PNNL-16784 Rev.0

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

# Ultrasonic Examination of Double-Shell Tank 241-AZ-101 Examination Completed July 2007

AF Pardini
DR Weier

August 2007

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY

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BATTELLE

*for the*

UNITED STATES DEPARTMENT OF ENERGY

*under Contract DE-AC05-76RL01830*

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Pacific Northwest National Laboratory
Richland, Washington 99352

# Summary

AREVA NC Inc. (AREVA), under a contract from CH2M HILL Hanford Group (CH2M HILL), has performed an ultrasonic examination of selected portions of Double-Shell Tank 241-AZ-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-AZ-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) and summarized on page 1 of this document, are to be reported to CH2M HILL and the Pacific Northwest National Laboratory (PNNL) for further evaluation. 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 ultrasonic examinations.

## Examination Results

The results of the examination of Tank 241-AZ-101 have been evaluated by PNNL personnel. The ultrasonic examination consisted of two vertical 15-in.-wide scan paths over the entire height of the tank and the heat-affected zone (HAZ) of five vertical welds and one horizontal weld from Riser 89. The examination also included two vertical 15-in.-wide scan paths over the entire height of the tank from Riser 90. The examination was performed to detect any wall thinning, pitting, or cracking in the primary tank wall.

### Primary Tank Wall Vertical Scan Paths

Two 15-in.-wide vertical scan paths were 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. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plates #1, #2, #3, #4, or #5.

Two 15-in.-wide vertical scan paths were performed on Plates #1, #2, #3, #4, and #5 from Riser 90. The plates were examined for wall thinning, pitting, and cracks oriented vertically on the primary tank wall. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plates #1, #2, #3, #4, or #5.

### Primary Tank Wall Weld Scan Paths

The HAZ of vertical welds in Plates #1, #2, #3, #4, and #5 from Riser 89 were examined for wall thinning, pitting, and cracks oriented either perpendicular or parallel to the weld. 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 HAZ areas in Plates #1, #2, #3, #4, and #5.

The HAZ of the horizontal weld between Plate #5 and the tank knuckle from Riser 89 was examined for wall thinning, pitting and cracks oriented either perpendicular or parallel to the weld. 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 HAZ areas on Plate #5 side or on the knuckle 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, 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 0.010-in. to 0.030-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, two paths per riser.

Three-parameter Weibull distributions were fit to individual plate courses and to all plate courses combined. The latter approach is preferred due to the nature of these tank measurements per plate; this generates a worst case <u>measured</u> wall thickness loss of 0.064-in. that might be expected if the entire surface area of the tank wall were UT inspected. A 95% confidence bound is computed based on the uncertainty in the Weibull parameters due to the quality of the Weibull fit and the number of measurements available; this 95% bound on measured wall thickness loss is 0.072-in. Note that such losses should be considered relative to the larger "estimated" nominal wall thicknesses and not the drawing nominal.

# Contents

# Figures

# 1.0 Introduction

AREVA NC Inc. (AREVA), under a contract from CH2M HILL Hanford Group (CH2M HILL), has performed an ultrasonic examination (UT) of selected portions of Double-Shell Tank (DST) 241-AZ-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 UT of Tank 241-AZ-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 that exceed 0.10 in. (through-wall) and are detected in the inner wall of the tank, 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-AZ-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 individuals participated in this examination and are trainees and are not qualified or certified to perform independent UT of the Hanford DST 241-AZ-101:

- **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-AZ-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

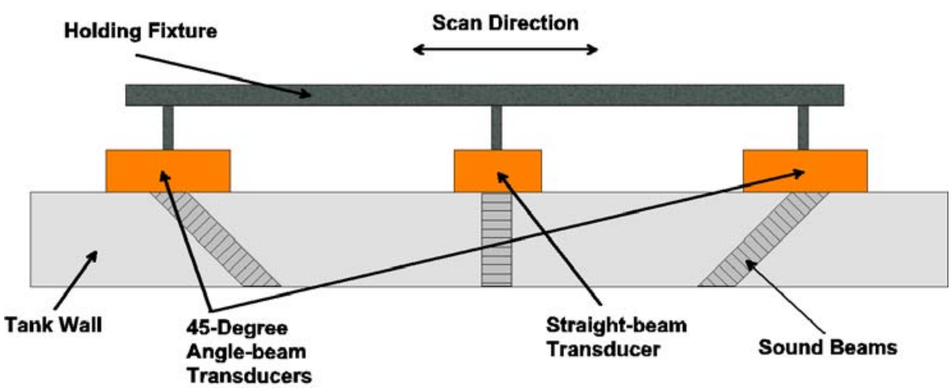
AREVA has provided the UT procedure for the examination of Tank 241-AZ-101. This procedure, COGEMA-SVUT-INS-007.3, Revision 3, outlines the type of UT and mechanical equipment that are to be used as well as the types of transducers. Both straight-beam and angle-beam transducers are used for the examination 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-AZ-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:**

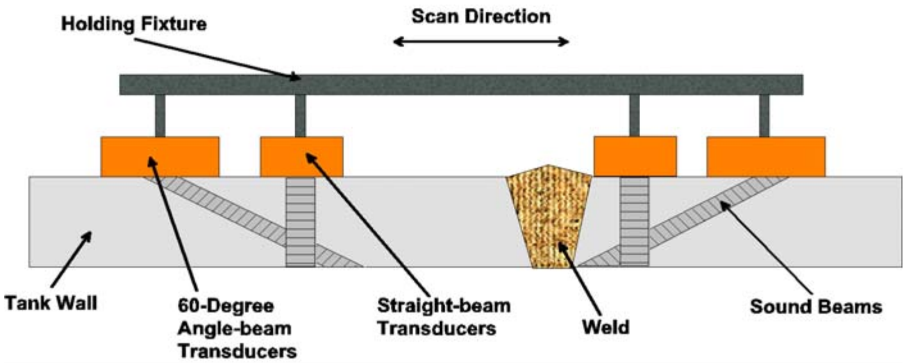
Angle-Beam
Type: MWB-45 04E
Frequency: 4 MHz
Size: 8 X 9 mm
Manufacturer: Krautkramer

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

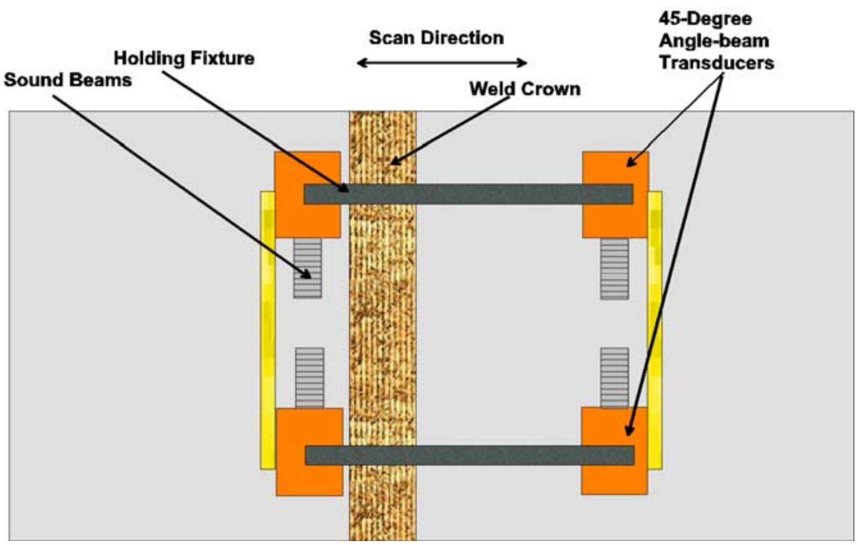
Figure 3.2 is a functional sketch that shows the configurations for examination of the weld zone. The area of interest (HAZ of the weld) is shown as lying adjacent to the weld. Both cracks and pitting may occur in this region. The "A" portion of this sketch shows the 60-degree angle-beam transducers 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.

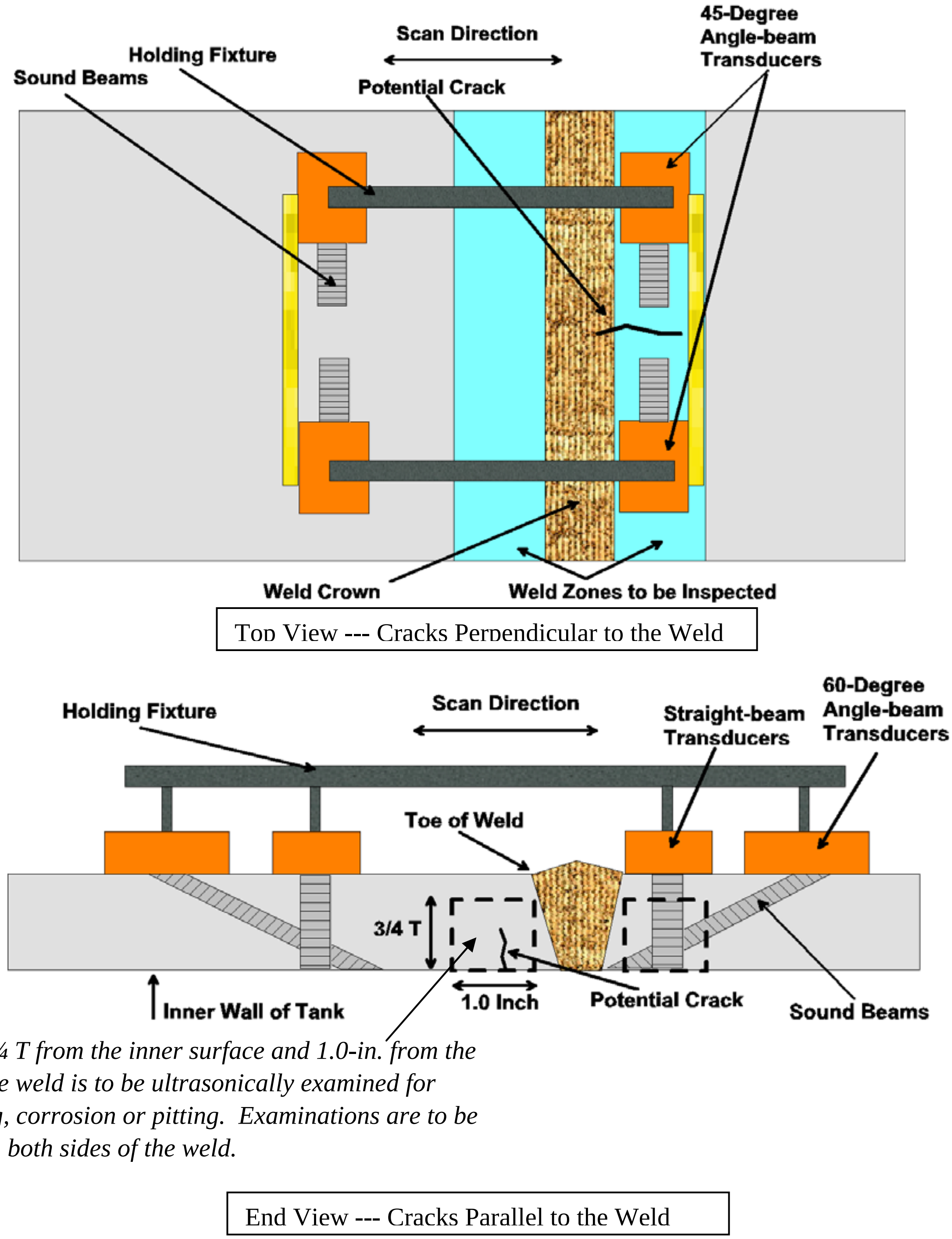



**Figure 3.3.** Views of the Weld Zone to be Ultrasonically Examined in the Primary Tank Wall

# 4.0 Ultrasonic Examination Location

Tank 241-AZ-101 is located in the Hanford 200 East area in AZ Tank Farm. The crawler and associated scanner that hold the transducers were lowered into the 24-in. risers located on the south side (Riser 89) and on the north side (Riser 90) of 241-AZ-101. Figure 4.1 provides a graphic of the location of the risers.

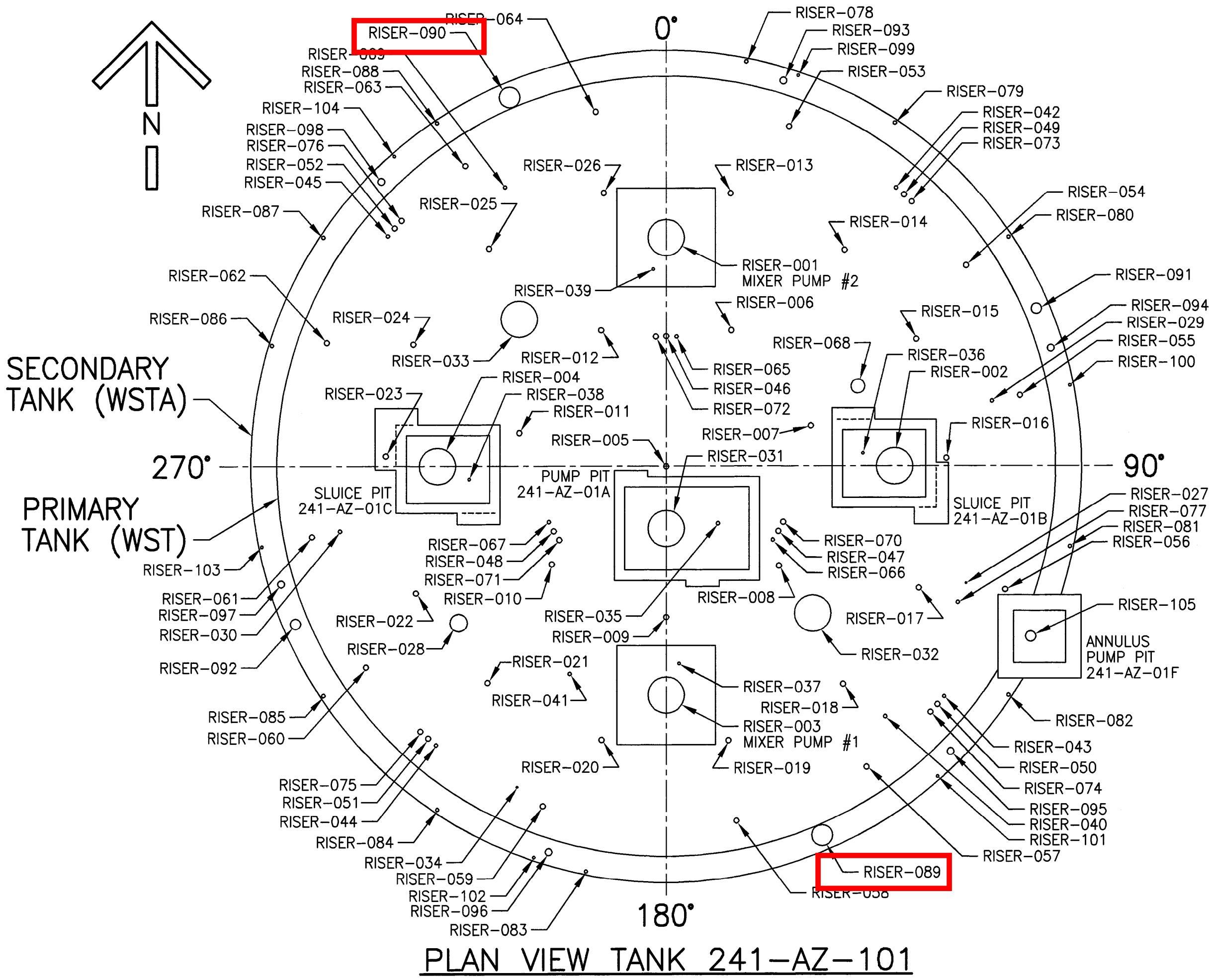



**Figure 4.1**. UT of Tank 241-AZ-101 Riser 89 and Riser 90

Figure 4.2 describes the areas on the primary wall of Tank 241-AZ-101 that were ultrasonically examined from Riser 89 located on the south side of the tank. Two 15-in.-wide vertical scan paths were performed on Plates #1, #2, #3, #4, and #5 below the entrance to Riser 89. Vertical weld HAZ examinations were done on Plates #1, #2, #3, #4, and #5, and the horizontal weld HAZ examination was done on the transition Plate #5 to knuckle weld.

Figure 4.3 describes the areas on the primary wall of Tank 241-AZ-101 that were ultrasonically examined from Riser 90 located on the north side of the tank. Two 15-in.-wide vertical scan paths were performed on Plates #1, #2, #3, #4, and #5 below the entrance to Riser 90.

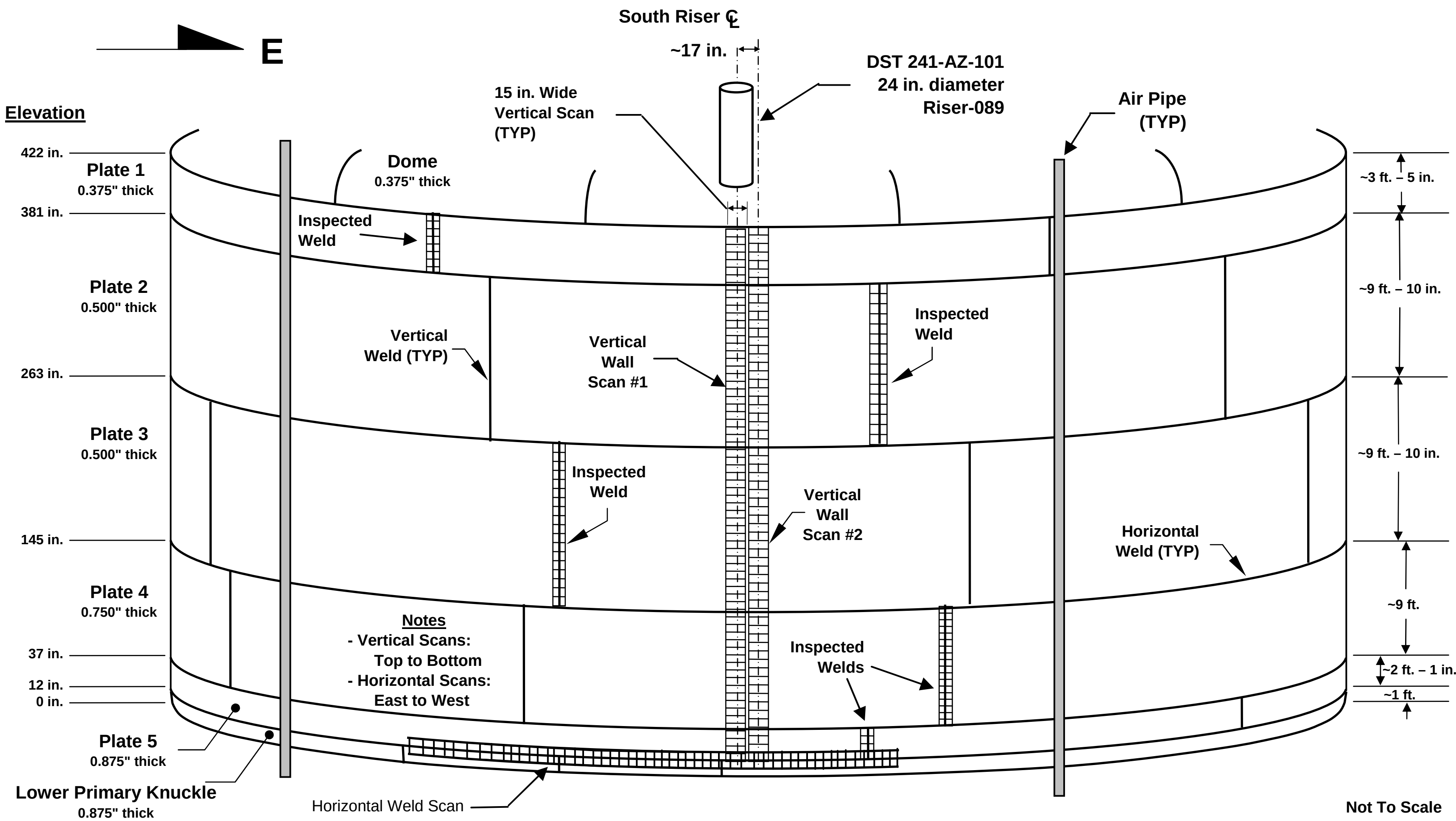



**Figure 4.2**. Sketch of Scan Paths on 241-AZ-101 Primary Tank from Riser 89

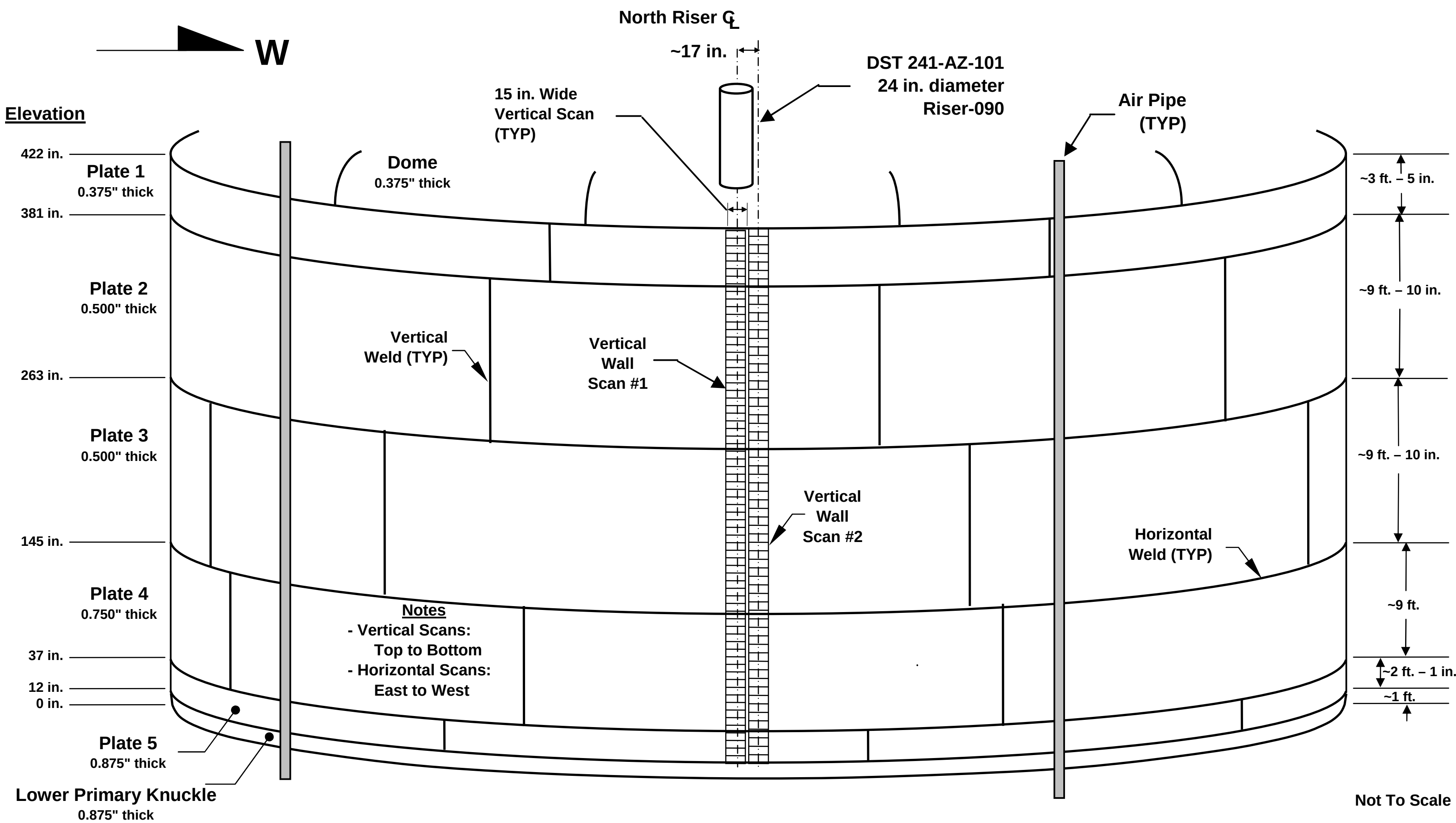



**Figure 4.3**. Sketch of Scan Paths on Tank 241-AZ-101 Primary Tank from Riser 90

# 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 Level III Mr. Wes Nelson, and peer reviewed by JBNDT Level III Mr. Jim Elder. The results of the examination of Tank 241-AZ-101 are presented in Figures 5.1, 5.2, 5.3, and 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 taken below Riser 89. The examination consisted of two vertical paths beneath the 24-in. diameter riser. Vertical scan #1 was 15-in.-wide on Plate #1, #2, #3, #4, and #5 near the centerline of the 24-in. riser. Vertical scan #2 was adjacent to vertical scan #1 and was also 15-in.-wide on Plates #1, #2, #3, #4, and #5. Vertical scans were conducted in the downward direction. 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 #5 and the knuckle section was also examined. Weld area exams include approximately 5-in. on each side of the weld and figures 5.1 and 5.2 display the minimum readings taken in each 5-in.-wide by 12-in.-long area of the scan. 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.

Figures 5.3 and 5.4 show the wall thickness examination results for the primary tank wall taken below Riser 90. The examination consisted of two vertical paths beneath the 24-in. diameter riser. Vertical scan #1 was 15-in.-wide on Plate #1, #2, #3, #4, and #5 near the centerline of the 24-in. riser. Vertical scan #2 was adjacent to vertical scan #1 and was also 15-in.-wide on Plates #1, #2, #3, #4, and #5. Vertical scans were 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.

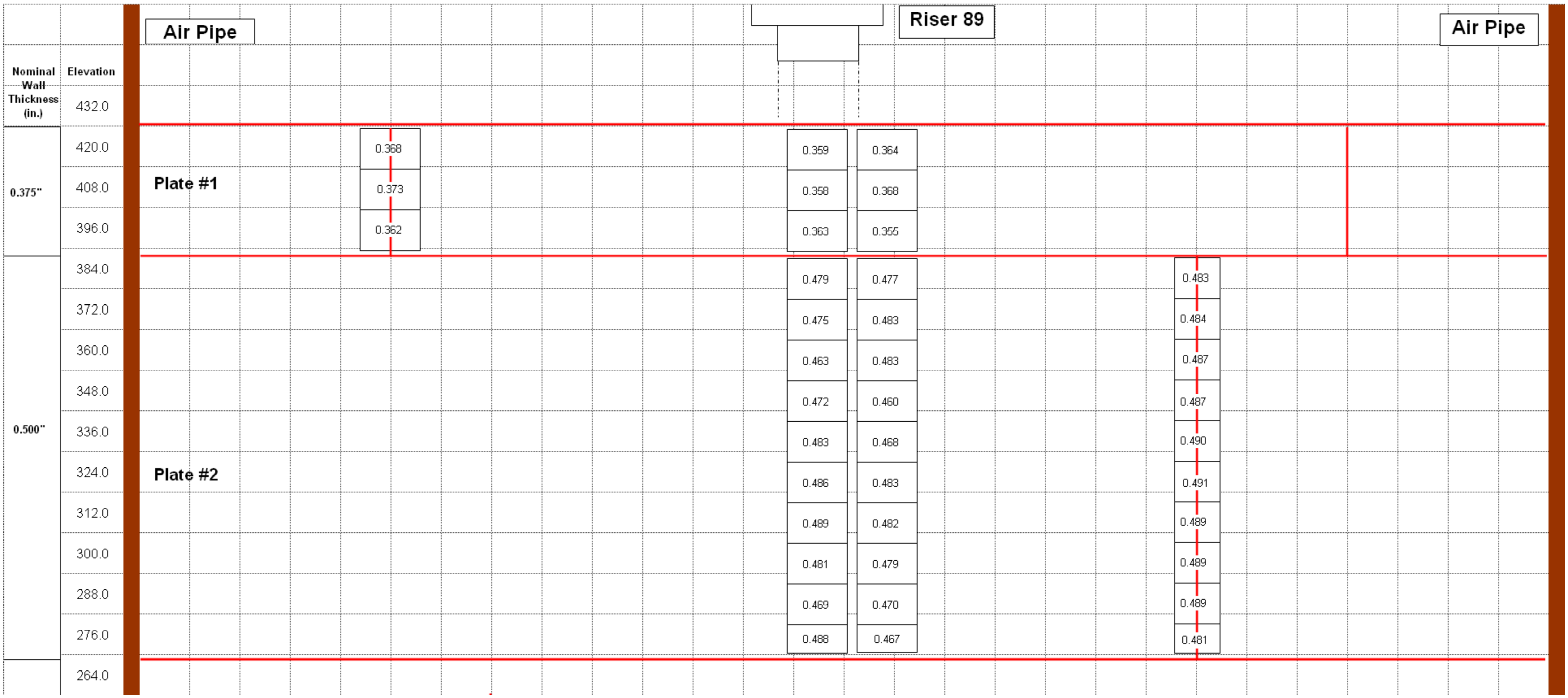



**Figure 5.1**. UT Data from Tank 241-AZ-101 Riser 89

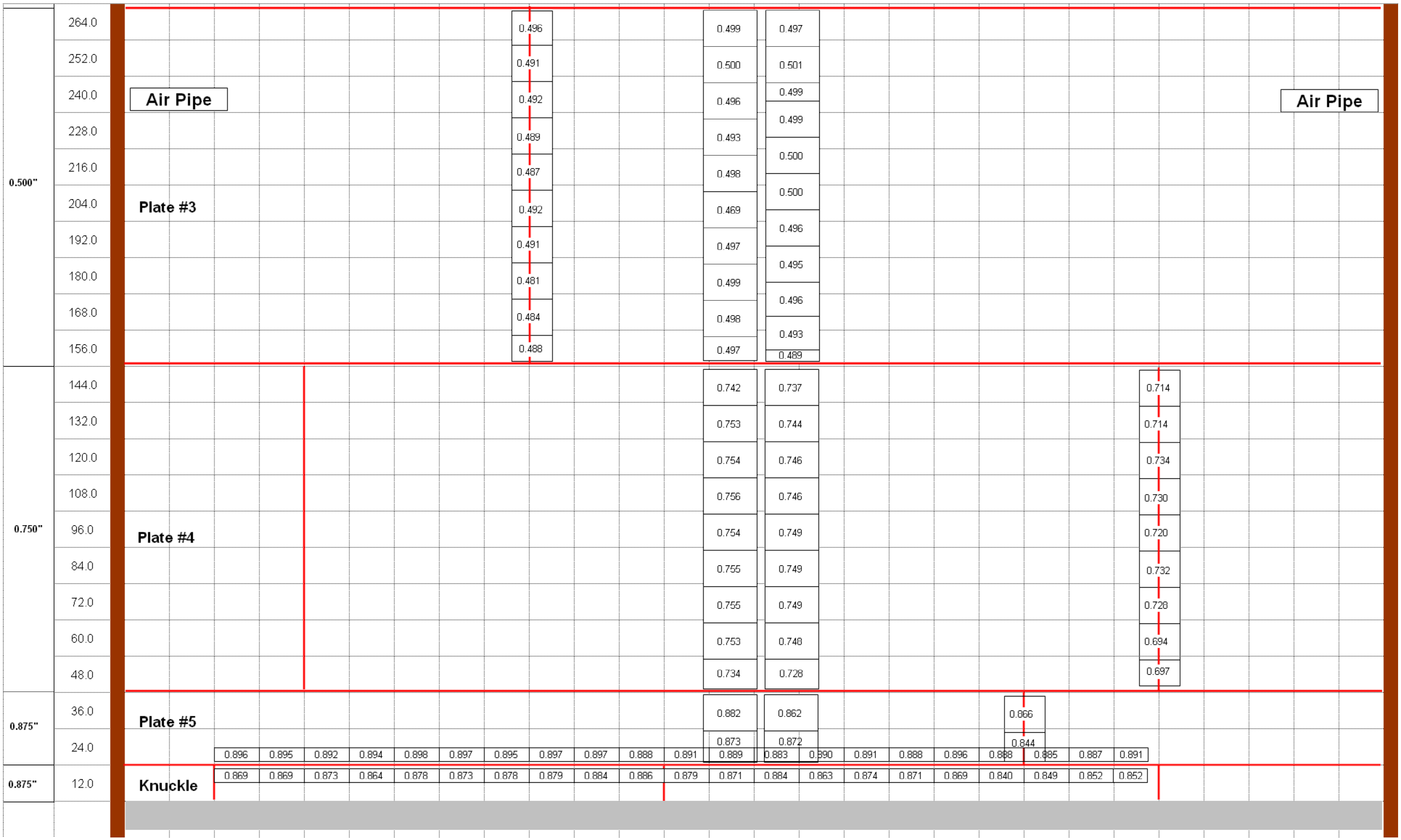



**Figure 5.2**. UT Data from Tank 241-AZ-101 Riser 89 cont.

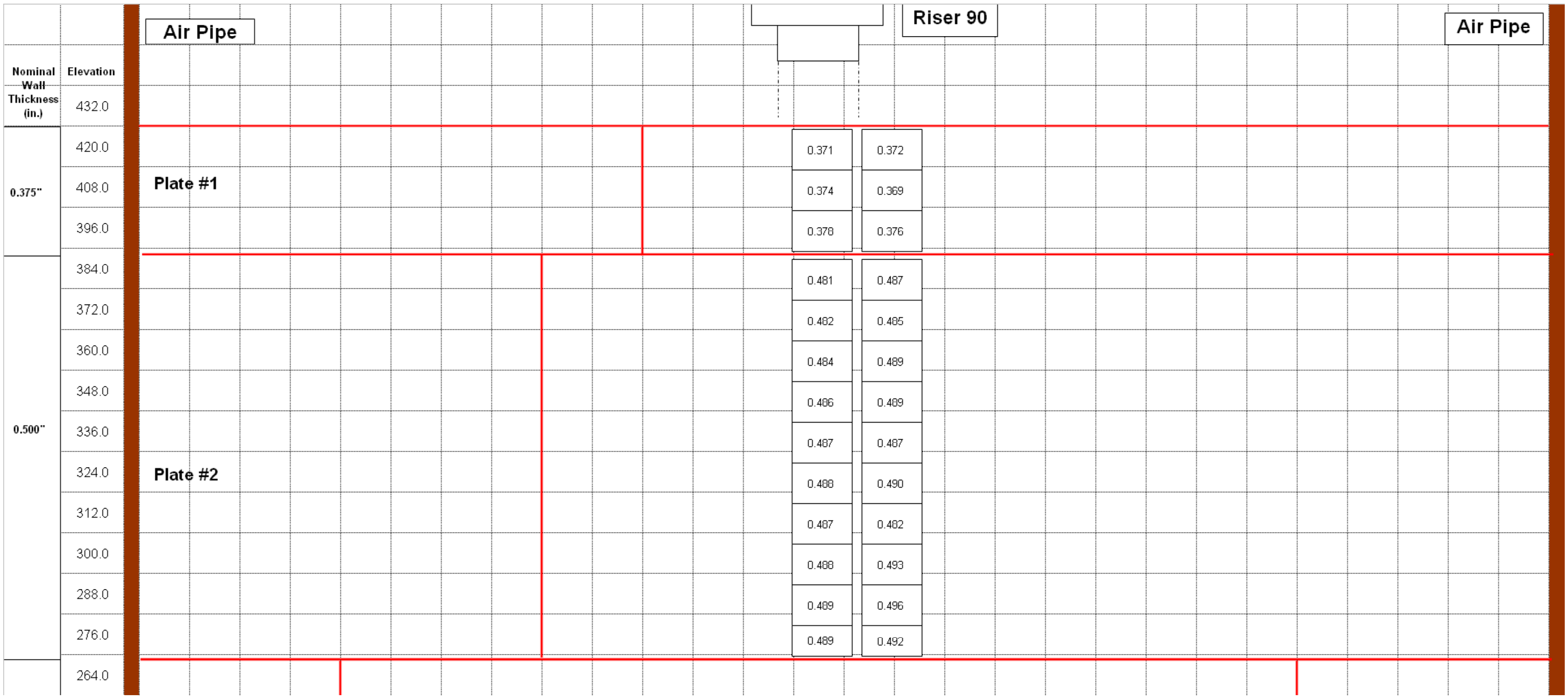



**Figure 5.3**. UT Data from Tank 241-AZ-101 Riser 90

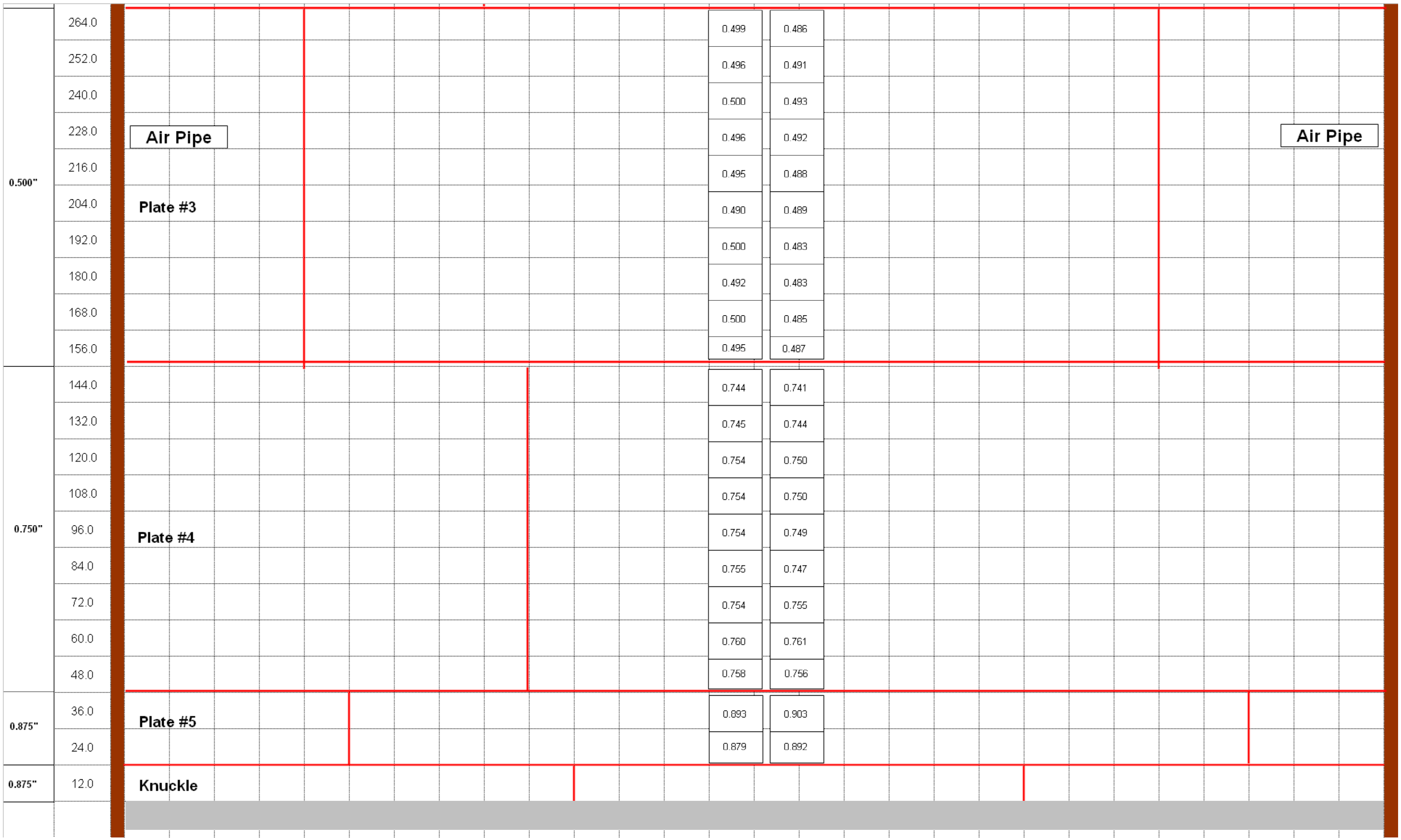



**Figure 5.4**. UT Data from Tank 241-AZ-101 Riser 90 cont.

# 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 depends somewhat on the pattern of these maximum values, but generally it could be described as approximately the 90$^{th}$ 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-AZ-101.

| **AZ-101** | **Plate Estimated Nominal** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| **Riser 89** | 0.3825 | 0.5125 | 0.5175 | 0.7675 | 0.9075 |
| **Riser 90** | 0.3875 | 0.5025 | 0.5125 | 0.7725 | 0.9175 |

**Figure 6.1.** 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 maximum value for that plate/riser from Figure 6.1. In this manner 9 estimated UT maximum wall thickness losses could be obtained for such a plate/riser combination, and then these were combined across the two risers, two paths per riser, so about 36 such losses were available for the entire plate course. This is a relatively minimal amount of data for distribution fitting as performed in this work, which is why combining measurements across plates is desirable.

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).

Deciding whether grouping the estimated wall thickness maximum losses across plates is appropriate is somewhat difficult for the Tank 241-AZ-101 measurements. Figure 6.2 shows the four paths of maximum UT loss values obtained when using the estimated nominal values from Figure 6.1. In Figure 6.2, plate courses are as indicated near the top of the figure. Each line represents a riser/path combination as indicated in the legend below the figure. Plate #5 shows somewhat elevated losses; Plate #4 less loss, except at its lowest edge for Riser 89; Plate #3 has less loss except for a single outlying value; Plate #2 dramatically differs between Riser 89 and Riser 90 with much greater losses in the particular plate associated with Riser 89; Plate #1 losses are again reduced. If the plate courses are treated individually, the histograms in Figure 6.3 result.

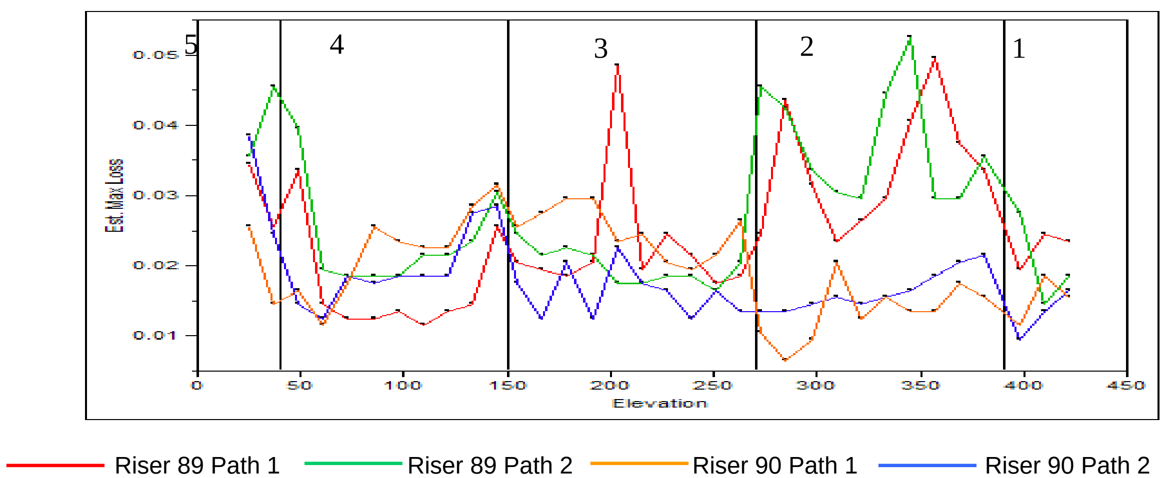



**Figure 6.2.** Estimated Maximum Loss by Path

The histograms in Figure 6.3 show estimated maximum wall thickness loss data for the individual plate courses. Three-parameter Weibull distributions are fit to these histograms and are shown as the smooth curves. The total surface area of a plate course, 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 expected estimated worst case 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 this estimated worst case loss. Therefore 95% confidence bounds on the worst case losses are also computed using these uncertainties.

The values indicated by the arrows on the histograms are the estimated worst case losses per plate course (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 around the entire circumference of the tank, and 3) the 95% confidence bound for the extreme value loss.

Recall that the relatively large loss values for Plate #2 result only from Riser 89. With so much variability in the losses between the two risers, the extreme value estimate and bound are quite large for this plate course. The Plate #4 estimate and bound seem rather large relative to the measured values; this occurs rather unfortunately due to the "pile-up" of measurements at the low end of the distribution and the nature of the estimated Weibull distribution that results.

Other tanks have shown natural combinations of plate course to consider in the extreme value estimation. This sometimes results in all plate courses being combined, or possibly split into two groups. Here the progression from least loss to worst loss, while including outlying values and the riser differences in Plate #2 is rather gradual, and it prevents identifying obvious desirable groupings. For this reason all plates are combined with the understanding that the relative numbers of measurements per plate course reflect the actual relative areas of those plate courses in the tank. Each plate course is therefore given proportionate weight in impacting the resulting combined Weibull fit. In this manner a single worse case results is identified. It is largely driven by the more extreme loss values found in Plates #2 or #5, or even Plate #3, and indeed such a worst case loss would be expected to be realized in those plates.

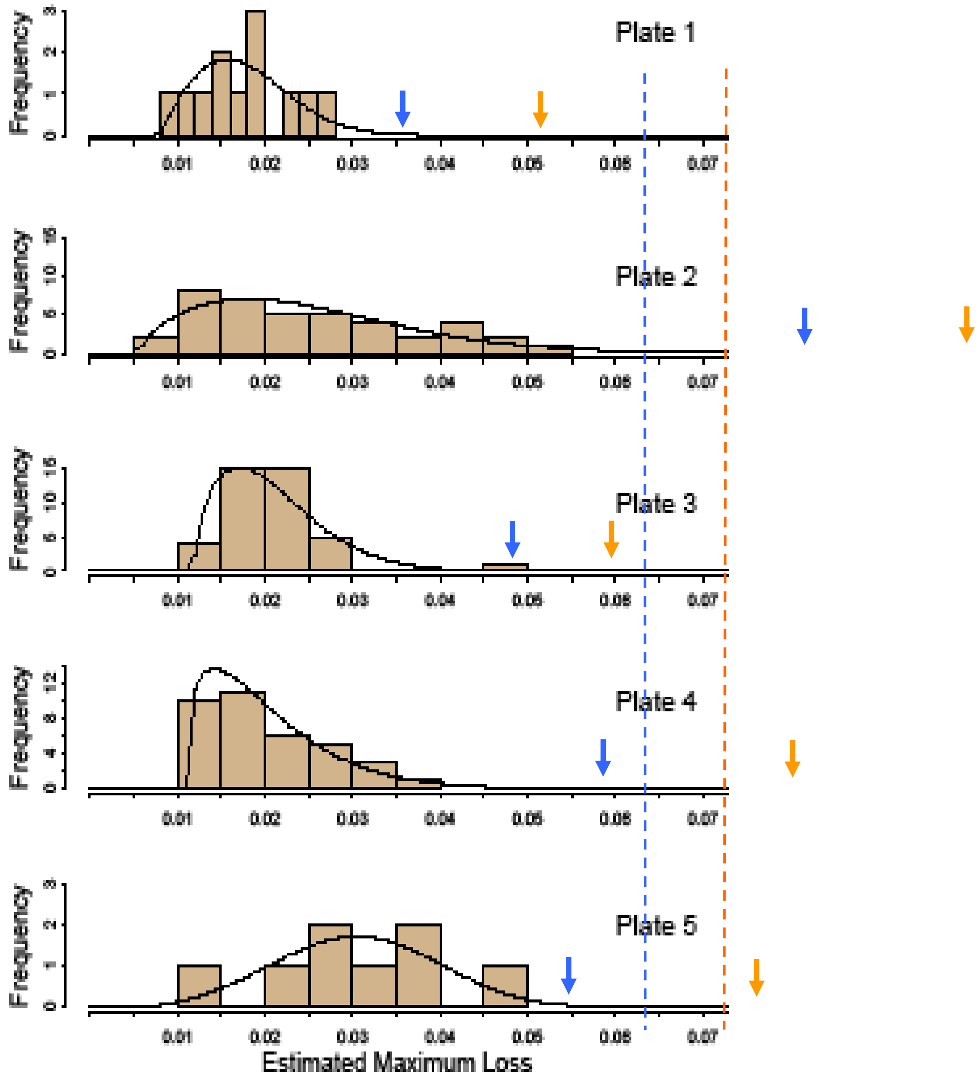



**Figure 6.3.** Weibull Distribution Fits to UT Maximum Wall Thickness Loss by Plate Course

| AZ-101 Extreme Values | Plate | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Combined |
| Estimate | 0.036 | 0.081 | 0.049 | 0.059 | 0.055 | 0.064 |
| 95% Bound | 0.052 | 0.102 | 0.060 | 0.082 | 0.078 | 0.072 |
| Measurements | 12 | 40 | 40 | 36 | 8 | 136 |

**Figure 6.4.** Tank 241-AZ-101 Wall Thickness Extreme Value Loss Estimates and Bounds

The resulting Weibull fit to the combined measurements is shown in Figure 6.5. The fit of this distribution is much better than those for the individual plates. The quality of this fit, and the larger numbers of measurements, result in the tighter upper bound as well. With the understanding that we have proportionately represented the various plate courses in the numbers of measurements taken, this combined approach is recommended for this tank for the extreme value estimate and bound. They are shown by the arrows in Figure 6.5, the vertical dotted lines in Figure 6.3, and in the final column of the table in Figure 6.4. The extreme value estimated measured maximum loss for the tank is therefore 0.064-in. with an upper 95% confidence bound of 0.072-in. Recall that these losses should not be considered relative to the tank drawing nominal values, but rather relative to the estimated plate maximum values given in the table of Figure 6.1.

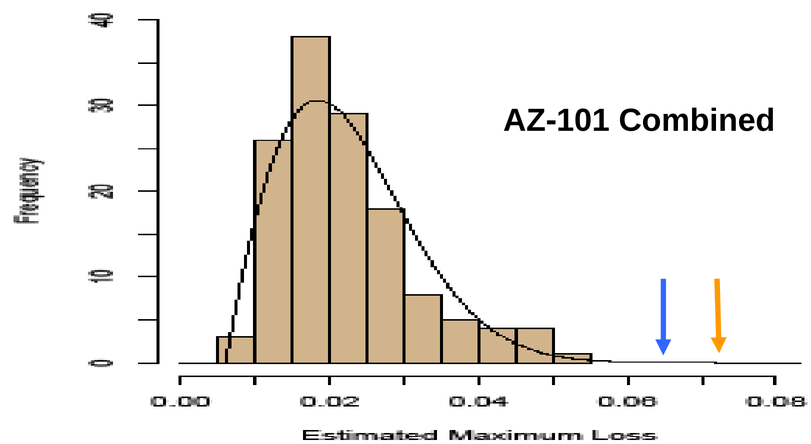



**Figure 6.5.** Weibull Distribution Fit to Combined UT Maximum Wall Thickness Loss

# 7.0 Conclusions

The results of the examination of Tank 241-AZ-101 have been evaluated by PNNL personnel. The ultrasonic examination consisted of two vertical 15-in.-wide scan paths over the entire height of the tank and the heat-affected zone (HAZ) of five vertical welds and one horizontal weld from Riser 89. The examination also included two vertical 15-in.-wide scan paths over the entire height of the tank from Riser 90. The examination was performed to detect any wall thinning, pitting, or cracking in the primary tank wall.

## 7.1 Primary Tank Wall Vertical Scan Paths

Two 15-in.-wide vertical scan paths were 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 results indicated that the minimum thicknesses in the areas that were scanned are as follows: The nominal thickness in Plate #1 is 0.375-in. and the minimum thickness in this area was 0.355-in. The nominal thickness in Plate #2 is 0.500-in. and the minimum thickness in this area was 0.460-in. The nominal thickness in Plate #3 is 0.500-in. and the minimum thickness in this area was 0.469-in. The nominal thickness in Plate #4 is 0.750-in. and the minimum thickness in this area was 0.728in. The nominal thickness in Plate #5 is 0.875-in. and the minimum thickness in this area was 0.862-in. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plates #1, #2, #3, #4, or #5.

Two 15-in.-wide vertical scan paths were performed on Plates #1, #2, #3, #4, and #5 from Riser 90. The plates were examined for wall thinning, pitting, and cracks oriented vertically on the primary tank wall. The results indicated that the minimum thicknesses in the areas that were scanned are as follows: The nominal thickness in Plate #1 is 0.375-in. and the minimum thickness in this area was 0.369-in. The nominal thickness in Plate #2 is 0.500-in. and the minimum thickness in this area was 0.481-in. The nominal thickness in Plate #3 is 0.500-in. and the minimum thickness in this area was 0.483-in. The nominal thickness in Plate #4 is 0.750-in. and the minimum thickness in this area was 0.741in. The nominal thickness in Plate #5 is 0.875-in. and the minimum thickness in this area was 0.879-in. There were no areas of wall thinning that exceeded the reportable level of 10% of the nominal thickness. No pitting or vertical crack-like indications were detected in Plates #1, #2, #3, #4, or #5.

## 7.2 Primary Tank Wall Weld Scan Paths

The HAZ of vertical welds in Plates #1, #2, #3, #4, and #5 from Riser 89 were examined for wall thinning, pitting and cracks oriented either perpendicular or parallel to the weld. The results indicated that the minimum thicknesses in the weld areas that were scanned are as follows: The nominal thickness in Plate #1 is 0.375-in. and the minimum thickness in this area was 0.362-in. The nominal thickness of Plate #2 is 0.500-in. and the minimum thickness in this weld area was 0.481-in. The nominal thickness in Plate #3 is 0.500-in. and the minimum thickness in this weld area was 0.481-in. The nominal thickness in Plate #4 is 0.750-in. and the minimum thickness in this weld area was 0.694-in. The nominal thickness in Plate #5 is 0.875-in. and the minimum thickness in this weld area was 0.844-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 Plates #1, #2, #3, #4, and #5.

The HAZ of the horizontal weld between Plate #5 and the tank knuckle from Riser 89 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 0.875-in. on Plate #5 was 0.883-in.  The minimum thickness in the weld area with nominal thickness of 0.875-in. on the knuckle was 0.840-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 #5 side or on the knuckle side of the horizontal weld.

## 7.3 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 0.010-in. to 0.030-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, two paths per riser.

Three-parameter Weibull distributions were fit to individual plate courses and to all plate courses combined.  The latter approach is preferred due to the nature of these tank measurements per plate; this generates a worst case measured wall thickness loss of 0.064-in. that might be expected if the entire surface area of the tank wall were UT inspected.  A 95% confidence bound is computed based on the uncertainty in the Weibull parameters due to the quality of the Weibull fit and the number of measurements available; this 95% bound on measured wall thickness loss is 0.072-in.  Note that such losses should be considered relative to the larger "estimated" nominal wall thicknesses and not the drawing nominal.

# 8.0 References

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