PNNL-16601 Rev. 0

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

Ultrasonic Examination of Double-Shell Tank 241-AY-102 Examination Completed January 2007

AF Pardini
DR Weier

May 2007

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

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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-AY-102. The purpose of this examination was to provide information that could be used to evaluate the integrity of the wall of the primary and secondary tank. The requirements for the ultrasonic examination of Tank 241-AY-102 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-AY-102 have been evaluated by PNNL personnel. The primary tank ultrasonic examination consisted of two vertical 15-in.-wide scan paths over the entire height of the tank from Riser 88 and two vertical 15-in.-wide scan paths over the entire height of the tank, a short vertical 15-in-wide scan on Plates #4 and #5, the heat-affected zone (HAZ) of five vertical welds, one horizontal weld, and a short section of the knuckle from Riser 89. The examinations were 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 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 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 #2.
- Plate #3 results indicate three areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these three areas (with remaining ligament of 0.403-in., 0.440-in., and 0.441-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.
- 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 0.646-in., and 0.666-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.

- Plate #5 results indicate one area that exceeded the minimum thinning reportable level of 10% of the nominal thickness. However, this one area (with remaining ligament of 0.783-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 vertical crack-like indications were detected in Plate #5.

Two 15-in.-wide vertical scan paths were performed on Plates #1, #2, #3, #4, and #5 below the entrance to Riser 89 and an additional 15-in.-wide short scan on Plates #4 and #5 was performed just south of these two. 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 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 #2.
- Plate #3 results indicate nine areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these nine areas (with remaining ligament of 0.441-in., 0.443-in., 0.443-in., 0.444-in., 0.445-in., 0.447-in., 0.447-in., 0.448-in.,and 0.449-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.
- Plate #4 results indicate five areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, two of these areas (with remaining ligament of 0.666-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. Three of the five areas were evaluated by the UT Level III and were considered wall thinning with minimum thicknesses of 0.648-in., 0.670-in., and 0.672-in. and do exceed the reportable level of 10% of the nominal thickness. No vertical crack-like indications were detected in Plate #4.
- Plate #5 results indicate two areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, one of these areas (with remaining ligament of 0.759-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. One of the two areas was evaluated by the UT Level III and was considered wall thinning with minimum thicknesses of 0.775-in., and does exceed the reportable level of 10% of the nominal thickness. No vertical crack-like indications were detected in Plate #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 in Plates #1, #2, #3, and #5. No pitting or crack-like indications were detected in the weld HAZ areas in Plates #1, #2, #3, and #5.

Plate 4 results indicate one area with a minimum thickness of 0.656-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 #4

The HAZ of the horizontal weld between Plate #2 and Plate #3 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 #2 side or on Plate #3 side of the horizontal weld.

Primary Tank Wall Knuckle Scan Paths

The upper portion of the knuckle area of the primary tank was scanned utilizing the Y-arm scanner attached to the AWS-5D crawler. The Y-arm scans the transducer down around the knuckle approximately 9-in. from a starting position 2-in. below the upper knuckle weld joining Plate #5 to the knuckle. The knuckle was examined for wall thinning, pitting, and cracks oriented circumferentially around the primary tank. There were no areas that exceeded the reportable level of 10% of the nominal thickness. No pitting or circumferentially oriented crack-like indications were detected in the upper portion of the knuckle area.

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 as-built wall thickness per plate/riser combination. These thicknesses tend to run about 0.030-in. to 0.040-in. greater than drawing nominal for most tanks being considered in this manner, so these larger values are used as in improved estimate of original tank thickness. However, they are much less for Tank 241-AY-102, with some indeed being quite close to drawing nominal. These estimated nominal values were in turn 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 UT measurement paths per riser.

Three parameter Weibull distributions were fit to the plate course measurements as well as to the measurements combined over all plates. For previously examined tanks (Tank 241-AN-107 and Tank 241-AW-103), grouping the measurements over all plates could reasonably be justified. This is not the case for Tank 241-AY-102. For this reason it is difficult to identify an appropriate worst case maximum wall loss for the tank, especially for Plate #5, the lowest considered in the study. When only minimal amounts of data are available within plate courses (as is the case for Plate #5), the estimated extreme values and related confidence bounds can become quite large and conservative. Alternative plate groupings are examined for Tank 241-AY-102 with extreme values computed that might be expected if the entire surface area of the tank wall for the particular plate combinations were UT inspected.

In all cases considered 95% confidence bounds are 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. Such losses are larger for Tank 241-AY-102 compared to other tanks similarly studied. Note that the losses characterized here should be considered relative to the somewhat larger "estimated" nominal wall thicknesses and not the drawing nominal when the drawing nominal is exceeded by the estimated maximum value.

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-AY-102. 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-AY-102 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 and the wall of the secondary 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-AY-102:

- **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-102. This equipment consists of a Force Institute P-Scan ultrasonic test instrument and Force Institute 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 and Y-arm scanner attachment have been qualified through a PDT administered by PNNL. (Posakony and Pardini 1998) (Pardini 2001)

2.3 Ultrasonic Examination Procedure

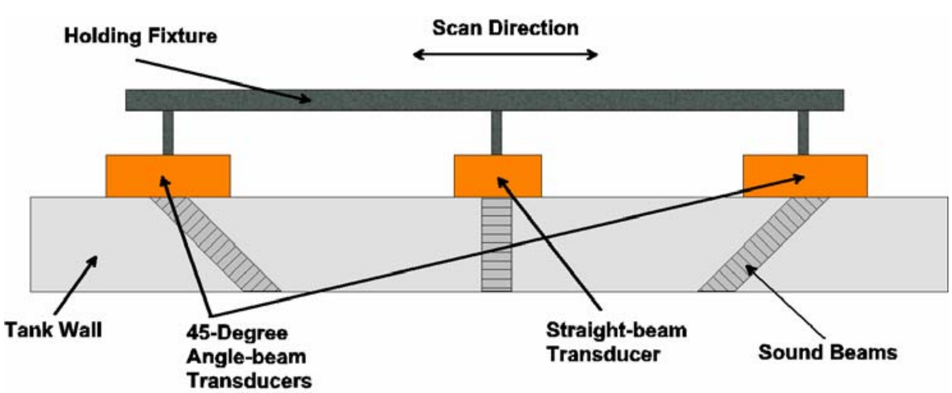
AREVA has provided the UT procedure for the examination of Tank 241-AY-102. This procedure, COGEMA-SVUT-INS-007.3, Revision 3, outlines the type of UT and mechanical equipment that are to be used as well as the types of transducers. Both straight-beam and angle-beam transducers are used for the examination 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-102 included UT of the primary tank walls 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:

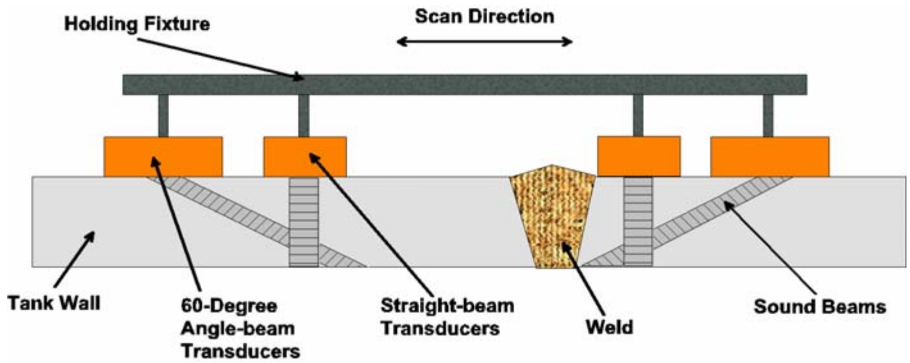
Angle-Beam
Type: MWB-45 04E
Frequency: 4 MHz
Size: 8 X 9 mm
Manufacturer: Krautkramer

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

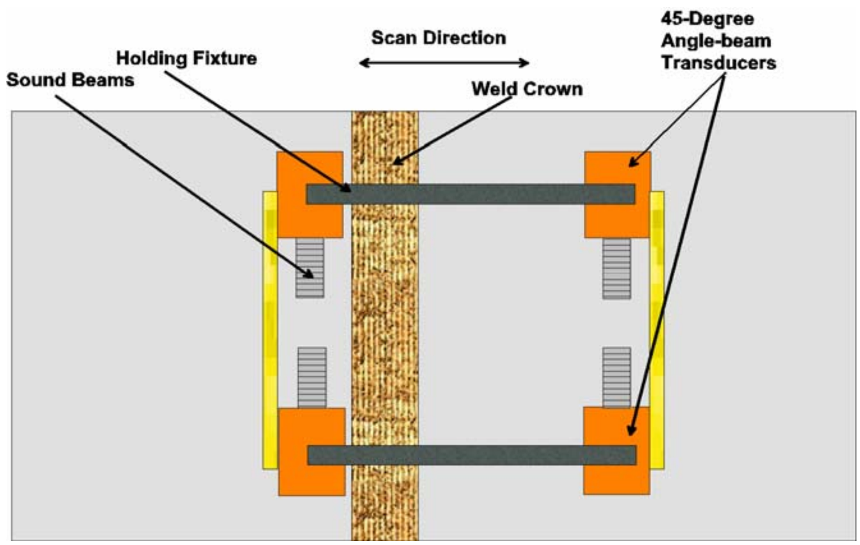
Figure 3.2 is a functional sketch that shows the configurations for examination of the weld zone. The area of interest (HAZ of the weld) is shown as lying adjacent to the weld. Both cracks and pitting may occur in this region. The “A” portion of this sketch shows the 60-degree angle-beam transducers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

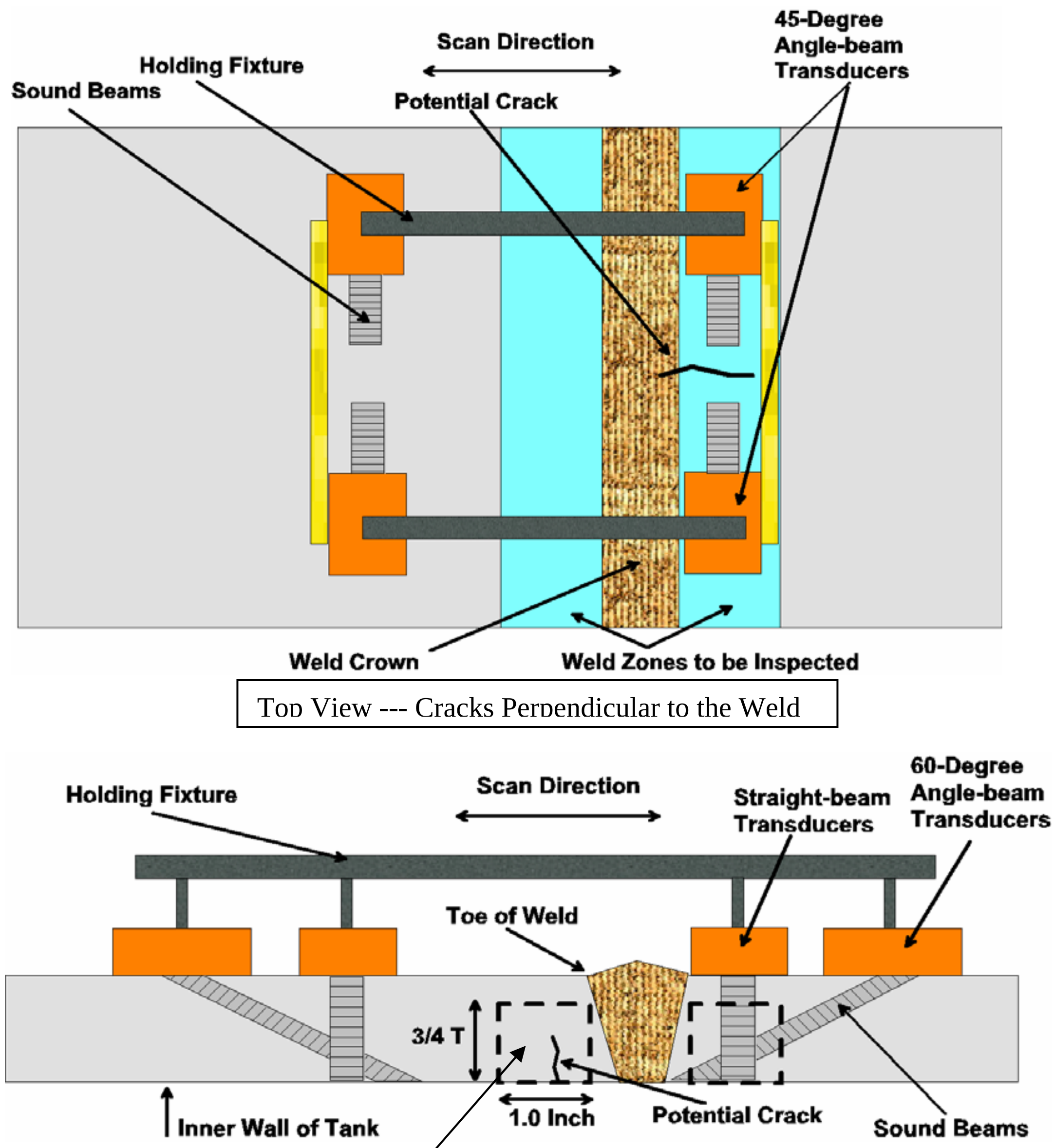


B. Configuration for cracks perpendicular to weld

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

3.3 Knuckle Area Transducer Configuration

Examination of the knuckle utilizes a modified scanning bridge known as the Y-arm scanner. The Y-arm provides scanning of the transducers directly on the knuckle region. The Y-arm is a special fixture that attaches to the AWS-5D magnetic wheel crawler. Its purpose is to extend the reach of the transducer assembly. This extension allows the transducer assembly to follow the curve of the upper portion of the knuckle below the transition Plate #5 to upper knuckle weld. It is designed to hold the dual 0-degree or two 45-degree transducers in the same configuration as used for the examination of the tank wall. The transducer configuration used for crack detection in this examination was two opposing 45-degree angle-beam transducers that were rotated 90-degrees from the orientation used for the wall crack inspection. This configuration is designed to detect cracks that are in a circumferential direction with respect to the axis of the tank. Figure 3.4 is a sketch showing the area of the section of the knuckle examined using the Y-arm fixture. With the transducer positioned 2-in. below the transition Plate #5 to upper knuckle weld, the scanning bridge was set to scan the transducer downward an additional distance of approximately 9-in. in 0.035-in steps (or as set by the operator). Upon completion of the scan, the bridge was indexed circumferentially 0.035-in. (or as set by the operator) and the scan downward is repeated to obtain a pixel size 0.035-in. x 0.035-in. (or as set by the operator).

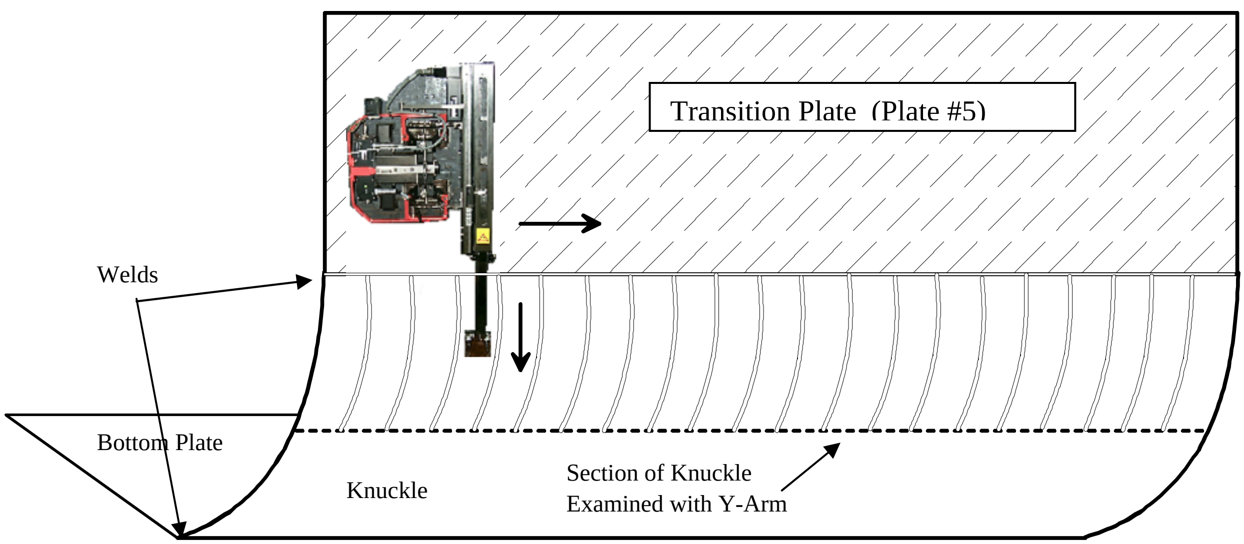


Figure 3.4. Sketch of a Section of the Knuckle Examined with the Y-Arm Scanner

4.0 Ultrasonic Examination Location

Tank 241-AY-102 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-102. Figure 4.1 provides a graphic of the location of the risers.

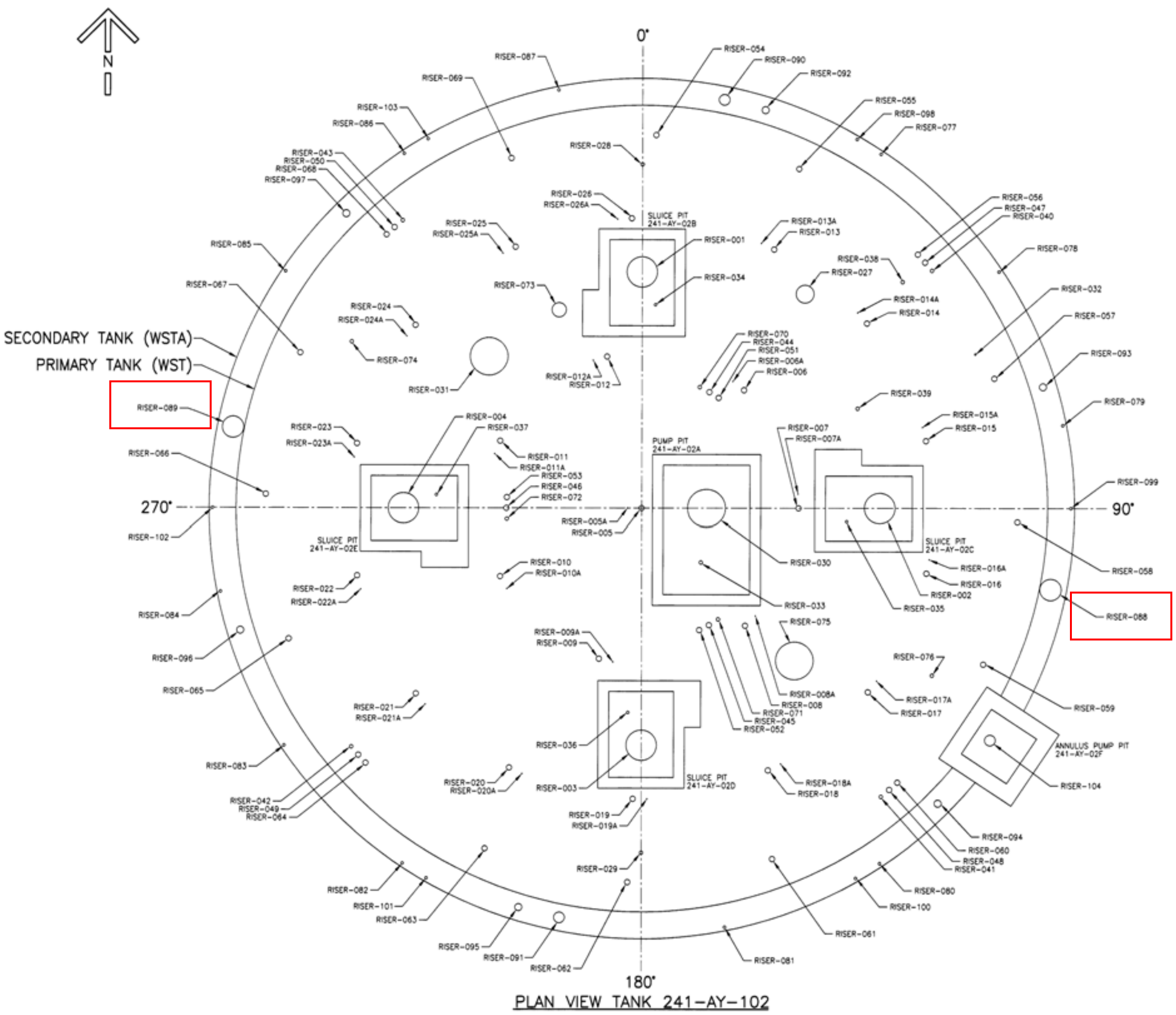


Figure 4.1. UT of Tank 241-AY-102 Riser 88 and Riser 89

Figure 4.2 describes the areas on the primary wall of Tank 241-AY-102 that were ultrasonically examined from Riser 88 located on the east 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 88.

Figure 4.3 describes the areas on the primary wall of Tank 241-AY-102 that were ultrasonically examined from Riser 89 located on the west 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 an additional short scan on Plates #4 and #5 was performed just south of these two. Vertical weld HAZ examinations were done on Plates #1, #2, #3, #4, and #5, and the horizontal weld HAZ examination was done on the Plate #2 to Plate #3 weld. A short section of the knuckle was also scanned from Riser 89.

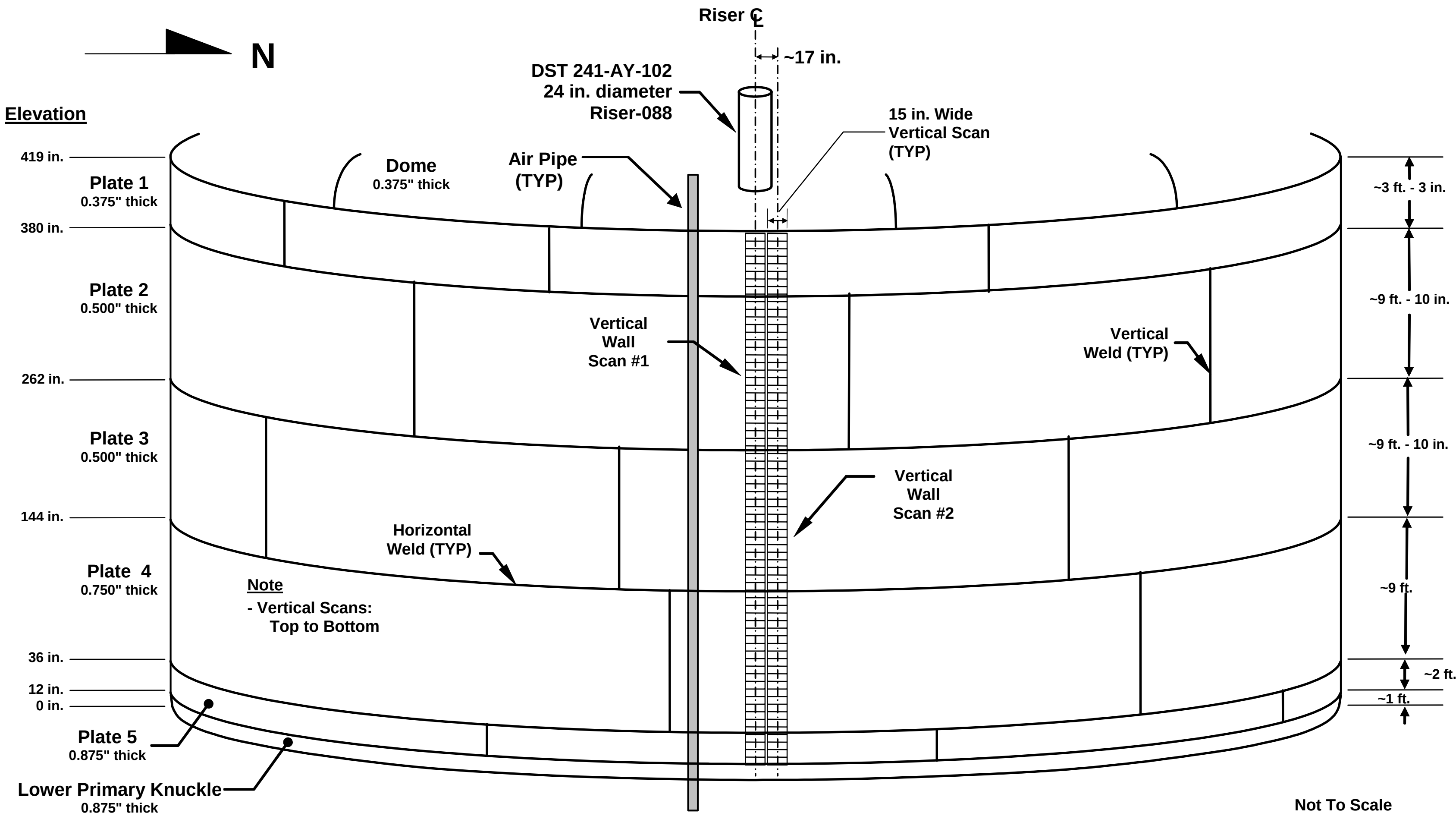


Figure 4.2. Sketch of Scan Paths on 241-AY-102 Primary Tank from Riser 88

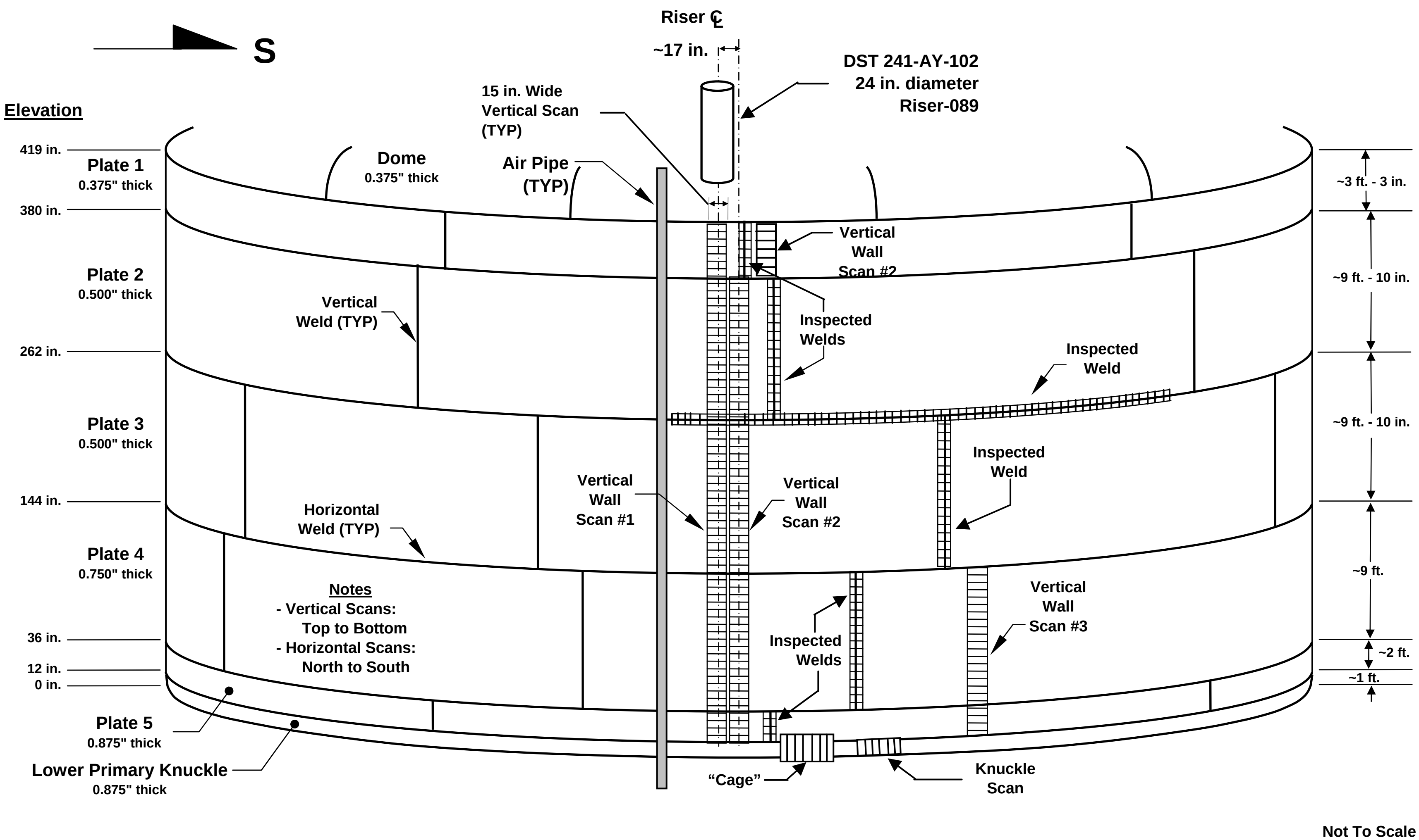


Figure 4.3. Sketch of Scan Paths on Tank 241-AY-102 Primary Tank from Riser 89

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 Level III Mr. Wes Nelson, and peer reviewed by JBNDT Level III Mr. Jim Elder. The results of the examination of Tank 241-AY-102 are presented in Figures 5.1 through 5.5.

Figures 5.1 and 5.2 show the wall thickness examination results for the primary tank wall from Riser 88. The examination consisted of two vertical paths beneath the 24-in. diameter riser. Vertical scan #1 was 15-in.-wide on Plates #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.

Figures 5.3, 5.4, and 5.5 show the wall thickness examination results for the primary tank wall, the HAZs of both vertical and horizontal welds, and a portion of the knuckle from Riser 89. The examination consisted of two vertical paths beneath the 24-in. diameter riser and an additional short vertical path on Plates #4 and #5. 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 Scan #3 was a few feet to the south of vertical scan #2 and was only performed on Plates #4 and #5. Vertical scans were conducted in the downward direction. The HAZs of vertical welds in Plates #1, #2, #3, #4, and #5 were examined and the HAZ in the horizontal weld between Plate #2 and Plate #3 was also examined. Weld area exams include approximately 5-in. on each side of the weld. Approximately 3-ft. circumferentially was examined on the upper portion of the knuckle. 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. 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 5.5 displays the minimum readings taken in each 9-in.-wide by 12-in.-long area of the scan. 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.

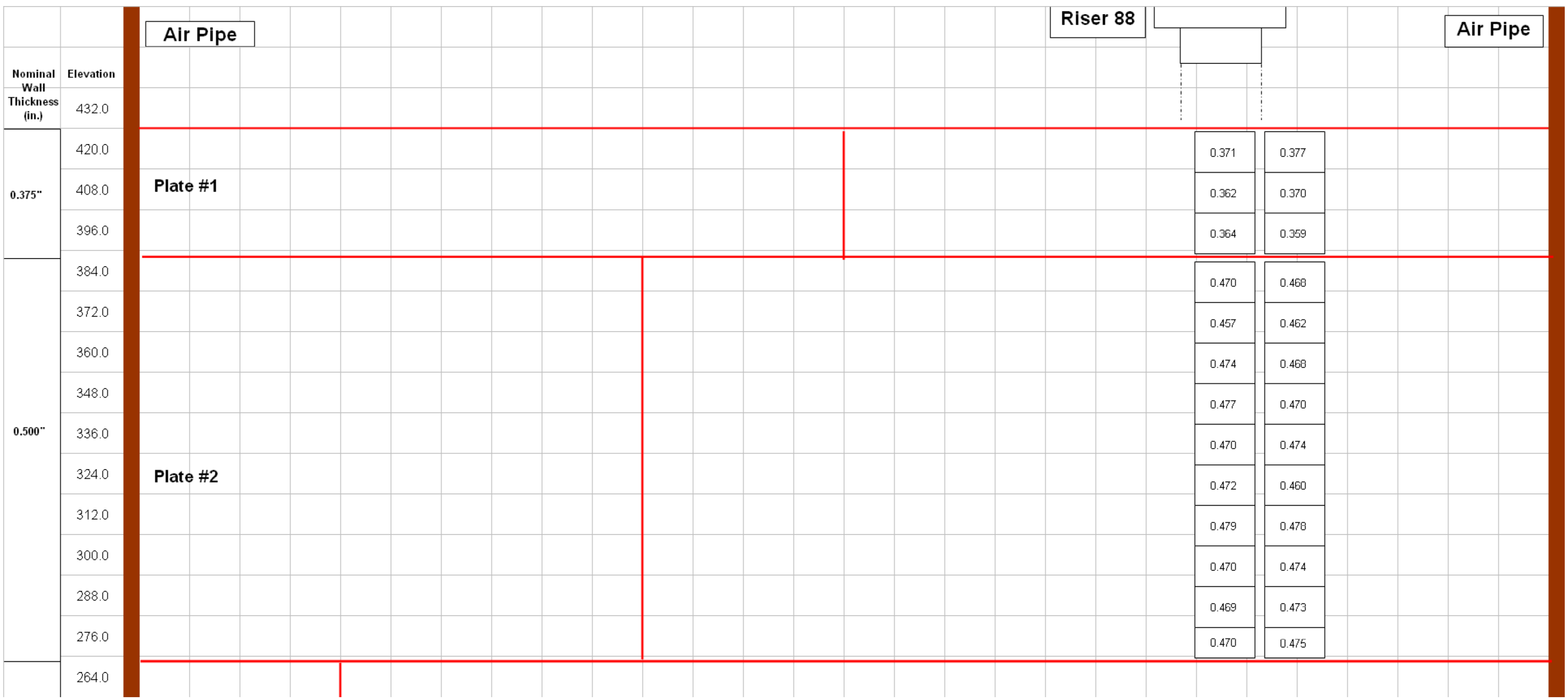


Figure 5.1. UT Data from Tank 241-AY-102 Primary Tank Riser 88

Figure 5.2. UT Data from Tank 241-AY-102 Primary Tank Riser 88 cont.

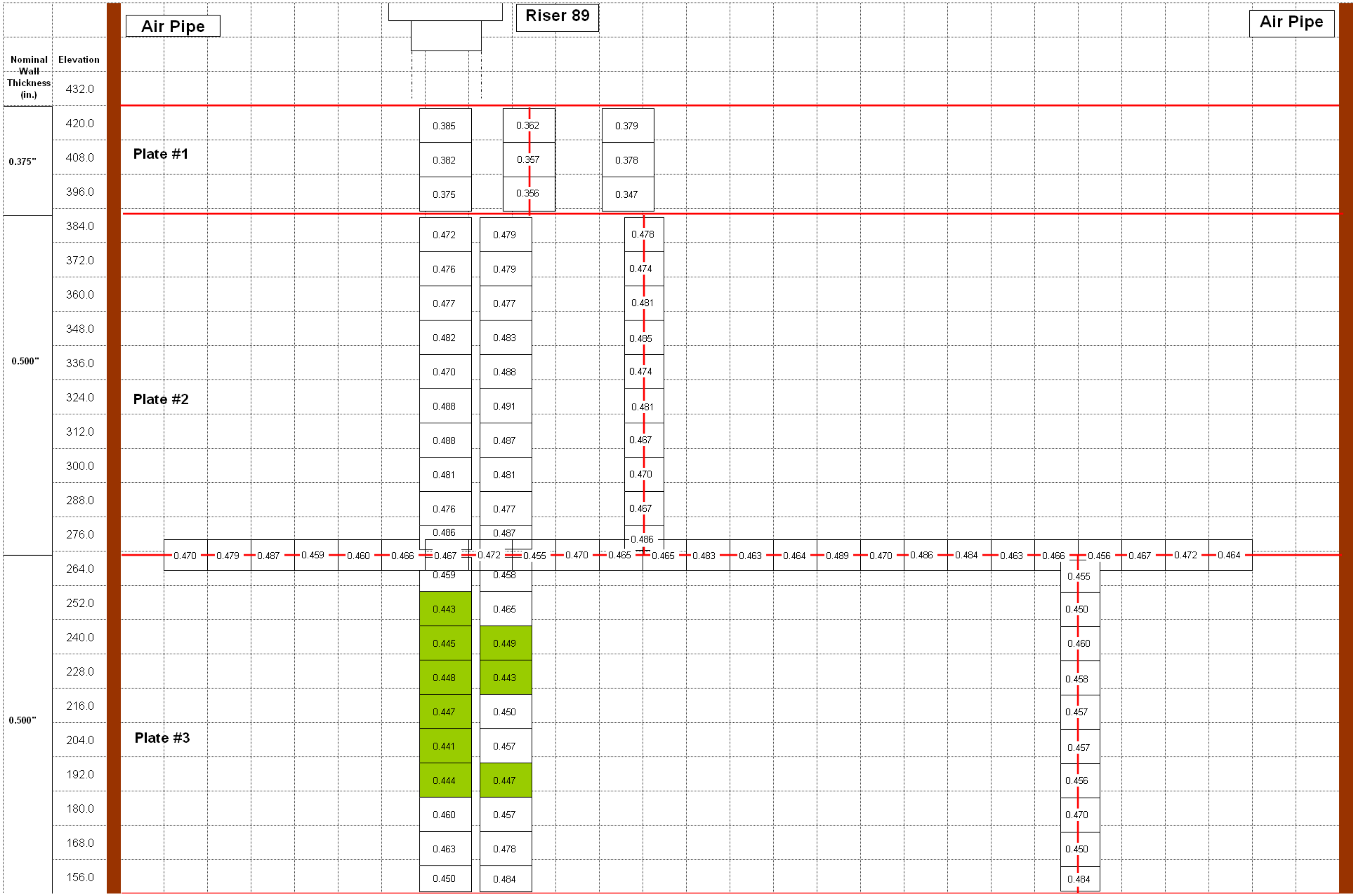


Figure 5.3. UT Data from Tank 241-AY-102 Primary Tank Riser 89

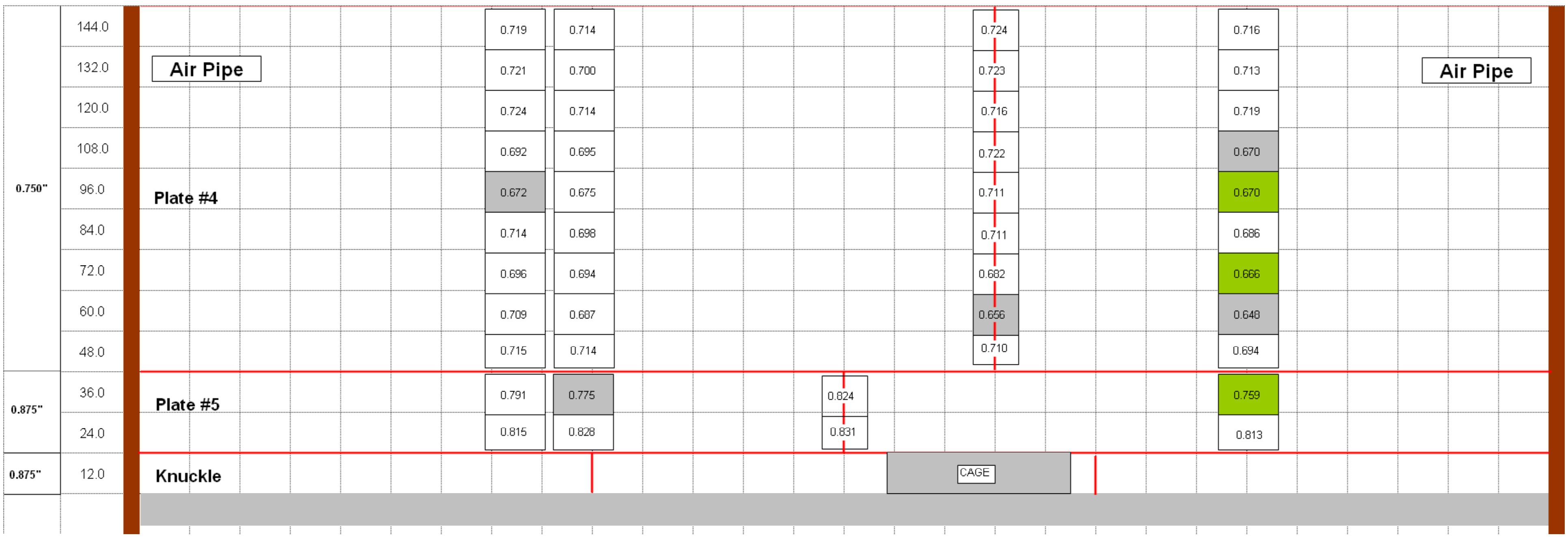


Figure 5.4. UT Data from Tank 241-AY-102 Primary Tank Riser 89 cont.

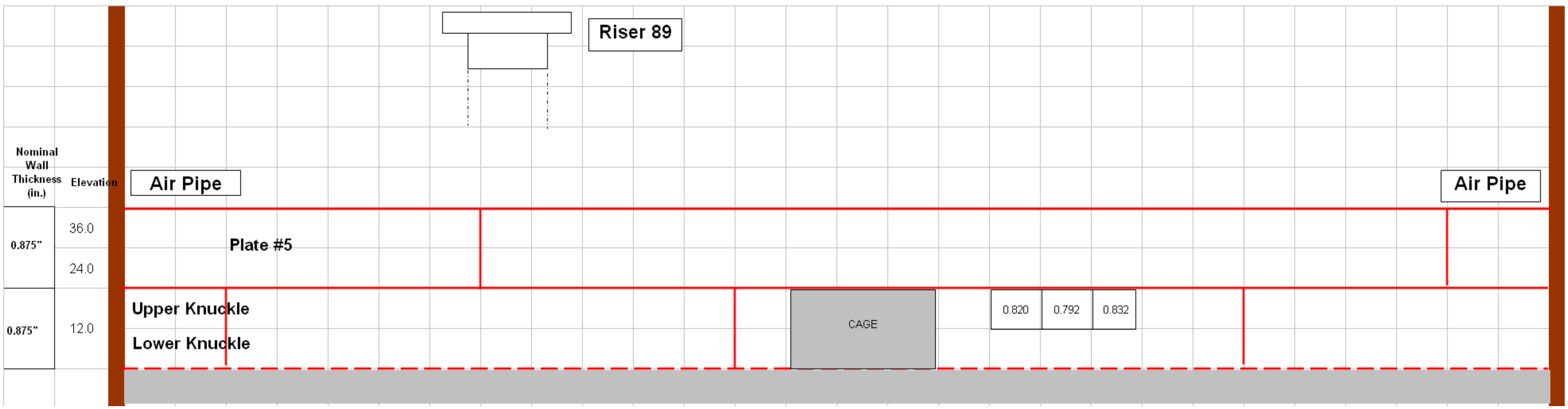


Figure 5.5. UT Data from Tank 241-AY-102 Primary Tank Riser 89 cont.

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 is 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 obtained since remaining wall thickness still sometimes exceed 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 nominal thickness. For other tanks considered these estimated original wall thickness typically exceed drawing nominal by about 0.030-in. to 0.040-in., but for Tank 241-AY-102, the estimated original thicknesses are much closer to drawing nominal. Since the AY tanks were the first double shell tanks constructed at the Hanford Tank Farms, it is not known if the smaller excess plate margin was due to original plate size or a greater corrosion rate over a longer period. This topic will be further investigated in subsequent studies that statistically compare current measurements to earlier sets taken in the late 1990's.

Note that measurement error and its variability have 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 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 in estimating only a worst case wall condition; to do that measurement error would have to be adequately characterized and removed from consideration. Determination of measurement error is a topic of ongoing analyses, and if successful will be used in later reports to better project wall thickness variability.

Two paths are available down each of two risers. For example, in a typical ~10-ft. plate (vertical dimension) for one riser, this generates about 18 maximum measured wall thickness values. 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 80th percentile of such measurements. It was considered too extreme to use the largest of the 18 or so maximum values due to potential measurement error from the uncertainty due to the AY-102 annulus side surface corrosion. If used, this would then grossly over-estimate the true nominal thickness. In this manner the following maximum remaining thicknesses shown in Figure 6.1 were obtained for Tank 241-AY-102.

AY-102	Plate Estimated Nominal				
	1	2	3	4	5
Riser 88	0.3875	0.5000	0.5000	0.7600	0.9075
Riser 89	0.3975	0.5025	0.5075	0.7525	0.9050

Figure 6.1. Table of Estimated Nominal Thickness from UT Maxima

The 18 or so (it actually varies from plate to plate depending on plate dimensions) individual UT image minimum values for a plate/riser combination were subtracted from the estimated maximum value for that plate/riser from the table. In this manner 18 estimated maximum wall thickness losses were obtained for a plate/riser combination, and then these were combined across the two risers, so about 36 such losses were available for the entire plate course. 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).

The histograms in Figure 6.2 show such wall thickness loss data grouped by plate course. That is, the UT image maximum losses from the four paths, two per riser, within each plate course are combined. Three parameter Weibull distributions are fit to these histograms and are shown as the smooth curves.

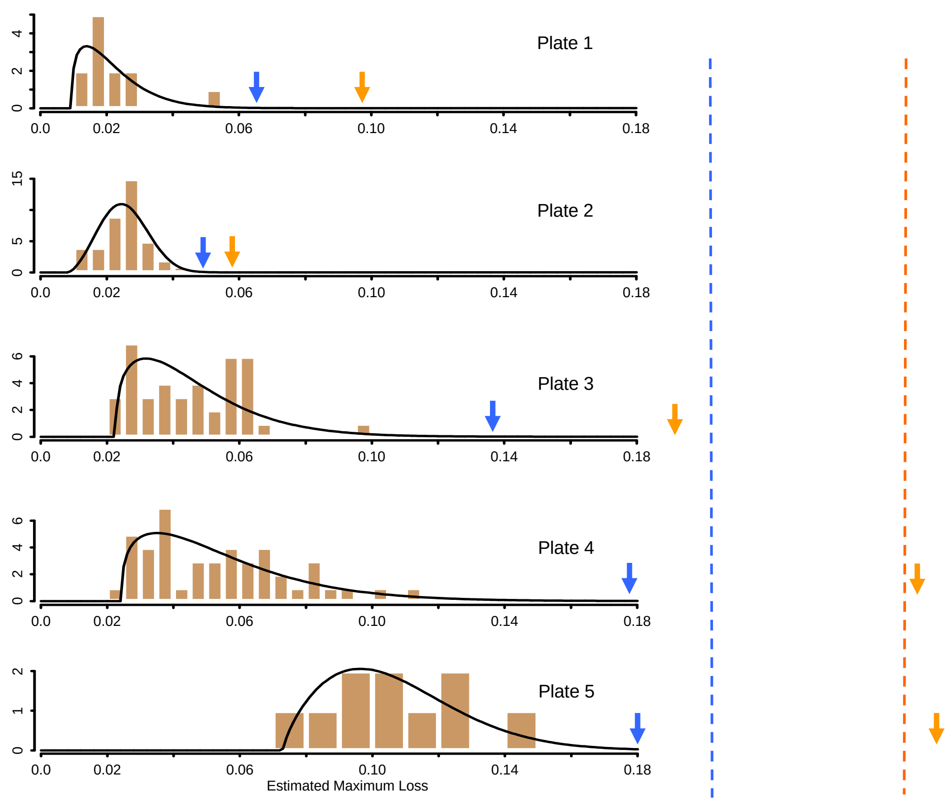


Figure 6.2. Weibull Distribution Fits to UT Maximum Wall Thickness Loss by Plate Course

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 plate course, is computed. The percentile of the distribution that then corresponds to the greatest expected loss among this many UT images, based on the distribution fit to the histogram, is considered as the estimated worst case loss. But 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 loss. 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 (blue) and their associated 95% confidence bounds (orange). The corresponding values are given in the table shown in Figure 6.3. 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 loss.

AY-102 Extreme Values	**Plates**					
	Combined	**1**	**2**	**3**	**4**	**5**
Estimate	0.198	0.065	0.049	0.137	0.178	0.180
Bound	0.231	0.097	0.058	0.190	0.235	0.248
Measurements	147	12	40	40	45	10

Figure 6.3. Table of Tank 241-AY-102 Wall Thickness Extreme Value Loss Estimates/Bounds

The obvious characteristic of the Tank 241-AY-102 histograms in Figure 6-2 is that grouping the measurements across plates is inappropriate. The deeper into the tank (that is, going from Plates #1 to #5), the more wall thickness loss that has apparently been realized. If all plates were indeed grouped, the

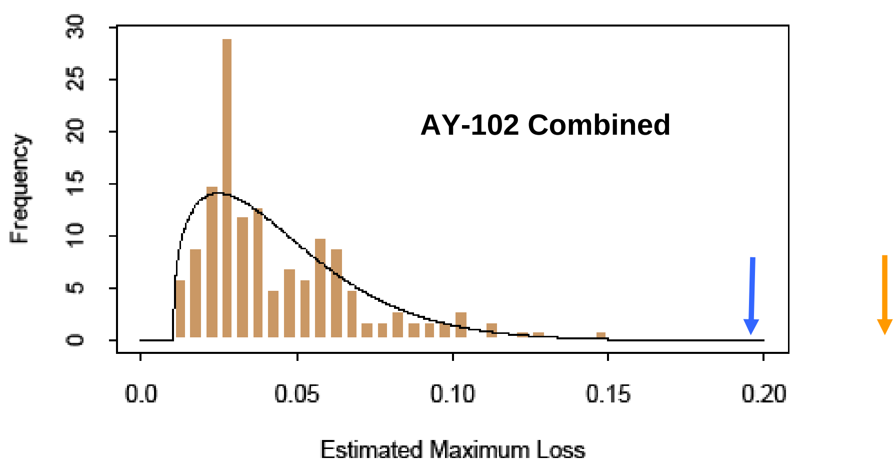


Figure 6.4. Weibull Distribution Fit to Wall Thickness Loss Combined over Plate Courses

“Combined” numbers from the table in Figure 6.3, and denoted by the vertical dotted lines in Figure 6.2 and the arrows in Figure 6.4, show an estimated worst case loss of 0.198-in. with a confidence bound of 0.231-in. Such losses obviously cannot be applied appropriately to Plate #1 with a drawing nominal of 0.375-in., which would result in obviously unrealistic losses. Also note that the combined distribution in Figure 6.4 appears to have a “double-hump”, again suggesting that grouping the measurements into a single distribution is inappropriate.

Therefore the wall thickness losses are considered separately across all five plate courses for Tank 241-AY-102, and shown both by the arrows in Figure 6.2 and the tabled values in Figure 6.3. But in so doing, the tendency to have fairly abrupt left-hand tails, with outlying values to the right for Plates #3, #4, and #5 give quite heavy-tailed distributions and resulting extreme values estimates and bounds considerably larger than any of the observed results. These characteristics of the distributions fit, and the minimal number of measurements per plate, result in the extremely large values. It is questionable if they are of practical use.

For this reason one other alternative was attempted to minimize the over-conservatism in the estimation scheme. Based on the histograms shown in Figure 6.2, plates were grouped into combinations as indicated in the table in Figure 6.5, and as shown by the histograms in Figure 6.6. The combinations include Plates #1 and #2, Plates #3 and #4, and alternatively Plates #3, #4 and #5. The resulting extreme value estimates and bounds are listed in the Figure 6.5 table and again shown by the arrows in Figure 6.6.

AY-102 Extreme Values	**Plate Combinationss**		
	1&2	**3&4**	**3&4&5**
Estimate	0.057	0.169	0.230
Bound	0.068	0.209	0.285
Measurements	52	85	95

Figure 6.5. Table of Extreme Value Estimates and Bounds for Plate Combinations

These combinations of plates give much more reasonable estimates for Plates #1 and #2, and even for the Plates #3 and #4 combination, but little can be done to avoid the problems caused by including Plate #5, either individually as before, or here grouped with Plates #3 and #4. The estimates and bounds simply become very extreme. Note the vertical dotted lines on Figure 6.6 are still those from the combination of all five plates as before in Figure 6.2.

While extreme value results have been relatively straightforward to interpret for previous tanks, Tank 241-AY-102 is obviously more problematical. It is suggested that the reader consider the tabled values in Figures 6.3 and 6.5, and interpret them appropriately. Preferred estimates for Plates #1 and#2 and for Plates #3 and #4 are probably those listed in Figure 6.5. But the methodology simply doesn’t lend itself to application to the minimal amount of data in Plate #5 alone. And when Plate #5 measurements are incorporated with those of other plates, many of the Plate #5 values become outlying values considerably greater than those for the other plates. They then unduly influence the estimates for the other plates as well.

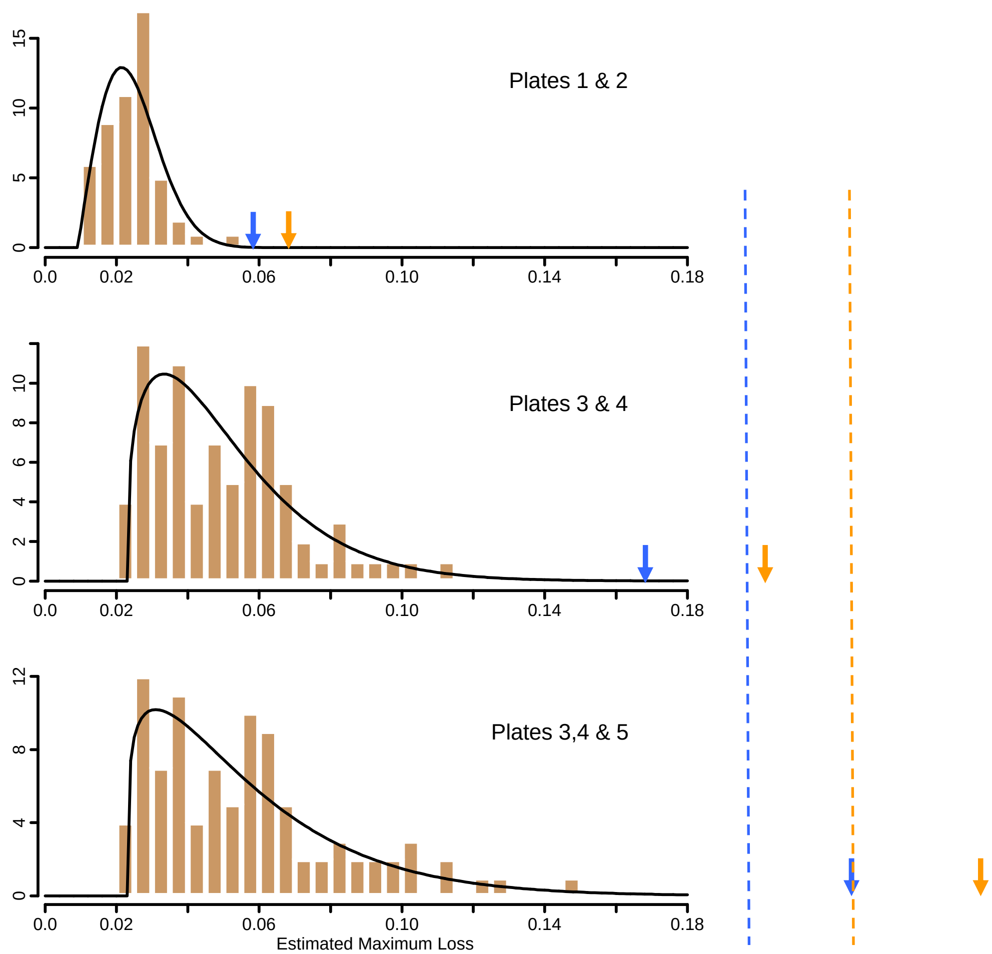


Figure 6.6. Weibull Distribution Fits to Wall Thickness Loss for Plate Course Combinations

7.0 Conclusions

The results of the examination of Tank 241-AY-102 have been evaluated by PNNL personnel. The primary tank ultrasonic examination consisted of two vertical 15-in.-wide scan paths over the entire height of the tank from Riser 88 and two vertical 15-in.-wide scan paths over the entire height of the tank, an additional short scan on Plates #4 and #5 just south of these two, and the heat-affected zone (HAZ) of five vertical welds and one horizontal weld, and a short portion of the upper knuckle region from Riser 89. 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

Two 15-in.-wide vertical scan paths were 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 0.359-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. and the minimum thickness in this area was 0.457-in. Plate #2 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 #2.
- The nominal thickness of Plate #3 is 0.500-in. Plate #3 results indicate three areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these three areas (with remaining ligament of 0.403-in., 0.440-in., and 0.441-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 0.646-in., and 0.666-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. Plate #5 results indicate one area that exceeded the minimum thinning reportable level of 10% of the nominal thickness. However, this one area (with remaining ligament of 0.783-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 vertical crack-like indications were detected in Plate #5.

Two 15-in.-wide vertical scan paths were performed on Plates #1, #2, #3, #4, and #5 from Riser 89 as well as a short scan on Plates #4 and #5 just south of these two. 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 0.347-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. and the minimum thickness in this area was 0.470-in. Plate #2 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 #2.
- The nominal thickness of Plate #3 is 0.500-in. Plate #3 results indicate nine areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, these nine areas (with remaining ligament of 0.441-in., 0.443-in., 0.443-in., 0.444-in., 0.445-in., 0.447-in., 0.447-in., 0.448-in.,and 0.449-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 five areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, two of these areas (with remaining ligament of 0.666-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. Three of the five areas were evaluated by the UT Level III and were considered wall thinning with minimum thicknesses of 0.648-in., 0.670-in., and 0.672-in. and do exceed the reportable level of 10% of the nominal thickness. No vertical crack-like indications were detected in Plate #4.
- The nominal thickness of Plate #5 is 0.875-in. Plate #5 results indicate two areas that exceed the minimum thinning reportable level of 10% of the nominal thickness. However, one of these areas (with remaining ligament of 0.759-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. One of the two areas was evaluated by the UT Level III and was considered wall thinning with minimum thicknesses of 0.775-in., and does exceed the reportable level of 10% of the nominal thickness. No vertical crack-like indications were detected in Plate #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 of Plate #1 is 0.375-in. and the minimum thickness in this weld area was 0.356-in. The nominal thickness of Plate #2 is 0.500-in. and the minimum thickness in this weld area was 0.467-in. The nominal thickness in Plate #3 is 0.500-in. and the minimum thickness in this weld area was 0.450-in. The nominal thickness in Plate #5 is 0.875-in. and the minimum thickness in this weld area was 0.824-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, and #5.
- The nominal thickness in Plate #4 is 0.750-in. Plate 4 indicates one area with a minimum thickness of 0.656-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 #4.

The HAZ of the horizontal weld between Plate #2 and Plate #3 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 areas with nominal thickness of 0.500-in. was 0.455-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 #2 side or Plate #3 side of the horizontal weld.

7.3 Primary Tank Wall Knuckle Scan Paths

The upper portion of the knuckle area was scanned utilizing the Y-arm scanner attached to the AWS-5D crawler. The Y-arm scanned the transducers down around the knuckle approximately 9-in. (from a starting position 2-in. down) from the upper knuckle weld joining Plate #5 to the knuckle. The knuckle was examined for wall thinning, pitting, and cracks oriented circumferentially around the primary tank. The results indicated that the minimum thickness in the approximately 3 circumferential feet of knuckle area examined with nominal thickness of 0.875-in. was 0.792-in. There were no areas that exceeded the reportable level of 10% of the nominal thickness. No pitting or circumferentially oriented crack-like indications were detected in the upper portion of the knuckle area.

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 as-built wall thickness per plate/riser combination. These thicknesses tend to run about 0.030-in. to 0.040-in. greater than drawing nominal for most tanks being considered in this manner, so these larger values are used as in improved estimate of original tank thickness. However, they are much less for Tank 241-AY-102, with some indeed being quite close to drawing nominal. These estimated nominal values were in turn 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 UT measurement paths per riser.

Three parameter Weibull distributions were fit to the plate course measurements as well as to the measurements combined over all plates. For previously examined tanks (Tank 241-AN-107 and Tank 241-AW-103), grouping the measurements over all pates could be reasonably be justified. This is not the case for Tank 241-AY-102. For this reason it is difficult to identify an appropriate worst case maximum wall loss for the tank, especially for Plate #5, the lowest considered in the study. When only minimal amounts of data are available within plate courses (as is the case for Plate #5), the estimated extreme values and related confidence bounds can become quite large and conservative. Alternative plate groupings are examined for Tank 241-AY-102 with extreme values computed that might be expected if the entire surface area of the tank wall for the particular plate combinations were UT inspected.

In all cases considered 95% confidence bounds are 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. Such losses are larger for Tank 241-AY-102 compared to other tanks similarly studied. Note that the losses characterized here should be considered relative to the somewhat larger “estimated” nominal wall thicknesses and not the drawing nominal when the drawing nominal is exceeded by the estimated maximum value.

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