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REMOTE INSPECTION OF A HIGH LEVEL RADIOACTIVE WASTE STORAGE TANK FOR CRACKING, THINNING, AND PITTING

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ABSTRACT

Several of the high level radioactive waste storage tanks at the Savannah River Site (SRS) have been in service nearly 50 years. Periodic visual and ultrasonic (UT) nondestructive examinations (NDE) have been performed on the tanks to monitor the effects of service. These inspections revealed that several of the older tanks had suffered cracking as detected by through-wall visual indications. A new UT in-service inspection program has been recently established to provide for detection and characterization of cracking, thinning, or pitting of the sidewalls of the waste tanks. The program specifies examination of regions of the tank that would be most susceptible to corrosion attack, and to characterize the flaws and demonstrate acceptance to protect against potential leakage and instability. This paper summarizes the implementation of the program and inspection results for a tank that has been in service for over 40 years.

No indications of reportable wall loss or pitting were detected. All thickness readings were above minimum design thickness. Several small indications of thinning were detected. The crack detection and sizing examinations detected five previously undetected indications, four of which were only partially through wall. The lengths of cracks that were examined are slightly longer than expected, but well below instability lengths.

INTRODUCTION

This paper provides a description of the ultrasonic (UT) nondestructive examinations (NDE) and the results of the examinations, performed on a high level waste (HLW) storage tank at the Savannah River Site that has been in service for 46 years. These inspections were performed in accordance with the site "In-Service Inspection (ISI) Program for High Level Waste Tanks" [1]. The ISI Program for HLW Tanks was developed using the "Guidelines for Tank Structural Integrity Programs" [2] for waste tank in-service inspection programs as a guide.

The inspections were performed from the contaminated, 30-inch wide annular space of the inactive, 1.03 million gallon waste storage tank. A steerable, magnetic wheel wall crawler was used to simultaneously collect data with up to 4 UT transducers and 2 cameras.

The purpose of this inspection was to verify known corrosion models and to investigate the possibility of previously unidentified corrosion mechanisms. The inspections included evaluation of previously identified leak sites as well as thickness mapping and crack detection scans on specified areas of the tank covering welds and all past and present interface levels.

A companion paper [3] provides a detailed service history of the inspected tank, and evaluates the inspection results in comparison with corrosion mechanisms, including the effects of weld residual stresses.

Tank Design

Figure 1 shows a schematic of the type of waste tank inspected. A summary of the tank features are as follows:

- Constructed – 1955 through 1956, Entered high level waste storage service in 1960.
- Capacity – 1,030,000 gallons
- Material – ASTM A285, Grade B Carbon Steel (Not stress relieved)
- Construction Code – ASME-52
- Five 5-foot steel secondary containment pan. Material

is A285, Grade B carbon steel

- Annulus Ventilation – Normally positive pressure (changed to negative during inspection)
- Annulus Access – Constructed with five inch carbon steel risers at the South, West, North and East annulus risers. Additional access provided through 6 inch diameter drilled inspection ports (IP). There are 12 IP's plus the four 5 inch risers spaced around the 267 foot circumference of the tank. The IP's are identified by the distance in feet from the South riser (see Figure 2)

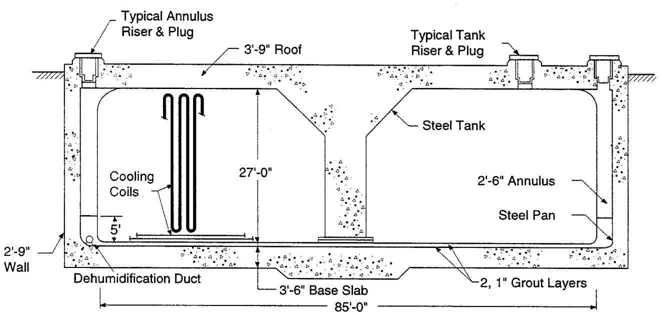

Figure 1: Type II High Level Waste Tank

NDE INSPECTION REQUIREMENTS

The ISI Program for HLW Tanks dictates the frequency and extent of the areas to be examined, as well as the damage mechanism(s) to be detected. The Program states: "[the specific tank] shall be inspected two times within a five-year time span to validate current degradation models. Known leak sites will be characterized in addition to the normal extent of examination. If leakage occurs in unexpected regions and unknown degradation mechanisms are suspected, additional inspections will be performed."

The ISI Program for HLW Tanks calls for the following regions of a HLW tank to be inspected:

- Liquid Vapor Interface
- Liquid Sludge Interface
- Upper Weld of Lower Knuckle of Primary Tank (5% of accessible circumference)
- Lower Knuckle Base Material
- External surface of primary tank (includes vapor space)
- Vertical and horizontal welds other than the lower knuckle weld (one vertical course section and 5% of middle horizontal weld)

These general requirements are further delineated in a tank-specific inspection plan. The tank-specific plan stipulated the following inspections specific to the primary wall:

1. Four vertical strips for the entire accessible height of the tank one each under riser IP55, IP107, IP182 and the East riser (see Figure 2).
2. 30 feet of middle horizontal weld between riser IP171 and IP207 (10% of circumference - additional 5% in lieu of 5% of upper weld of lower knuckle which was inaccessible due to tank geometry.)
3. Lower primary shell plate vertical weld below riser IP182
4. Five previously identified leak sites:
   - vertical weld at 53 feet, 200 inches above tank bottom
   - lower primary shell plate at 115 feet, 88 inches above tank bottom
   - middle horizontal weld at 172 feet
   - middle horizontal weld at 192 feet
   - middle horizontal weld at 207 feet

Figure 2 illustrates the approximate radial location of annulus access risers. Locations are in feet from the South riser. The North, South, East and West risers are 5 inch carbon steel pipe. The other inspection ports (IP) were added using a 6 inch diameter core drill.

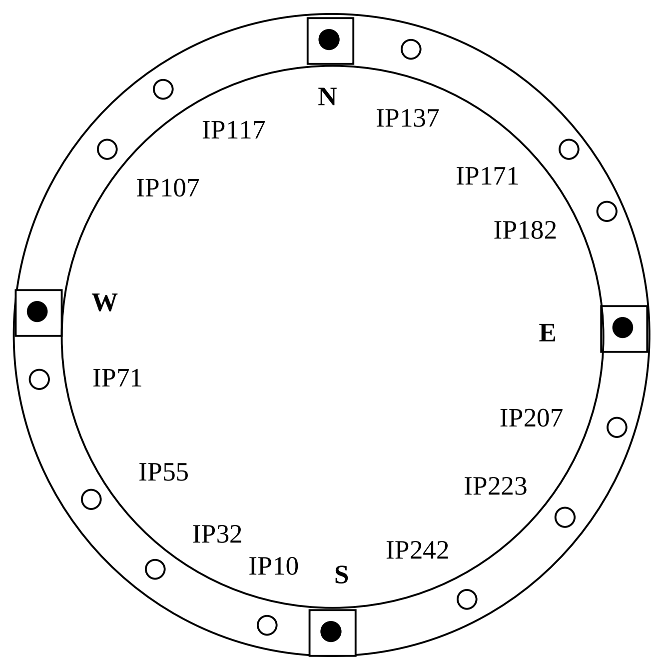

Figure 2 Tank Riser Layout Sketch

NDE TECHNIQUES

NDE inspection of the tank included remote automated ultrasonic inspection supplemented by remote visual inspection. Inspection of the tank included the following techniques which are described in this section:

1. Thickness Mapping
2. Weld Inspection/Crack Detection

3. Ultrasonic Flaw Sizing
4. Through Wall Bleed-out

Inspection Equipment

All ultrasonic inspections were performed utilizing the P-scan, automated ultrasonic system and remotely operated magnetic wheel scanner known as the wall crawler. The prescribed regions were inspected utilizing two basic data collection techniques:

1. Vertical Strips – base material thickness mapping and crack detection scans, and
2. Weld Inspection - scans of weld and heat affected zones to detect and characterize cracking oriented parallel and/or perpendicular to the weld seam.

Ultrasonic System. The UT system utilized for these inspections was the FORCE Technology, P-scan, PS4-Lite, automated, ultrasonic system. This system is capable of performing inspections with multiple transducers and techniques simultaneously.

The PS4-Lite is basically the same as the PS4, except that it can not operate more than 4 transducers simultaneously. It is capable of performing thickness mapping, weld inspection and A-scan recording all at the same time. During tank inspections it was used to operate 2 angle beam and 1 thickness mapping transducer or 4 angle beam probes simultaneously.

The PS4Lite is operated through a laptop computer as the user interface (Figure 3). The system also controls the wall crawler.

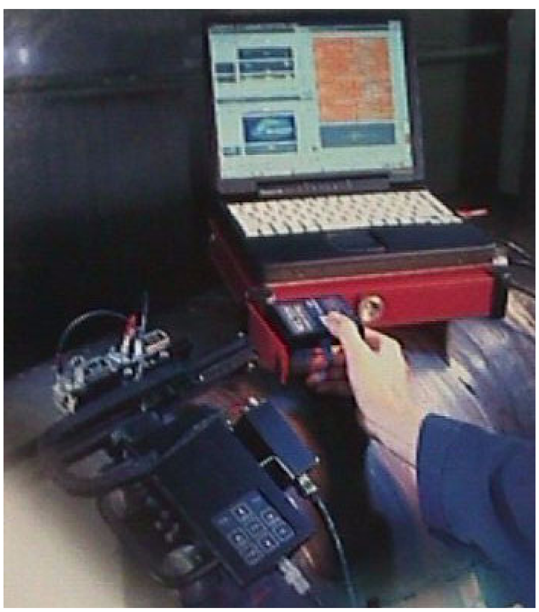

Figure 3 PS4-Lite

Wall Crawler. The wall crawler (Figure 4) is a commercially available, FORCE Technology, P-scan, AMS-1T crawler. The crawler is attached to the steel tank wall by the strong, permanent magnetic wheels.

The crawler is capable of being installed through a five inch carbon steel riser. It can scan with up to 4 transducers. The wall crawler is typically outfitted with a remote control pan and tilt camera system with auxiliary lighting.

The wall crawler included a pneumatically activated camera boom arm to lift the pan and tilt camera about 10 inches off the surface. It also has pneumatic lifting feet to de-couple it from the tank wall to allow removal from the annulus.

Figure 4 P-scan AMS-1T Wall Crawler

Procedure and Equipment Qualification

The ISI Program for HLW Tanks states that the UT system (instrument, transducer, scanning device, and cables) shall have the following detection capabilities (tested at ½ inch nominal thickness of the tank sidewall plate):

1. General corrosion/thinning detection greater than 0.020 inch.
2. Pitting detection (elliptical or hemispherical) greater than 0.050 inch depth.
3. Crack depth detection greater than 0.100 inch, $\geq$ 0.5 inch long. In the absence of an acceptable cracked sample, a machined notch 0.05 inch deep x 1 inch long can be used instead of a crack for qualification.

The procedures and equipment easily met the above requirements [4].

Thickness Mapping

Thickness mapping includes wall thickness measurement as well as the detection and sizing of corrosion, pitting, and liquid-air interface attack. Thickness mapping was performed in four vertical strips. Individual vertical strips were 8.5 inches wide so the combined width of all 4 strips provided coverage of 1% of the circumference of the tank. Thickness mapping data was collected over the entire accessible height of the tank to ensure coverage of all areas and environments in the tank. By collecting data in a continuous strip from top to bottom, all present and historic interface levels are examined as well as the vapor space of the tank.

Thickness mapping data was collected utilizing the PS4 Lite automated ultrasonic system. The "T-scan" thickness mapping program was utilized to provide color-coded thickness plots from the top, side and end views. This data was collected utilizing a dual element, 0 degree, longitudinal wave transducer (Krautkramer DA301) operating at 5 MHz.

Weld Inspection and Crack Detection

Weld Inspection and crack detection were performed with the same ultrasonic system utilizing the "P-scan" amplitude based weld inspection software. Crack detection was performed utilizing single element, 45 degree shear wave transducers (Krautkramer MWB-45-4E) operating at 4 MHz. This technique was incorporated into the thickness mapping vertical strips and was utilized to examine welds for cracking oriented parallel and perpendicular to the weld seam.

Ultrasonic Flaw Sizing

When indications were detected with ultrasonic techniques, the extent of the indications were measured or "sized". The location and length/width in the X and Y directions were determined based on where the indication was discernable from the background noise or thickness.

1. Pitting indications were reported based on remaining, sound, metal (ligament) above the pit. The depth of any pit indications was determined by subtracting the minimum thickness reading obtained from the pit from the thickness of the area adjacent to the pit.
2. Cracking lengths were reported to the point(s) where the indication was no longer discernable from the noise. Crack depths were determined utilizing planar flaw sizing techniques. Utilizing the same transducer(s) that were used for detection, the amplitude was adjusted to locate the deepest point on the crack. When indications were less than 100 percent through wall, a measurement of the remaining metal (ligament) was made utilizing the Absolute Arrival Time Technique (AATT). AATT is a planar flaw sizing technique, used throughout industry that provides a direct reading of depth to the crack tip.

Through-Wall Bleed-Out

Through-wall bleed-out is the term being used to describe the field implemented variation of a liquid penetrant surface inspection technique. It was noted that the water being used for UT couplant, would penetrate (through capillary action) surface cracks. Due to the elevated temperature of the tank wall (~120 degrees F), the wetted surface would dry after a few minutes. Where there was a crack open to the exterior surface, the water drawn into the crack would then bleed out providing a high contrast image of the open crack. Video cameras were utilized to view these indications and make crude measurements of length as the crawler was driven along the indication(s). Figure 5 shows an example of the video image of the bleed-out region.

Figure 5: Example of Through-Wall Bleed-Out

NDE DATA COLLECTION

Personnel

Nondestructive examination data was collected and analyzed by certified NDE personnel from SRS, including James B. Elder, ASNT Level III UT, Richard Holland and Rodney Vande Kamp both certified Level II UT.

Field Conditions

Inspections were performed from the annular space of the high level waste tank. The wall crawler and cameras were installed in the annulus and operated from the NDE control trailer (see Figure 6) which was up to 200 feet from the riser. Access to the annulus was through inspection ports or risers (see Figure 7) inside contamination control huts. These risers are approximately four feet long and are either five inch carbon steel pipe or six inch diameter concrete holes. All UT inspections were performed by inserting the wall crawler through the six inch concrete risers. Remote pan & tilt cameras were also inserted into the annulus to monitor crawler movement. The tank has a history of through wall leaks, therefore the annulus is contaminated. The tank ventilation was shut down and auxiliary ventilation (MAC-21) was installed to provide negative pressure ventilation during the inspections. Huts were set up around each riser that was used for crawler access to provide contamination control. In addition to the huts and ventilation, respiratory protection was typically required during crawler installation, removal and maintenance activities.

Figure 6 NDE Control Trailer and Generator

Figure 7 Typical Inspection Port / 5- 6 Inch Riser

Inspection Areas

All of the required inspections were performed by deploying the crawler through three risers. UT inspections were performed with the wall crawler in riser IP55, IP 107 and riser IP 182.

NDE RESULTS

All inspection data was analyzed by certified NDE level III personnel.

Summary of Inspection Results

The inspected tank was not stress relieved and had a history of Stress Corrosion Cracking (SCC) with 18 previously identified leak sites [5]. The tank is presently an inactive tank.

Cracking/Leak Sites. Several leak sites were selected to be ultrasonically evaluated to determine the length, depth and contributing factors e.g., weld attachments, weld beads, etc.). These indications are scheduled for re-inspection in five years to look for any changes and to evaluate crack growth.

Maximum crack lengths were determined to be longer than previously expected but still well within the established critical crack lengths at the crack locations [3].

Thickness Mapping. Thickness mapping was performed on 1% of the circumference of the tank for the entire accessible height of the tank (see Figure 8). These thickness mapping examinations were performed to detect and measure any general wall loss, pitting or interface attack in all regions of the tank including the vapor space. No reportable wall loss or pitting was detected.

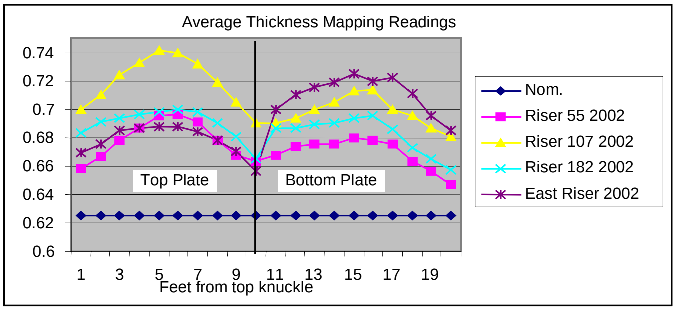

Figure 8 Average Thickness Summary Plot

Vertical Strip Results

Vertical Strip. Inspections the tank through riser IP 55 included one vertical strip for the entire accessible height of the tank. No reportable areas were detected in the vertical strip. The minimum thickness detected in the upper and lower plates are above nominal thickness. The minimum thickness detected in the upper plate was 0.639 inch and is near the edge of the plate toward the middle weld. The minimum thickness detected in the lower plate was 0.632 inch. This minimum thickness area is a 0.25 x 0.40 x 0.030 inch deep indication approximately 2.5 inches from the middle weld. The minimum thickness at the bottom of the same plate is 0.634 inch. The indication, inside the black circles on Figure 9, was approximately 0.030 inch deep. The results also show the plates to be thinner at the edges. There are several noise spikes shown in the side and end views. These noise indications were evaluated and determined to be non-relevant. No Crack-like indications were detected in this strip.

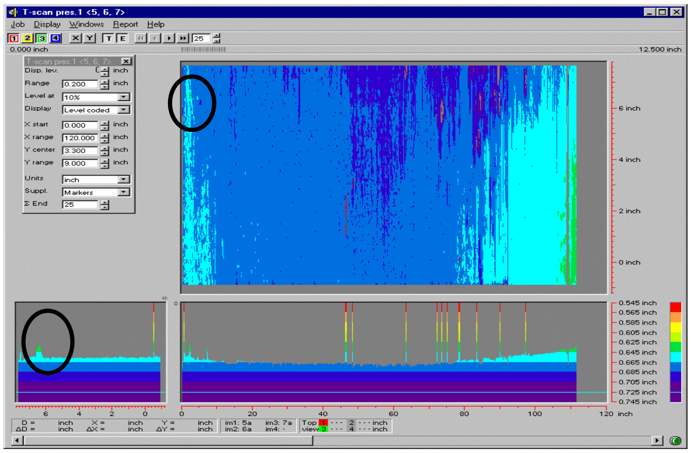

Figure 9 Thickness Mapping Image of Lower Plate, Riser 55

Previous Indication Investigation

Previous Indication Investigation. One previously identified indication in the upper plate vertical weld at approximately 53 feet was also examined under riser IP55. The indication was observed at 200 inches above the tank bottom. Due to the high weld profile and limited time and the fact that the examination of this leak site was not a requirement of the inspection scope, the indication was only examined from one side of the vertical weld. The examinations were performed on the side of the weld opposite the riser. The crack was confirmed to be through wall, but also had a partial through wall segment. Measuring the indication on the right side only, the through wall portion was 1.4 inches. The total length was 3.7 inches on that side of the weld. Figure 10 shows some of the UT data from this indication.

A picture of the indication, rotated to the same orientation as the P-scan data is shown in Figure 11. The image is rotated 180 degrees (up-side down). The vertical weld edges are marked on the image. Only the part of the indication on the left side of the picture was scanned (Right side of weld looking at tank). The through wall portion of that crack which is visible in the picture is represented by the blue portion of the P-scan data in Figure 10. The yellow and green portions of the P-scan image indicate the part of the crack that is only partially through wall.

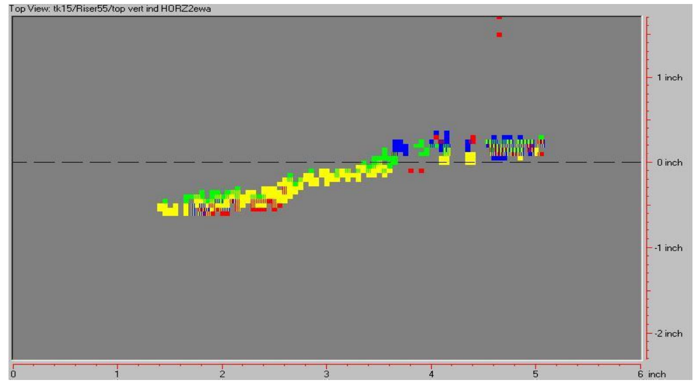

Figure 10 P-scan Data of Crack in Upper Plate Vertical Weld, Riser 55

Figure 11 Visual Image of Crack in Upper Plate Vertical Weld, Riser 55

Weld Inspection Results

Vertical Weld. The following is a summary of the indications detected in the lower plate vertical weld. The through wall indication (see Figure 12) measured 4.5 inches total length. The photograph overlay is from a liquid penetrant inspection performed on a similar tank in 1962. The recently detected crack is nearly identical to the crack from 1962.

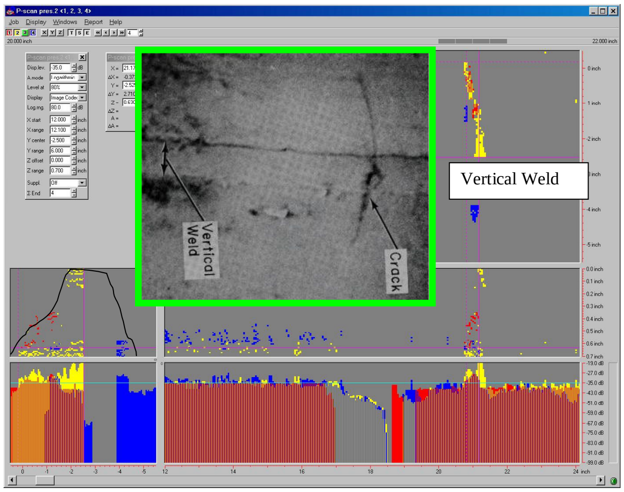

Figure 12 Image of Perpendicular Crack With Liquid Penetrant Results Overlay

Middle Horizontal Weld. Middle Horizontal Weld - Approximately 33 feet of the middle horizontal weld was examined for horizontal and vertical cracking. The middle horizontal weld was examined in three sections, as noted:
From 171 to 180 feet
From 183 to 195 feet
From 196 to 208 feet

Previously identified leak sites on the middle weld were also examined as follows:

Leak Site at 192 feet, Middle Horizontal Weld. The leak site at 192 feet is a horizontal/arched crack in lower plate at a weld repair location (see Figure 13). The through-wall portion (verified visually with bleed-out technique) of this crack was measured ultrasonically to be 10.2 inches. The indication is arch shaped around a weld repair region in the horizontal weld. The weld repair area appears to be approximately 8 inches long and centered on the through-wall portion of the crack. The total length of the indication was measured at 18.1 inches. As shown in Figure 14, this indication is longer at the inside surface than on the outside.

Figure 13 As-Found and Bleed-out Image of Crack at 192 feet, Middle Horizontal Weld

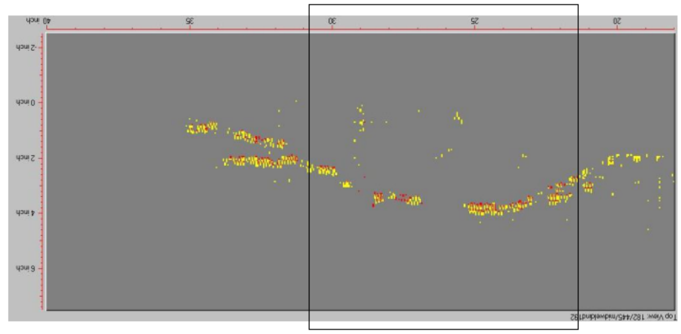

Figure 14 P-scan Image of Crack at 192 feet, Middle Horizontal Weld. The through wall part of crack shown in boxed area. The P-scan image has been rotated to same orientation as the visual image in Figure 14.

CONCLUSIONS

A new UT in-service inspection program for high level waste tanks at the Savannah River Site has been implemented. The inspection details, and the results from the inspection of a specific tank that has been in service for over 40 years, have been summarized.

No indications of reportable wall loss or pitting were detected. All thickness readings were above minimum design thickness. Several small indications of thinning were detected. The crack detection and sizing examinations detected five previously undetected indications, four of which were only partially through wall. The lengths of cracks that were examined are slightly longer than expected, but well below instability lengths.

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