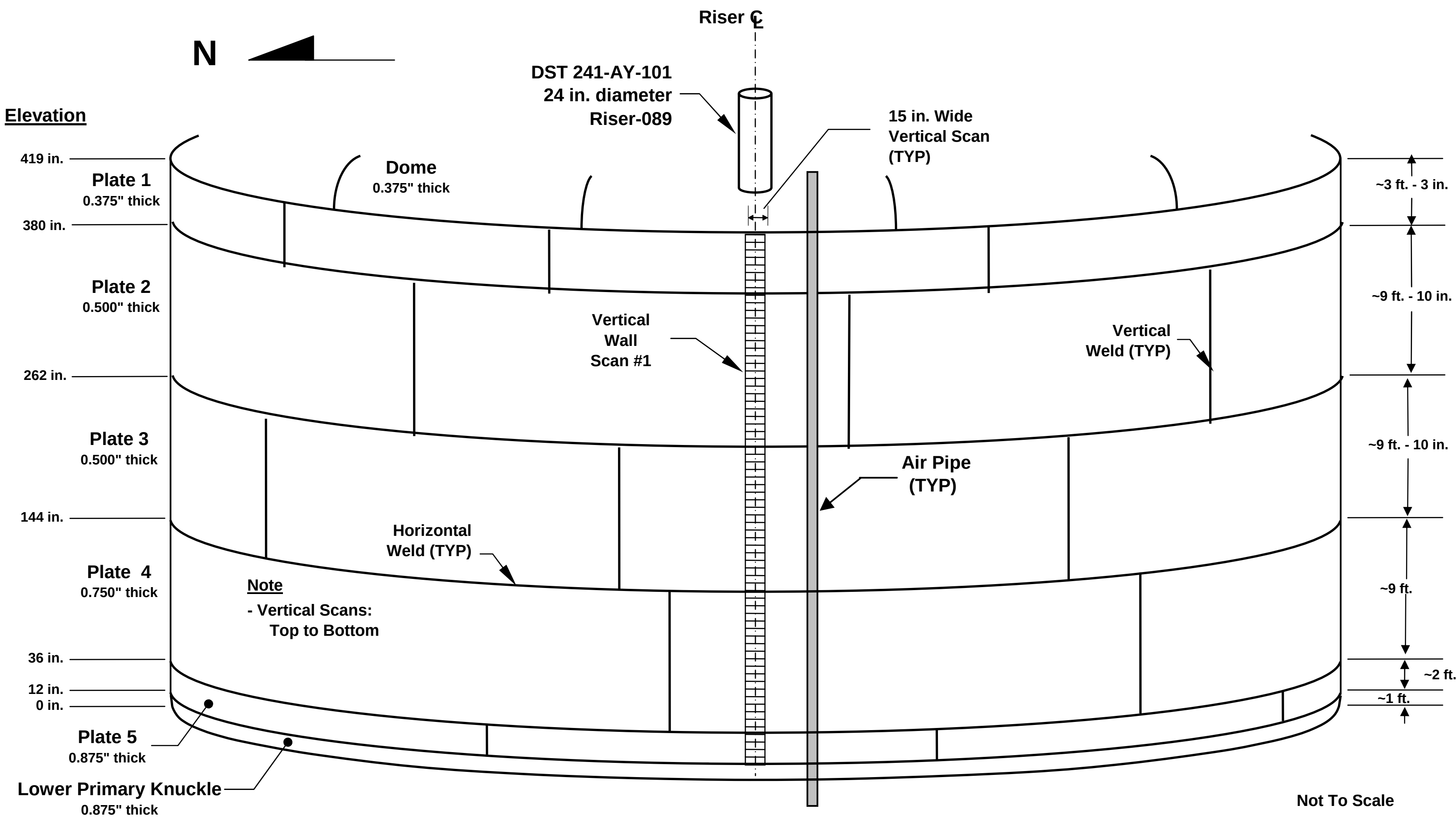


Figure 4.3. Sketch of Scan Paths on Tank 241-AY-101 Primary Tank from Riser 89

5.0 Ultrasonic Examination Results

AREVA has provided detailed reports including T-Scan and P-Scan hard copies of all areas that were ultrasonically examined to PNNL for third-party review. The data was analyzed by AREVA UT Level III Mr. Wes Nelson, and peer reviewed by JBNDT UT Level III Mr. Jim Elder. The results of the examination of Tank 241-AY-101 are presented in Figures 5.1 through 5.4.

Figures 5.1 and 5.2 show the wall thickness examination results for the primary tank wall and the HAZs of both vertical and horizontal welds from Riser 88. The examination consisted of one 15-in.-wide vertical path beneath the centerline of the 24-in. diameter riser on Plates #1, #2, #3, #4, and #5. Vertical scan was conducted in the downward direction. Three horizontal scans were performed in the LAI region on Plate #2. Figures 5.1 and 5.2 display the minimum readings taken in each 15-in.-wide by 12-in.-long area of the scan. The HAZs of vertical welds in Plates #1, #2, #3, #4, and #5 were examined and the HAZ in the horizontal weld between Plate #3 and Plate #4 was also examined. Weld area exams include approximately 5-in. on each side of the weld. Areas in the figures that show two measurements in the same box are the result of the vertical scan paths overlapping the horizontal scan paths. In the overlapping areas, both minimum readings from each vertical and horizontal scan paths are given. The gray highlighted areas indicate that the minimum wall thickness exceeded the reportable level of 10% of the nominal wall thickness. The green highlighted areas indicate that the minimum wall thickness exceeded the 10% level, but the UT Level III has characterized these as pit-like indications. None of these pit-like indications exceed the pitting criteria of 25% of nominal thickness and are therefore not reportable.

Figures 5.3 and 5.4 show the wall thickness examination results for the primary tank wall from Riser 89. The examination consisted of one vertical path beneath the centerline of the 24-in. diameter riser on Plates #1, #2, #3, #4, and #5. Vertical scan was conducted in the downward direction. Figures 5.3 and 5.4 display the minimum readings taken in each 15-in.-wide by 12-in.-long area of the scan. The gray highlighted areas indicate that the minimum wall thickness exceeded the reportable level of 10% of the nominal wall thickness. The 0.397-in. shown as a gray highlighted area exceeded the acceptance criteria of 20% and will require the tank owner to take special action. The green highlighted areas indicate that the minimum wall thickness exceeded the 10% level, but the UT Level III has characterized these as pit-like indications. None of these pit-like indications exceed the pitting criteria of 25% of nominal thickness and are therefore not reportable.

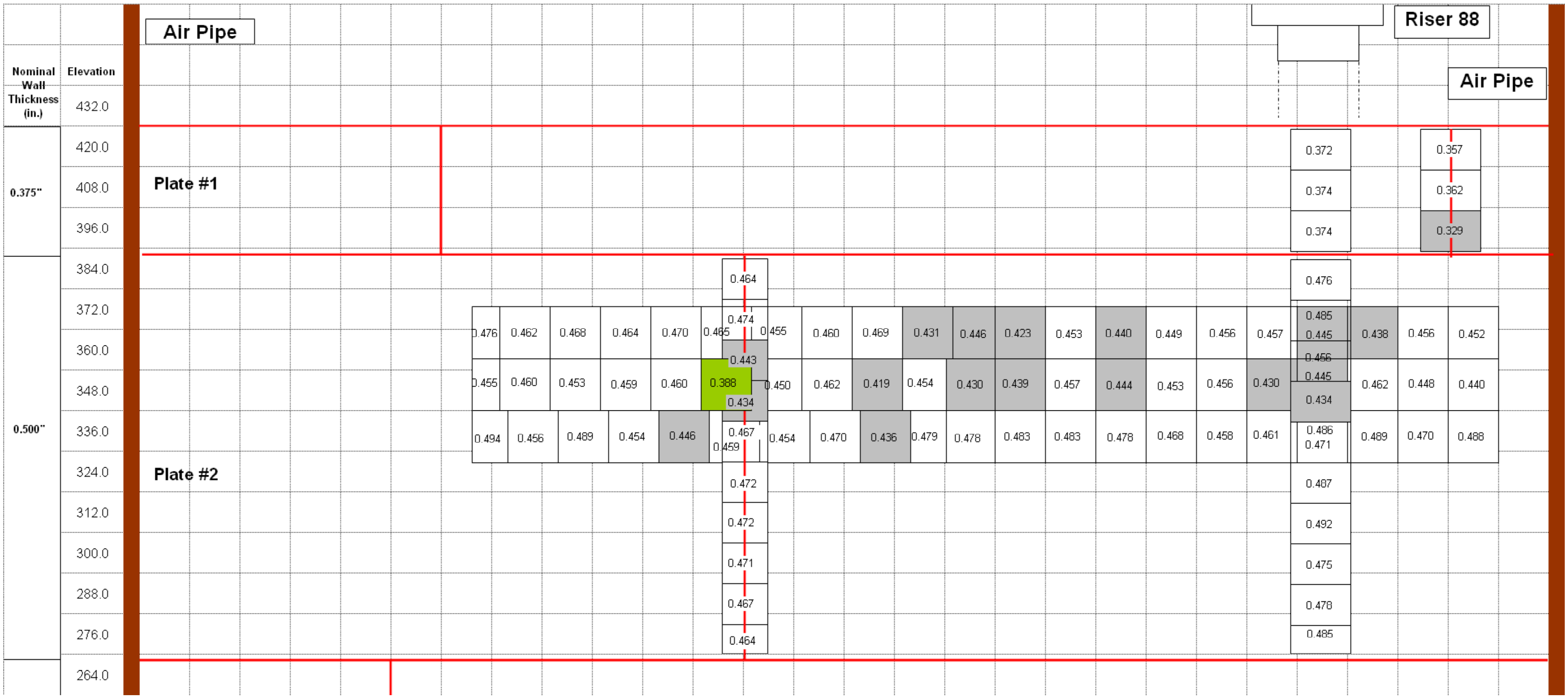


Figure 5.1. UT Data from Tank 241-AY-101 Primary Tank Riser 88

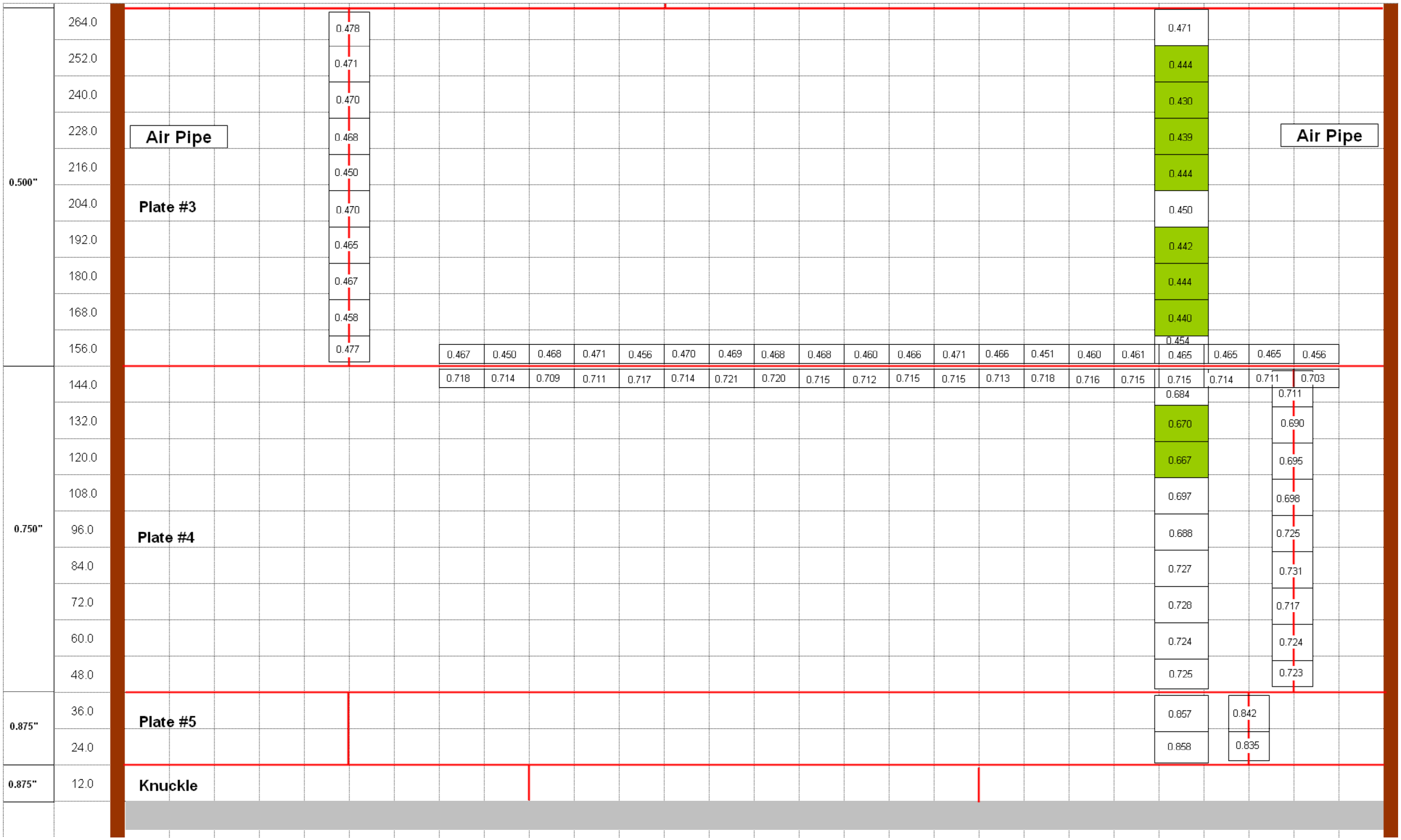


Figure 5.2. UT Data from Tank 241-AY-101 Primary Tank Riser 88 cont.

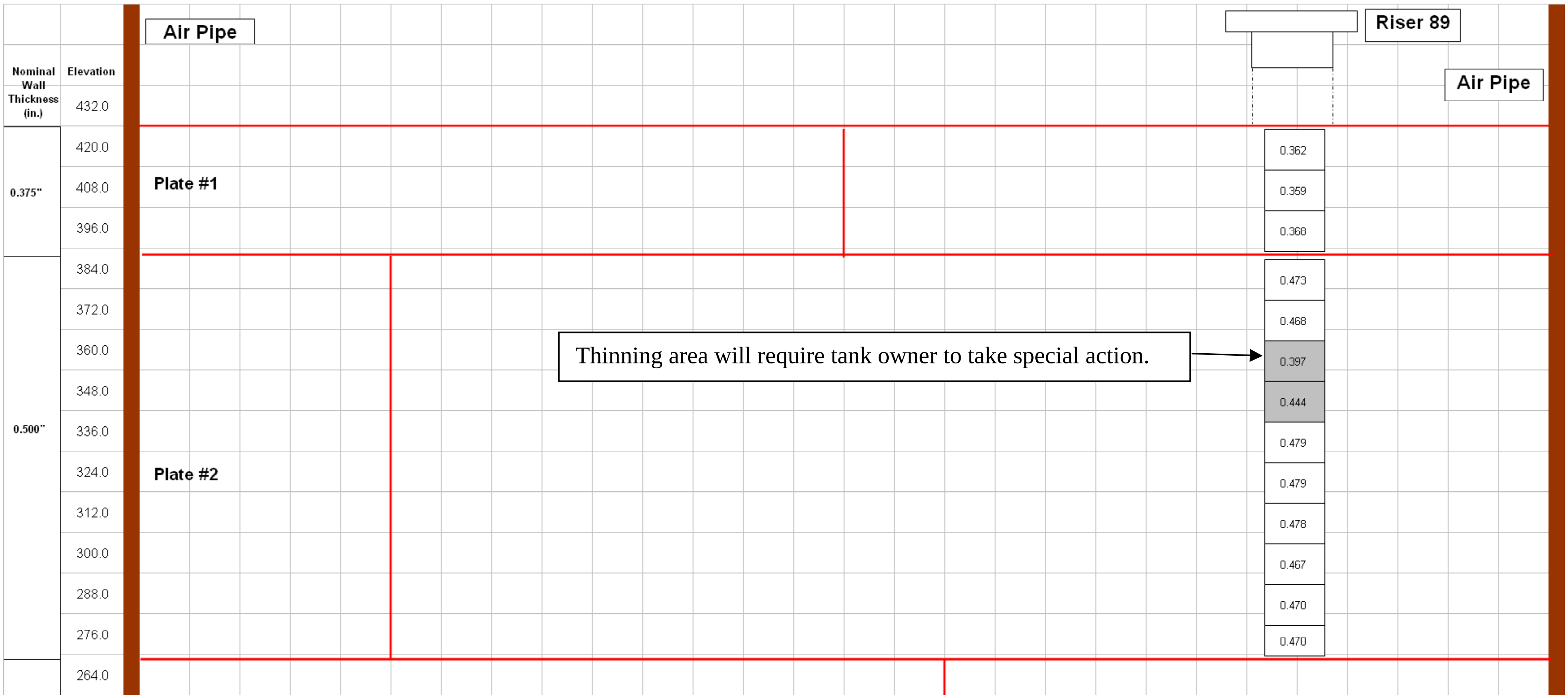


Figure 5.3. UT Data from Tank 241-AY-101 Primary Tank Riser 89

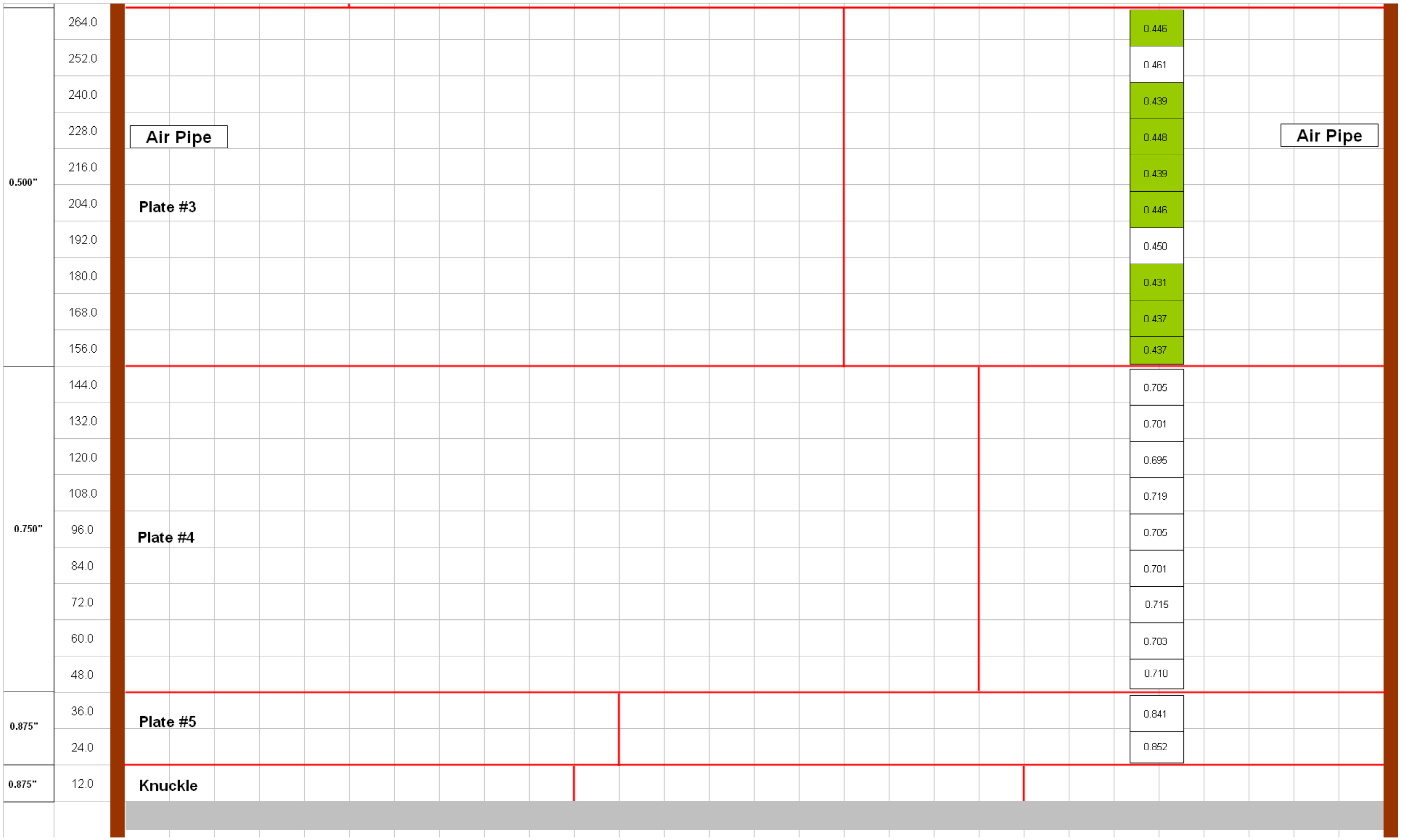


Figure 5.4. UT Data from Tank 241-AY-101 Primary Tank Riser 89 cont.

6.0 Extreme Value Analysis

The objective of this section is to estimate a worst case wall condition with respect to thinning (see Weier, Anderson, 2005, for a description of the methodology). If remaining wall thickness were used to estimate such a worst case condition, wall thickness measurements from plates with differing nominal thicknesses could not be combined to fit a common distribution. Extreme value distribution fitting will benefit from having more measurements to fit, so if results can be reasonably combined across plates, this approach is preferred. For this reason, extreme value plate loss is computed instead of using remaining wall thickness. However if the original nominal values for tank wall thicknesses of 0.375-in., 0.500-in., 0.750-in., and 0.875-in. are used, negative losses are often obtained since remaining wall thickness still exceeds drawing nominal. For this reason UT image maximum values were used to provide a better estimate of original wall thickness than the drawing nominal values. This assumes some areas of plates are in near pristine condition. But of course such maximum values would not be used if they were less than the original drawing nominal thickness.

Note that measurement error and its variability has not been separated from the actual wall thickness variability here. Therefore when an extreme value is generated using the following methodologies, a worst case "measured wall thickness loss" is being estimated. That is, both the measurement variability and the actual wall thickness variability contribute to the overall uncertainty. When we obtain a worst case value, we are then deriving a worst case "measured result" that would be expected if the entire tank were inspected using UT methodology. This is a more extreme value than would be obtained estimating only a worst case wall condition; to do that, measurement error would have to be adequately characterized and removed from consideration. That has not yet been undertaken since appropriate data might not be available to do so, but it is a topic of ongoing analyses.

A single path is available down each of two risers. For example, in a ~10-ft. plate (vertical dimension) for one riser, this generates about 9 maximum measured wall thickness values (it actually varies from plate to plate depending on plate dimensions). These values were considered for each riser/plate combination. The alternative "nominal thickness" selected in this manner then depended somewhat on the pattern of these maximum values, but generally it could be described as approximately the 90th percentile of such measurements. It was considered too extreme to use the largest of the 9 or so maximum values due to potential measurement error then grossly over-estimating the true nominal thickness. In this manner the Figure 6.1 maximum remaining thicknesses were obtained for Tank 241-AY-101.

AY-101	**Plate Estimated Nominal**				
	1	**2**	**3**	**4**	**5**
Riser 88	0.400	0.515	0.500	0.760	0.890
Riser 89	0.400	0.505	0.520	0.760	0.900

Figure 6.1. Table of Estimated Nominal Thickness from UT Maxima

The 9 or so individual UT image minimum values for a plate/riser combination were then subtracted from the estimated nominal value for that plate/riser from Figure 6.1. In this manner 9 estimated maximum wall thickness losses could be obtained for such a plate/riser combination, and then these were combined across the two risers, so about 18 such losses were available for the entire plate course. This is a fairly minimal amount of data for distributions fitting as performed in this work.

Note that since two risers are used, the riser variability within the tank does contribute to the overall variability in the results. For this reason an added one-sigma uncertainty, to accommodate riser variability if only a single riser were used, is not added here (see Weier, Anderson, Berman 2005).

Maximum wall thickness loss results obtained in the manner described above are shown for each riser in Figure 6.2. Red points with the solid red curve are for Riser 88, while blue points with the dashed blue line are for Riser 89. Numbered sections of the graphs represent the different plate courses; note that the top of the tank is to the right on the figure. Within Plate #2 the increased corrosion associated with the LAI is readily apparent. The greater corrosion in the LAI was addressed in Weier, Anderson, Berman 2005 where LAI measurements were treated separately for extreme value estimation.

Additional UT inspection was done along the LAI in the current efforts. Three horizontal paths about 20 feet long were measured generating about 20 images per path. But since the paths were "stacked" vertically, the minimum value for each linear foot from the three paths was used to represent the minimum wall thickness at that point of the LAI. The resulting values are the vertical set of black points at an elevation of about 355 on the figure.

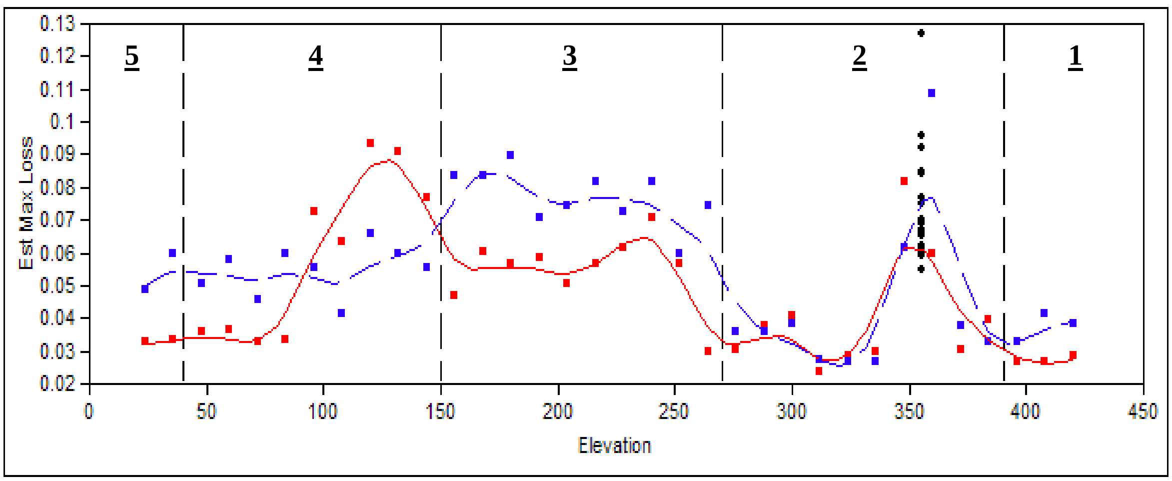


Figure 6.2. Estimated Maximum Wall Thickness Loss by Riser Path

As in the earlier work, Plate #2 areas, within and outside the LAI, are considered separately. While all points combined, except for the LAI, were treated as a single group with a single Weibull distribution fit, the results were not representative due to the considerable variability between the plates. For this reason the plates were instead grouped based on Figure 6.2. Plate #1 and #2 measurements (outside the LAI) were combined into one group since they tend to be considerably consistently less than those for the other plates; Plates #3, #4, and #5 were combined into a second group. The LAI measurements formed the third group.

The histograms in Figure 6.3 show such wall thickness loss data for the indicated plate groupings. Three parameter Weibull distributions are fit to these histograms and are shown as the smooth curves. The total surface area of a plate course combination, and thus the number of 15-in. by 12-in. UT images needed to 100% inspect the entire plate course combination, is computed. The percentile of the distribution that then corresponds to the maximum expected loss among this many UT images, based on the distribution fit to the histogram, is considered as the estimated worst case loss. For the LAI, the linear feet inspected were used analogously with the required worst case percentile based on the total circumference of the tank at the LAI.

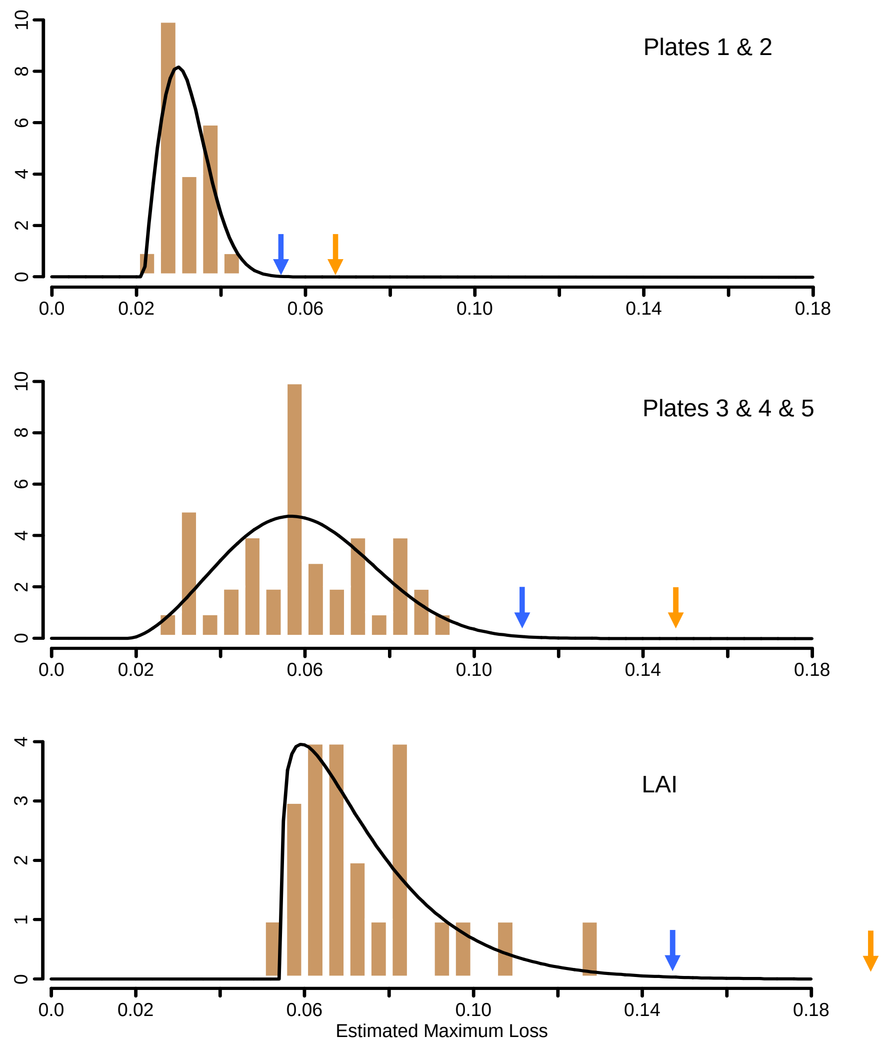


Figure 6.3. Weibull Distribution Fits to UT Maximum Wall Thickness Loss

The number of measurements available and the quality of the fit of the Weibull distribution affect the uncertainty in the estimated Weibull parameters, and in turn, the uncertainty in the estimated worst case losses. Therefore 95% confidence bounds on the worst case values are also computed using these uncertainties.

The values indicated by the arrows on the histograms are the estimated worst case losses per plate course combination (blue, to the left) and their associated 95% confidence bounds (orange, to the right). The corresponding values are given in the table shown in Figure 6.4. Included in the table are: 1) the number of measurements, 2) the estimated extreme value loss expected for the plate course combination around the entire circumference of the tank, and 3) the 95% confidence bound for the extreme loss.

AY-101 Extreme Values	Plates		
	1,2 Combined	3,4,5 Combined	LAI
Estimate	0.054	0.122	0.148
95% Bound	0.067	0.149	0.192
Measurements	26	38	25

Figure 6.4. Table of Tank 241-AY-101 Wall Thickness Extreme Value Loss Estimates and Bounds

The Plate #1 & #2 distribution fit is quite reasonable and gives a fairly small worst case loss and bound (0.054-in. and 0.067-in.). The greater variability, generally larger losses, and relatively poor fit of the Weibull distribution for Plates #3, #4, & #5 result in a considerably larger estimated loss and bound (0.122-in. and 0.149-in.). The LAI loss and bound are even greater due to the considerable measured loss and again a somewhat marginal Weibull distribution fit (0.148-in. and 0.192-in.).

7.0 Conclusions

The results of the examination of Tank 241-AY-101 have been evaluated by PNNL personnel. The primary tank ultrasonic examination consisted of one vertical 15-in.-wide scan path over the entire height of the tank, the heat-affected zone of five vertical welds and one horizontal weld from Riser 88 and one vertical 15-in.-wide scan path over the entire height of the tank from Riser 89. Additionally, three horizontal scans were performed at the liquid-air interface region from riser 88. The examinations were performed to detect any wall thinning, pitting, or cracking in the primary tank wall.

7.1 Primary Tank Wall Vertical Scan Paths

One 15-in.-wide vertical scan path was performed on Plates #1, #2, #3, #4, and #5 from Riser 88. The plates were examined for wall thinning, pitting, and cracks oriented vertically on the primary tank wall.

- The nominal thickness of Plate #1 is 0.375-in. and the minimum thickness in this area was 0.372-in. Plate #1 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #1.
- The nominal thickness of Plate #2 is 0.500-in. Plate #2 results indicate one area with minimum thickness of 0.434-in. exceeds the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #2.
- The nominal thickness of Plate #3 is 0.500-in. Plate #3 results indicate seven areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these seven areas (with remaining ligament of 0.430-in., 0.439-in., 0.440-in., 0.442-in., 0.444-in., 0.444-in., and 0.444-in.) were analyzed by the UT Level III and were considered pit-like and therefore do not exceed the reportable pitting level of 25% of the nominal thickness. No vertical crack-like indications were detected in Plate #3.
- The nominal thickness of Plate #4 is 0.750-in. Plate #4 results indicate two areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these two areas (with remaining ligament of 0.667-in., and 0.670-in.) were analyzed by the UT Level III and were considered pit-like and therefore do not exceed the reportable pitting level of 25% of the nominal thickness. No vertical crack-like indications were detected in Plate #4.
- The nominal thickness of Plate #5 is 0.875-in. and the minimum thickness in this area was 0.857-in. Plate #5 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #5.

One 15-in.-wide vertical scan path was performed on Plates #1, #2, #3, #4, and #5 from Riser 89. The plates were examined for wall thinning, pitting, and cracks oriented vertically on the primary tank wall.

- The nominal thickness of Plate #1 is 0.375-in. and the minimum thickness in this area was 0.359-in. Plate #1 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #1.

- The nominal thickness of Plate #2 is 0.500-in. Plate #2 results indicate two areas with minimum thickness of 0.397-in. and 0.444-in. that exceed the minimum thinning reportable level of 10% of the nominal thickness. The 0.397-in. area exceeded the acceptance criteria of 20% and will require the tank owner to take special action. No pitting or vertical crack-like indications were detected in Plate #2.
- The nominal thickness of Plate #3 is 0.500-in. Plate #3 results indicate eight areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these eight areas (with remaining ligament of 0.431-in., 0.437-in., 0.437-in., 0.439-in., 0.439-in., 0.446-in., 0.446-in., and 0.448-in.) were analyzed by the UT Level III and were considered pit-like and therefore do not exceed the reportable pitting level of 25% of the nominal thickness. No vertical crack-like indications were detected in Plate #3.
- The nominal thickness of Plate #4 is 0.750-in. and the minimum thickness in this area was 0.695-in. Plate #4 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #4.
- The nominal thickness of Plate #5 is 0.875-in. and the minimum thickness in this area was 0.841-in. Plate #5 results indicate no areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plate #5.

7.2 Primary Tank Wall Horizontal Scan Paths

Three 15-in.-wide horizontal scan paths were performed in the liquid-air interface region on Plate #2 from Riser 88. The plates were examined for wall thinning, pitting, and cracks oriented in a circumferential direction on the primary tank wall. The results indicated that the minimum thicknesses in the areas that were scanned with nominal thickness of 0.500-in. are as follows;

- LAI scan #1 results indicated six areas (with remaining ligament of 0.423-in., 0.431-in., 0.438-in., 0.440-in., 0.445-in., and 0.446-in. exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or circumferentially oriented crack-like indications were detected in LAI scan #1.
- LAI scan #2 results indicated nine areas (with remaining ligament of 0.388-in., 0.419-in., 0.430-in., 0.430-in., 0.439-in., 0.440-in., 0.444-in., 0.445-in., and 0.448-in. exceed the minimum thinning reportable level of 10% of the nominal thickness. However, one of these areas (0.388-in.) was analyzed by the UT Level III and was considered pit-like and therefore does not exceed the reportable pitting level of 25% of the nominal thickness. No circumferentially oriented crack-like indications were detected in LAI scan #2.
- LAI scan #3 results indicated two areas (with remaining ligament of 0.436-in., and 0.446-in. exceed the minimum thinning reportable level of 10% of the nominal thickness. No pitting or circumferentially oriented crack-like indications were detected in LAI scan #3.

7.3 Primary Tank Wall Weld Scan Paths

The HAZ of vertical welds in Plates #1, #2, #3, #4, and #5 from Riser 88 were examined for wall thinning, pitting and cracks oriented either perpendicular or parallel to the weld.

- The nominal thickness in Plate #1 is 0.375-in. Plate 1 indicates one area with a minimum thickness of 0.329-in. that exceeded the minimum thinning reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #1.
- The nominal thickness in Plate #2 is 0.500-in. Plate 2 indicates two areas with a minimum thickness of 0.434-in. and 0.443-in. that exceeded the minimum thinning reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #2.
- The nominal thickness in Plate #3 is 0.500-in. and the minimum thickness in this weld area was 0.450-in. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #3.
- The nominal thickness in Plate #4 is 0.750-in. and the minimum thickness in this weld area was 0.690-in. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #4.
- The nominal thickness in Plate #5 is 0.875-in. and the minimum thickness in this weld area was 0.835-in. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas in Plate #5.

The HAZ of the horizontal weld between Plate #3 and Plate #4 from Riser 88 was examined for wall thinning, pitting and cracks oriented either perpendicular or parallel to the weld. The results indicated that the minimum thickness in the weld area with nominal thickness of 0.500-in. on Plate #3 was 0.450-in. The minimum thickness in the weld area with nominal thickness of 0.750-in. on Plate #4 was 0.703-in. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or crack-like indications were detected in the weld areas on Plate #3 side or on Plate #4 side of the horizontal weld.

7.4 Extreme Value Analysis

Extreme value measured wall thickness losses were estimated. Since current remaining wall thickness typically still exceeds drawing nominal, thereby generating negative losses, UT image maximum values were instead used to determine estimated nominal wall thickness per plate/riser combination. These thicknesses tended to run up to about 0.020-in. greater than drawing nominal. They in turn were used with each UT image minimum value to determine estimated wall thickness losses, which were then combined for a plate course over the two risers, with a single UT measurement path per riser.

Three parameter Weibull distributions were fit to combinations of plate course measurements as well as to the measurements for the LAI. Plates #1 & #2 combined generate a worst case <u>measured</u> wall thickness loss of 0.054-in. that might be expected if the entire surface area of the tank wall in these plates, but outside the LAI in Plate #2, were UT inspected. A 95% confidence bound is computed based on the uncertainty in the Weibull parameters caused by the relatively minimal amounts of data for distribution fitting and the quality of the Weibull fit; this 95% bound on measured wall thickness loss is 0.067-in. Note that such losses should be considered relative to the larger "estimated" nominal wall thicknesses and not the drawing nominal.

The corresponding estimated worst case loss and bound for Plates #3, #4, & #5 are respectively 0.122-in. and 0.149-in. These larger values result from generally larger measured losses, their greater variability, and a rather poor Weibull distribution fit. Even larger measured LAI losses, with some outlying values as well, give the corresponding loss and bound values for the LAI as 0.148-in. and 0.192-in.

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