Technical Evaluation Report
Review of Ultrasonic Data for Flaws Detected at Duane Arnold Energy Center, Unit 1
JCN-J3218, Task 6, TAC MD4630
June 18, 2007

## 1.0 BACKGROUND

During a recent refueling outage (February 2007) at Duane Arnold Energy Center (DAEC), Unit 1, the licensee, FPL Energy, detected circumferentially-oriented ultrasonic indications emanating from the inside surface in two recirculation riser safe end-to-nozzle dissimilar metal welds (Weld RRF-F002 on nozzle N2F and Weld RRC-F002 on nozzle N2C). The indications were characterized as being inter-granular stress corrosion cracks (IGSCC) and exhibited significant through-wall depths on the order of 50-70%. The safe ends are Alloy 600 and are welded with Alloy 82/182 to the SA-508 Class 2 carbon steel reactor pressure vessel nozzles. The carbon steel nozzles are buttered with Alloy 182 weld metal.

Previous ultrasonic testing (UT) examinations were conducted on Nozzle N2F in 1996, 1999, and 2005, yet these inspections failed to identify the cracks detected in 2007. The licensee, upon review of previous UT data, contends that these cracks were detectable in the 1999 and 2005 data, but that complications associated with weld crown geometry and UT coupling issues caused the indications to be overlooked. The licensee engaged UT experts from the Electric Power Research Institute (EPRI) to review the previous and most recent data, and a report[1] was issued which confirmed that the indications were present in the 1999 and 2005 data.

## 2.0 OBJECTIVE

Based on re-evaluations by the licensee and EPRI that the cracks are believed to be IGSCC and present in the UT data since 1999, the examinations performed prior to 2007 apparently failed to identify this degradation. The NRC requested that nondestructive examination (NDE) experts from the Pacific Northwest National laboratory (PNNL) review the UT data from 1999, 2005 and 2007, provide an independent assessment of the indications observed, and assess the effectiveness of previous and most recent examinations. In particular, the NRC requested that PNNL address the following issues:

i. Whether the flaws observed in 2007 were present in the prior UT data,

ii. Whether the indications should have been identified in inspections prior to 2007 (i.e., a personnel performance deficiency or whether these indications would not typically be identified due to the nature of the signals - that is, a threshold of detection/probability of detection issue),

iii. Possible causes (i.e., weld crown interference, lift off, etc.), to the extent practical, for why the indications were not identified during inspections prior to 2007 (if, in fact, they were present),

iv. For each of these possible causes identified above, discuss whether the inspector/licensee should have identified the cause at the time of inspection and taken corrective action,

v. Any additional guidance or procedural modifications warranted to prevent similar

issues in the future by this, or other, licensees (i.e., assess the extent to which these issues could be generic),

vi. Flaw length/depth profile determined for each of the inspections in which the flaws were detectable,

vii. Describe the NDE methods used for the examinations, and

viii. Discuss any shortcomings, limitations, assumptions, inconsistencies and reliability aspects associated with the NDE methods or ASME Code requirements.

## 3.0 UT DATA REVIEW AND EVALUATION

Data sets from the 1999 examinations performed by General Electric (GE), and the 2005 and 2007 examinations, both performed by Lambert, McGill, Thomas, Incorporated (LMT, Inc.), were reviewed to assess the overall quality of data and determine whether ultrasonic responses should have reasonably been correctly reported as flaws, geometrical indications, or of metallurgical origin. The evaluation of these data sets is reported separately below. The data from the 1996 examinations performed by GE were not provided or reviewed due to limited examination coverage in the area of the reported flaw.

### 3.1 1999 Examinations

Automated examinations were performed with conventional UT transducers having interrogation angles of 45, 60, and 70 degrees and were applied from both the nozzle (downstream) and safe end (upstream) side of Welds RRC-F002 and RRF-F002 using GE Procedure GE-UT-209V7[2], Revision DRR#DAEC-99-04, October 21, 1999. Mechanical raster scanning was the method used to insonify the material volumes of interest, however, the weld crowns remained in place, which severely limited access for transducer movement toward the weld centerline. In fact, transducers were unable to scan from the weld centerline to approximately 1.1-inch on either side of the weld due to the presence of these weld crowns. This significantly impacted the ability of the UT analysts to characterize reflectors that were located near the weld root. In addition, the GE procedure used at this time (which is indicative of most other examinations performed prior to performance demonstration) based flaw detection on reflectors having amplitudes that exceeded a threshold, or distance-amplitude-compensation (DAC) curve, that was established by using responses from machined reflectors in a calibration block. Since the scanning areas were limited by the weld crowns, several reflectors could not be adequately peaked, and therefore, may not have been correctly identified, as they would not have crossed the reporting threshold and could not be confirmed to have an echo-dynamic envelope indicative of a potential flaw. This vendor also acquired “skewed” data sets, or UT data taken at slightly off-normal angles to the weld, but these showed poor axial resolution and lack of coupling along the length of the weld, which rendered the data unusable.

As can be seen from the data in Figure 1, a corner-trap reflector is observed near the inner diameter (ID) surface, but cannot be peaked because of weld crown interference, i.e., the signal appears very near the edge of the scan image. This data has been taken from the safe end side of weld RRC-F002, and the potential flaw response is approximately 11-inches long, located between the 14- and 25-inch circumferential position (centered near the 5:00-6:00 position on the pipe; or near the bottom, as the scans were started at top dead center). Very low amplitude, potential crack-tip responses can be observed in the images, and the deepest

penetration shows approximately 0.32-inch of remaining unflawed material. Given that the safe end is approximately 1.1-inches thick, this flaw is estimated to be around 70% through-wall at the time of the 1999 examination. From the original vendor's report, this indication was characterized as either an ID surface geometrical reflector [using a 45-degree refracted longitudinal (RL) probe] or a weld root signal (using the 60-degree RL probe). Furthermore, there appears to be deep tip-diffracted signals in the data, which should have prompted the analysts to have been more cautious in their interpretation of this UT response.

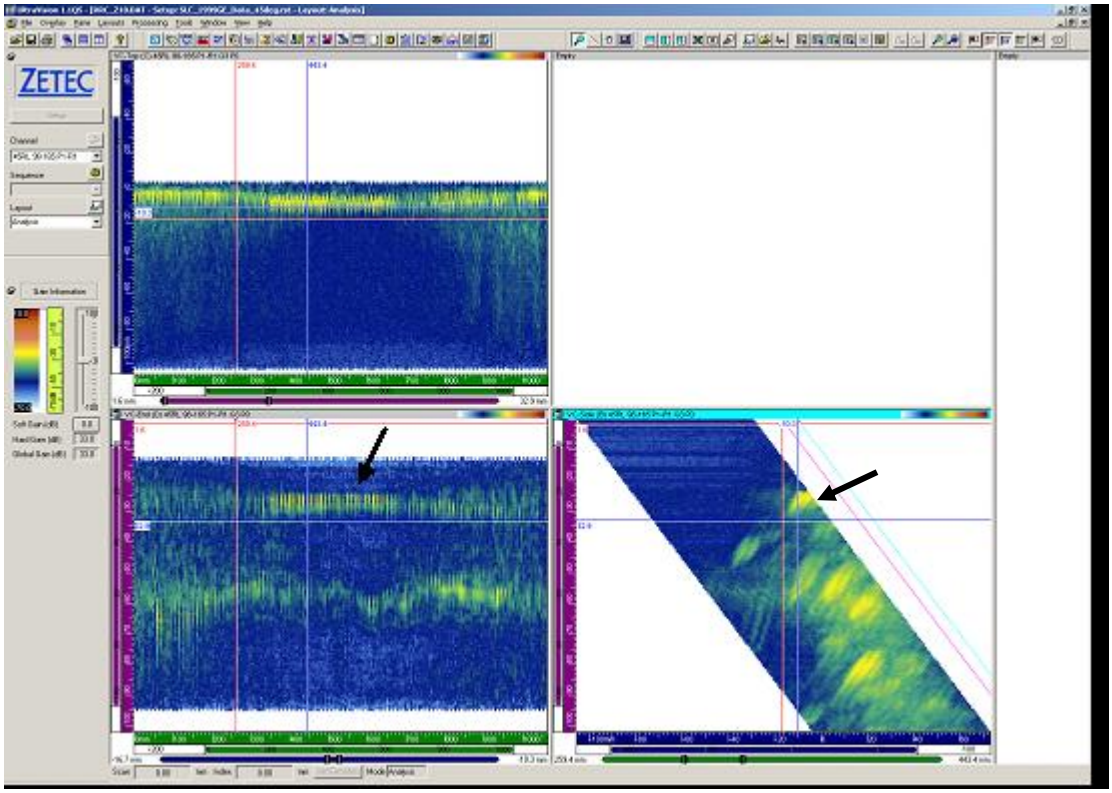


**Figure 1 Weld RRC-F002, 60-degree RL showing corner-trap reflections for 70% through-wall flaw at edge of data.**

Data from weld RRF-F002 show similar results. Figure 2 displays imaging from a 60-degree RL scan performed from the safe end side of this weld. Again, the response is located very near the edge of the data set, which does not allow it to be peaked due to the interference from the weld crown. However, the flaw appears ID-connected, is located at the 5.5 to 10.2-inch circumferential location (or about 4.7-inches in length), and is approximately 54% through-wall, based on tip-diffracted responses. Note that this flaw was reported by GE as ID geometry and this circumferential location does not correlate with the large flaw observed in later examinations. In fact, the larger flaw, detected in 2005 and 2007, and located from approximately 17-24 inches from top dead center, could not be adequately imaged in the 1999 data due to the weld crown interference. However, possible crack tip responses were detectable in this region, which indicates the flaw was present at this time.

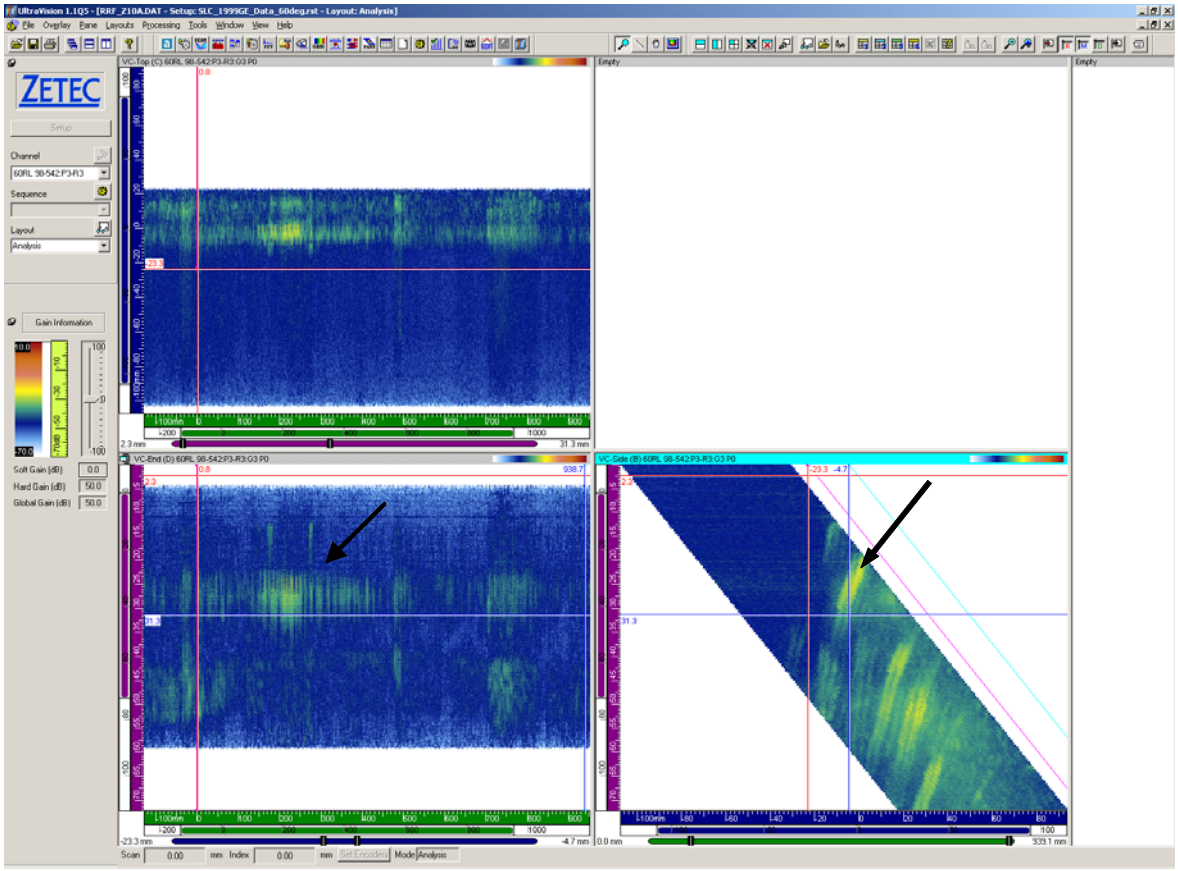


**Figure 2  RRF-F002, 60-degree RL from upstream (safe end) side of weld; arrows show potential 54% through-wall flaw response located near edge of data.**

## 3.2 2005 Examinations

Examinations performed in 2005 were completed by the vendor using LMT, Inc. Procedure UT-103, Revision 2[3], (March 28, 2005) which employed an automated scanner and a DOS-based in-house software package (ADAMS PLUS system). The weld crowns had been removed prior to the 2005 examinations. However, in general, this data is of poor quality in that it has very low signal-to-noise and inconsistent responses throughout the circumferential scans. The vendor applied 40, 45 and 60-degree RL sound beams, but used a gel-type couplant which can cause problems for automated devices. Most of these gel-types are water-based couplants and can "gum" up on the transducer wedge, which may not allow adequate coupling to occur during certain raster movements. In addition, LMT, Inc. chose to collect data in both the forward and reverse raster motions, which can save scanning time, but can also result in signal loss due to different mechanical pressures, and wiping of couplant from the surface, that usually occur during forward and reverse motions. Finally, the in-house software is DOS-based and not very user friendly for imaging and viewing of data. Limitations in this software inhibit thorough investigation of geometrical and flaw responses, and pixilation of the images does not provide adequate resolution for depth-sizing, and in some cases, for determining accurate spatial positions of responses. This can make distinguishing cracks from geometrical reflectors very challenging. Nevertheless, PNNL was able to identify the potentially flawed area of Weld RRF-F002 (no data for Weld RRC-F002 was acquired in 2005). This flaw is shown in Figures 3 and

4 from the 45-degree RL data set. The flaw indication has intermittent response along its length and appears to be roughly 10-11-inches in total length.

No through-wall information could be readily obtained from the 2005 data set. However, this flaw is located in the same approximate position as was shown in the 2007 data, which was sized to be approximately 54% through-wall. It should be noted that the 2005 data does not mimic the 1999 images for this flaw; it is unclear whether scanning apparatus, coupling issues, or positional differences caused this discrepancy. However, the analysts should have required re- scanning in this area so that a proper characterization could be made, albeit the data acquisition and imaging software may have been somewhat difficult to use and interpret.

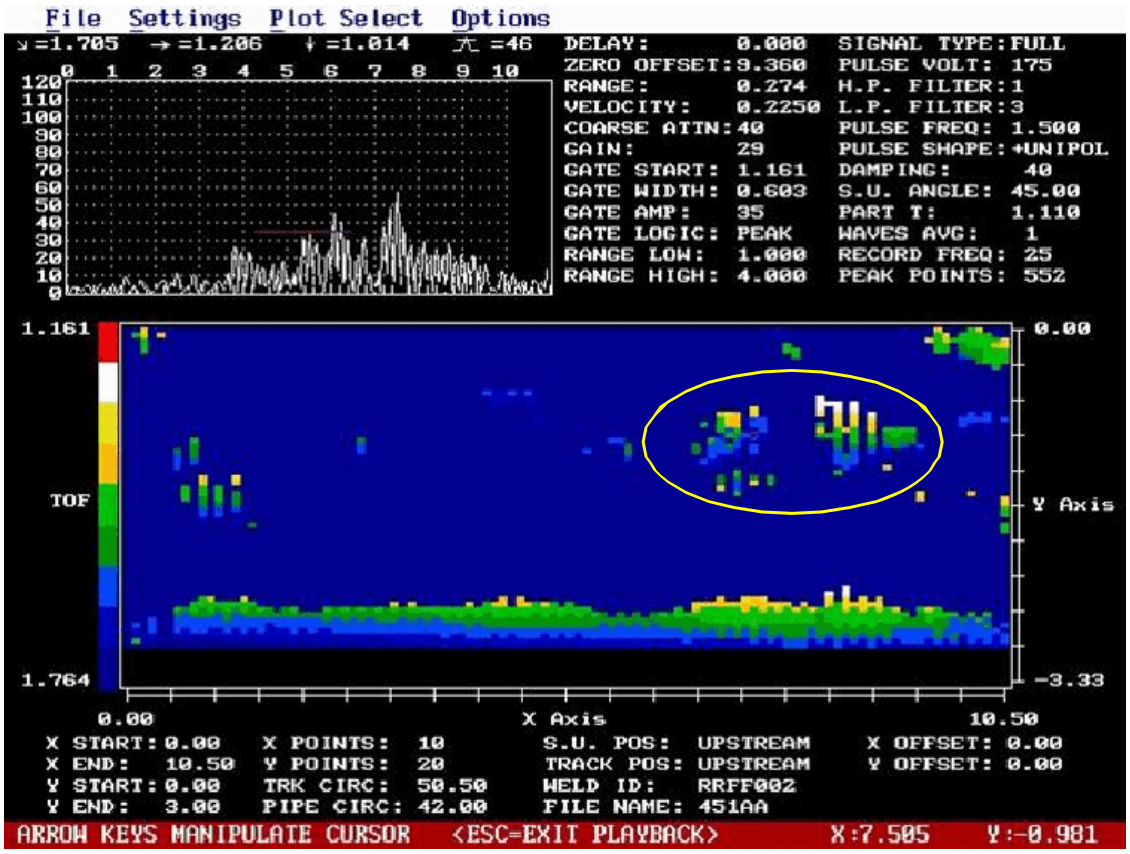


**Figure 3 Circumferential C-scan data on Weld RRF-F002 from 0 (top dead center) to 10.5-inches of scan length; scan was made from safe end side of the weld. Flaw response is shown in yellow ellipse.**

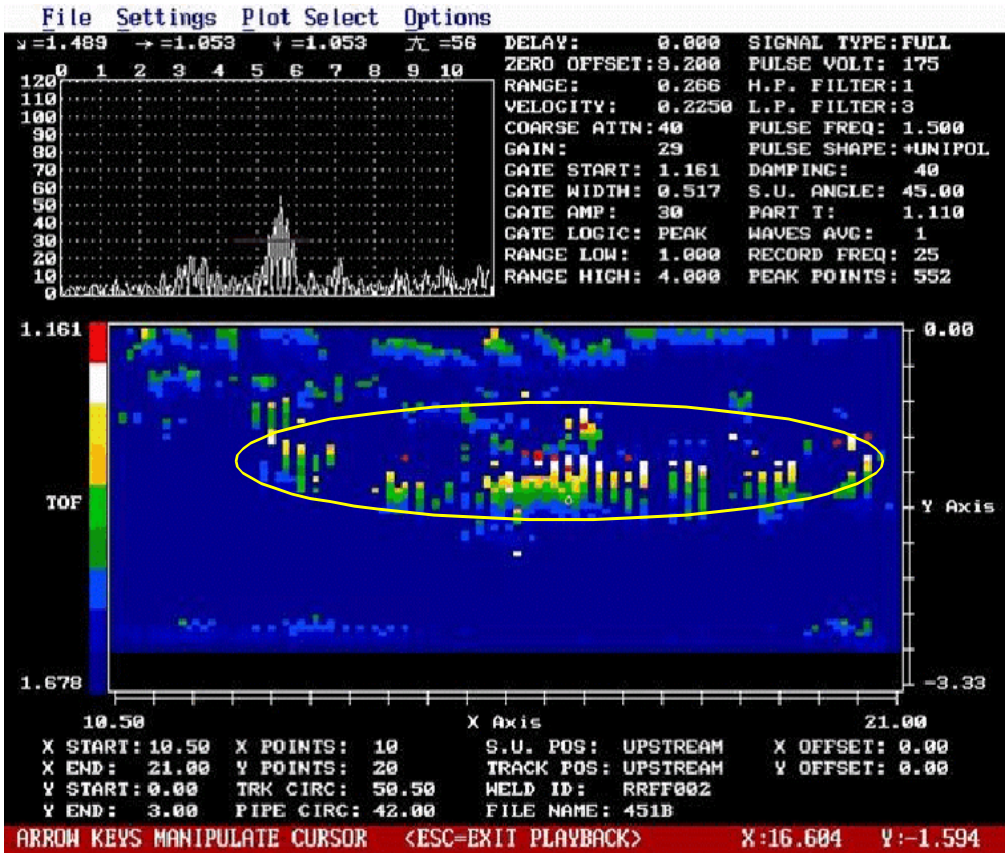


**Figure 4 Circumferential C-scan data on Weld RRF-F002 10.5 to 21 inches of scan length; scan was made from safe end side of weld. Flaw response is shown in yellow ellipse.**

## 3.3 2007 Examinations

The most recent examinations of Welds RRC-F002 and RRF-F002 were performed in 2007 by LMT, Inc. and consist of manually driven, encoded phased array data collected in accordance with Procedure Zetec OmniScanPA 03, Revision D[4] (January 25, 2007). This process is a type of manual/automated hybrid in that a scanning device with encoding was used to gather spatial information, while the attached phased array probe is moved around the pipe manually. The advantage of this set-up is that the inspector can feel the probe and its contact with the pipe surface, allowing one to know if areas of inadequate coupling due to surface irregularities or other problems are encountered. If inadequate contact is suspected, one simply re-scans the area and the data set is revised automatically. Of course, the disadvantage (as opposed to fully automated) is that the inspector must remain in close proximity to the weld, which may be in a high radiation field. However, given that phased array technology enables the inspections to proceed as line scans only, no raster scan movements are required, and the inspection time is greatly reduced. In fact, inspection times on the order of only a few minutes are normal for this size piping weld.

Phased array data was acquired from both the nozzle and safe end sides of these welds. The nozzle side data included 30, 45 and 60-degree RL, and the safe end was examined with 45, 60, and 70-degree RL, and 45 and 60-degree shear waves. The 2007 data is by far the most

explicit with very good signal-to-noise ratios and high resolution images. The arrays were designed to enable electronic raster scans for the separate sound beams, which allowed the inspector to only make single line passes adjacent to the weld. Of course, the weld crowns had been removed prior to these examinations, so access was not a problem.

Weld RRC-F002 displayed two distinct flaw-type responses; one that appears to be a surface-connected crack and roughly corresponds with the 1999 GE data, and another that is interpreted to be an embedded flaw probably associated with a welding fusion problem during fabrication. PNNL used a combination of data from both sides of the weld to size the crack response. Figures 5 and 6 show the ID-connected crack, as detected with 45 and 60 degree shear waves from the safe end side of the weld. Using tip diffraction methods (see Figure 7) the crack has been sized by PNNL to be approximately 74% through-wall.

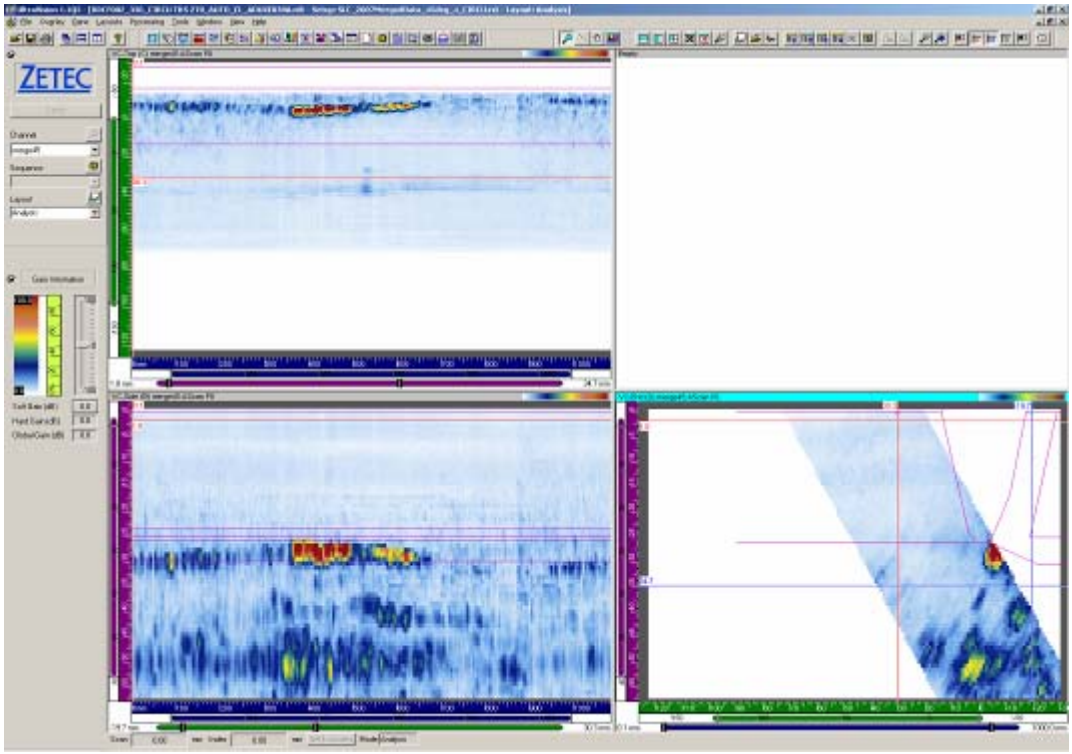


**Figure 5 Weld RRC-F002, 45-degree shear wave data from the safe end side; flaw response at 14 to 19.7-inch circumferential location. The weld profile has been superimposed on the B-scan image to indicate where the corner-trap flaw response is approximately located.**

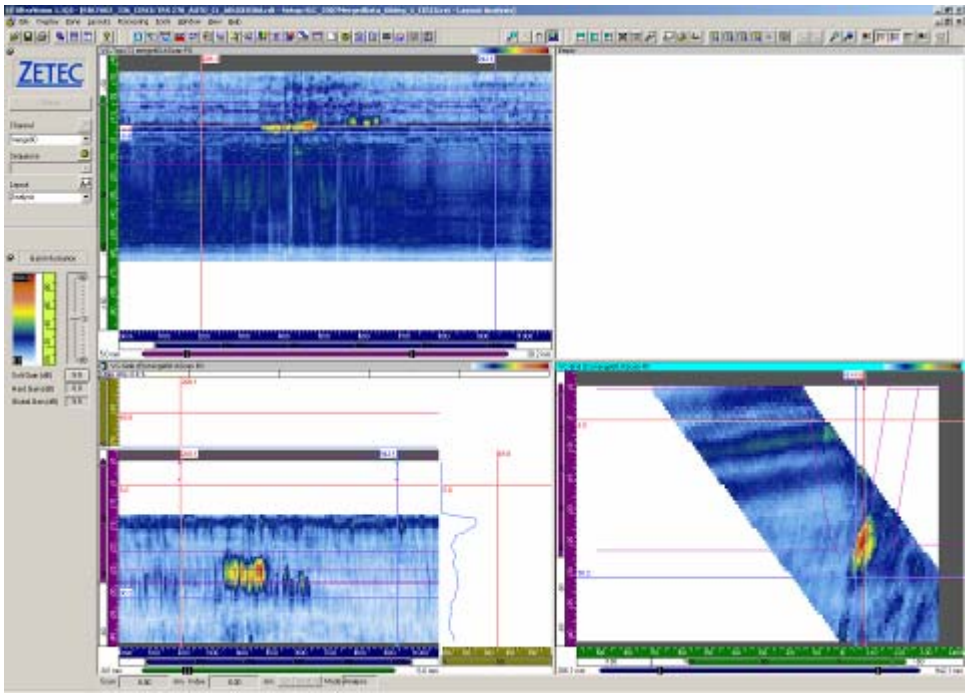


**Figure 6  Weld RRC-F002, 60-degree shear wave data from safe end; flaw response at 13.9 to 19.8-inch circumferential location.**

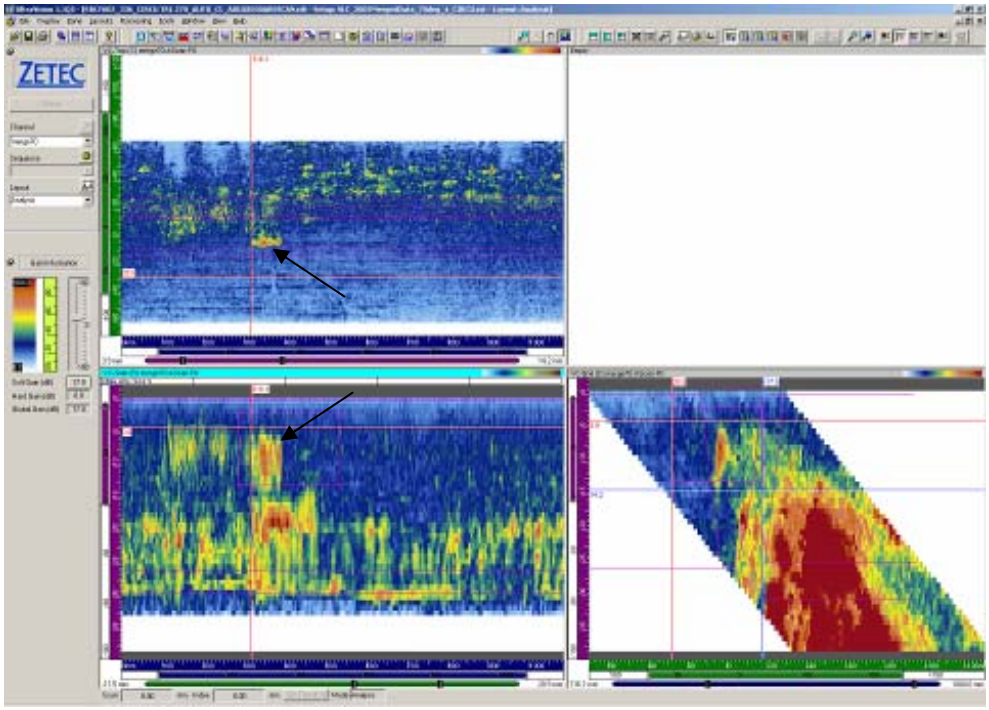


**Figure 7  Arrows point to the crack tip response from the flaw in Weld RRC-F002 showing remaining ligament of approximately 0.31-inch (8 mm).**

The embedded flaw is not as well-defined in the B- and C-scan images as the surface-connected crack, but is evident in several of the data sets from both sides of the weld. It appears to be approximately 6.8 inches in length and is located near mid-wall, extending to approximately 0.28-inches from the OD surface. This flaw is believed to be associated with the fusion area of the weld, and not service-induced, therefore only of limited interest to this investigation, and no images are included in the report.

Data sets from Weld RRF-F002 included the same type of propagation angles and wave modes as the previous weld. These data also have very good signal-to-noise that permitted high quality images and allowed fairly straightforward evaluation. This weld appears to have two surface-connected flaws; one that corresponds with the LMT, Inc. 2007 data, and another potential flaw that was only reported as lack of fusion by LMT, Inc. in 2007. It is of note that PNNL's review of the GE 1999 data did not identify the first flaw; however, this is probably due to the limited scan area available caused by the presence of the weld crown. Figures 8 and 9 contain UT displays of these two flaws.

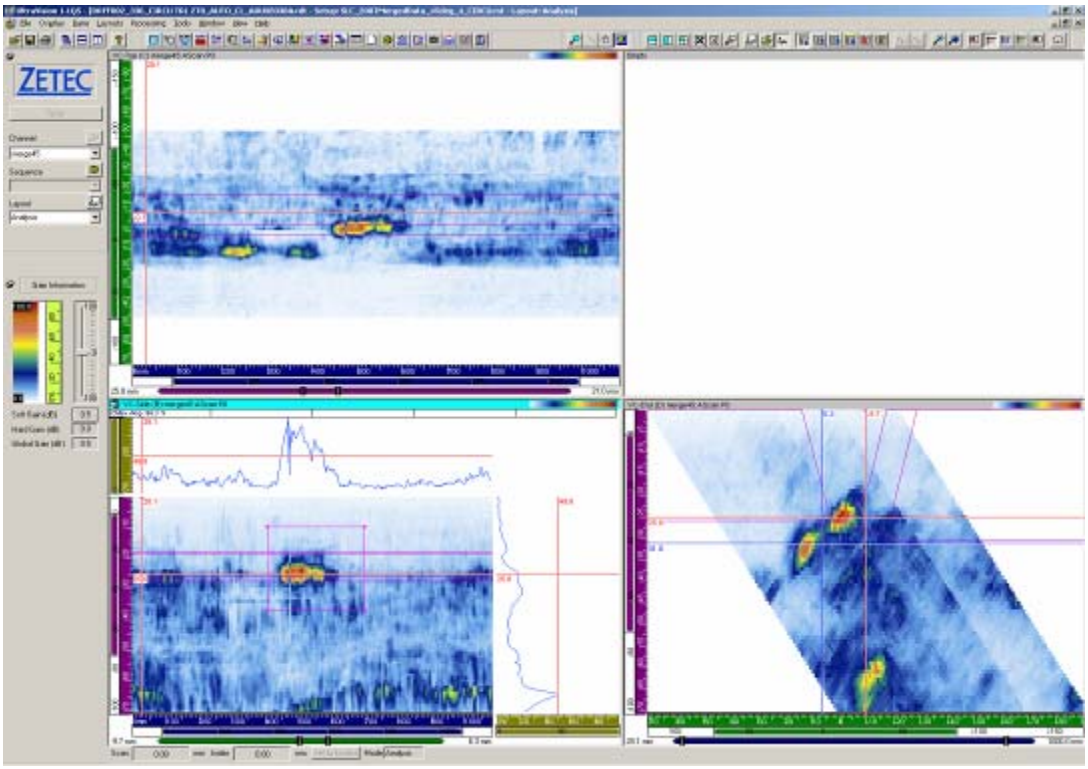


**Figure 8 Weld RRF-R002, 45-degree shear wave showing potential crack located at 17.2 to 24.4 inch circumferential location.**

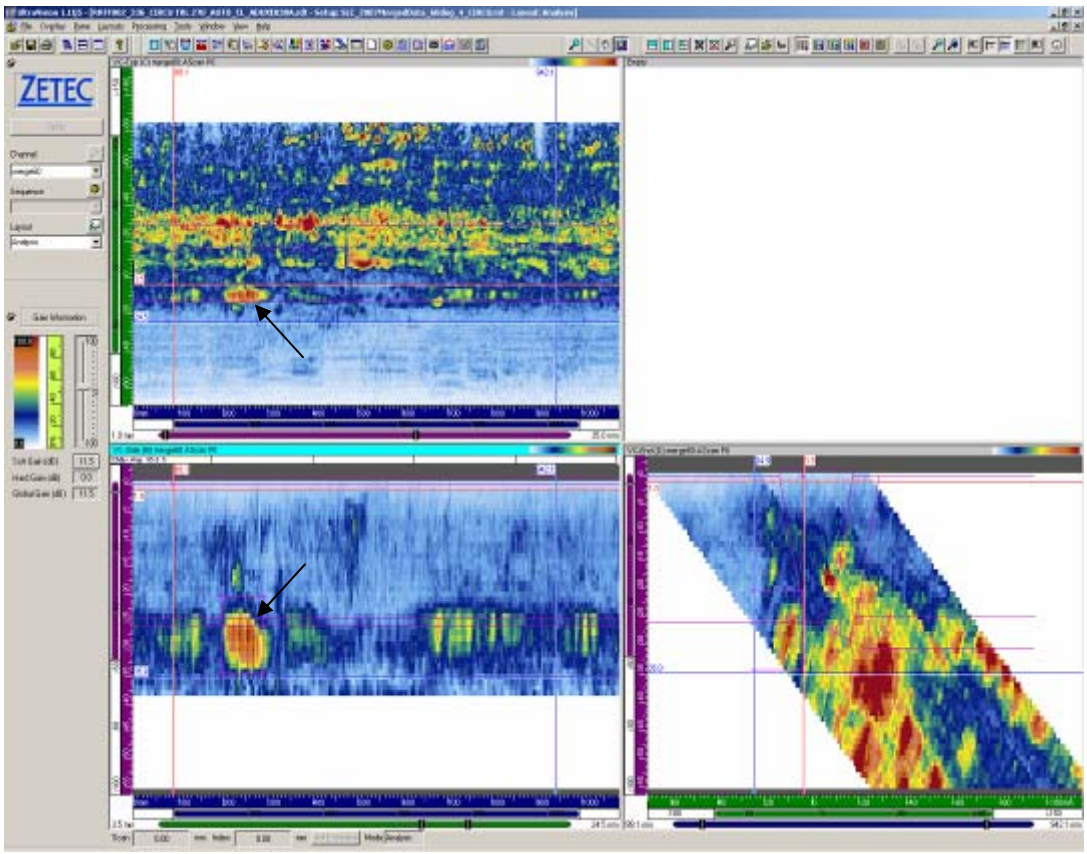


**Figure 9 Weld RRF-F002, 60-degree RL from safe end side; arrows show second ID-connected flaw reported as lack of fusion by LMT, Inc. in 2007.**

A graphical summary of the PNNL and LMT, Inc. detection calls for the data from 1999, 2005 and 2007, as applicable, are shown in Figures 10 and 11. As can be seen, the data correlate well for the crack indications, except that PNNL has length-sized these larger than was reported by LMT, Inc. This could simply be the end points chosen by the analysts, i.e., whether the response was sized down to the noise level, or a 50% amplitude drop method. The data also show an embedded flaw for Weld RRC-F002 that was not reported by LMT, Inc., and a second surface-connected flaw for Weld RRF-F002 that was characterized by LMT, Inc. to be lack of fusion. PNNL believes this second flaw may also potentially be a crack. An ID corner trap response is evident, and the signal appears generally the same as the reported crack. This potential crack is located from 8 to 12-inches circumferentially (approximate 4.0-inch length) from top dead center of the pipe, but no tip responses could be observed. This potential crack was not included within the length of the originally reported crack. In addition, Figure 11 shows the intermittent, poor quality responses from the 2005 data as well.

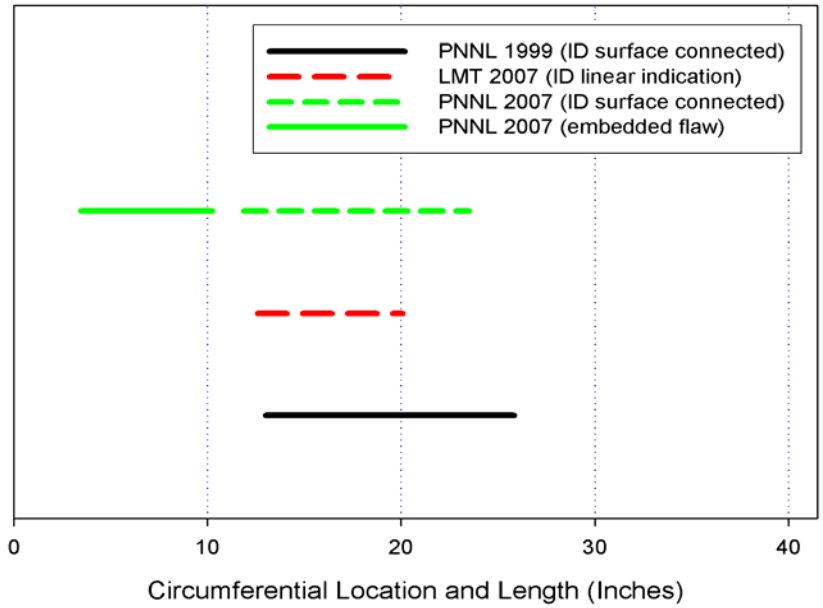


**Figure 10 Detection calls for Weld RRC-F002 showing length and circumferential location for 1999 and 2007 data sets.**

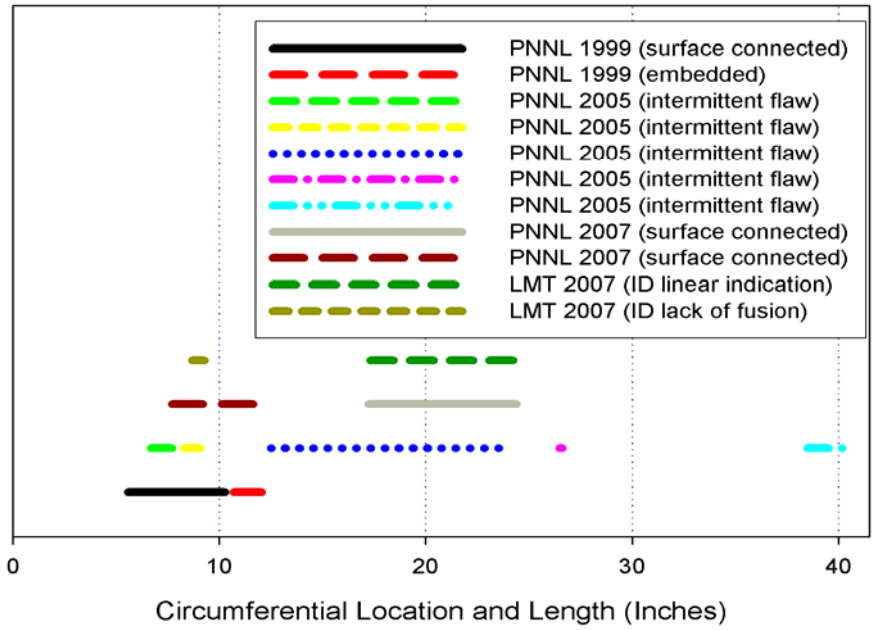


**Figure 11 Detection calls for Weld RRF-F002 showing length and circumferential location for 1999, 2005 and 2007 data sets.**

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

As can be seen in the 1999 data collected by GE, the crack-like indications in Welds RRC-F002 and RRF-F002 existed at that time, and were of similar through-wall size as shown in the most recent data acquired by LMT, Inc. in 2007. The primary cause of these cracks not being detected by GE appears to have been the presence of weld crowns, which limited scanning and did not allow responses to be fully maximized (peaked), or the entire ASME inspection volume to be adequately interrogated. The ID corner-trap responses from the indications were on the edge of the data sets and were misinterpreted as ID geometry. However, a closer review shows that some of the flaw responses exhibited fairly deep tip-diffracted signals, which should have prompted the GE analysts to be more cautious with this interpretation. One has to remember that the procedures used in 1999 were based on prescriptive, amplitude-threshold reporting criteria, as opposed to improved noise-level analyses required by current ASME Appendix VIII performance demonstrated methods. Therefore, while the crack responses may have been noted by the analysts in 1999, there was no requirement to report them since they did not exceed the minimum amplitude threshold established from machined calibration reflectors.

However, the GE analysts should have noted that the subject responses were being limited by the presence of weld crowns, and that the appearance of tip-diffracted signals may have indicated possible deeper through-wall extent than would have been indicative of ID geometrical reflectors. In light of the fact that several BWR licensees had recently (mid-1990s) experienced IGSCC in dissimilar metal welds[1], this vendor was best positioned to know the circumstances surrounding the degradation, and its occurrence. For these reasons, PNNL concludes that GE should have brought this issue to the attention of the licensee, and perhaps the weld crowns should have been removed at that time, in an effort to maximize the responses and ascertain their true cause. It is noted that weld crown removal was performed on a limited portion of Weld RRC-F002 so that a flaw signal, subsequently determined to be embedded (lack of fusion), could be properly analyzed. If weld crown removal had been extended for the entire circumference, it is likely that GE would have detected the crack responses, as these could have been peaked, and the signals may have exhibited sufficient amplitude to require a more thorough investigation.

Recommendation: PNNL strongly recommends that all OD weld crowns be removed prior to performing examinations on all DMW piping welds. This is consistent with PDI-qualified procedures in that the mock-ups used for qualification represent this optimized accessibility.

The 2005 data was acquired by LMT, Inc. with conventional automated UT methods, and the weld crowns had been removed prior to this examination. However, the procedure, which had been qualified through performance demonstration, allowed coupling issues to significantly degrade the examination. EPRI and the licensee contend that the coupling problems were the result of the weight of the search unit and OD surface roughness in the area of the flaw. These factors may have influenced the loss of coupling in this region of the weld, however PNNL believes other problems exist with the manner the data was acquired, because intermittent signal drop-out was observed throughout the circumference. It is well known that coupling with automated mechanical scanning devices can be difficult, and most vendors applying these methods use a continuous water flow to mitigate many of the coupling issues. Other considerations, such as only acquiring data in one raster direction, are also well known because seldom can the scanning device be optimized (with proper spring tension to ensure gimbaled wedge contact) for both forward and reverse raster strokes. LMT, Inc. elected to acquire data on both the forward and reverse stroke of the raster motion in an attempt to reduce the inspection time, and used a gel-based couplant, which may dry out and lose surface wetting

capability, and can result in decreased contact during the examination. For these reasons, PNNL believes all of the factors noted above contributed to poor quality of data which exhibits generally low amplitudes and intermittent loss of signals.

In reviewing the LMT, Inc. procedure used for the 2005 data acquisition, there were a number of items that were vague and difficult to understand as to how the data should be analyzed. This type of vagueness would certainly lead to inconsistent performance when different inspectors tried to follow these instructions. For example, in Section XII.D., Indication Discrimination, a number of factors are listed that an inspector should consider. The procedure did not give any guidance as to how many of these factors needed to be considered or whether some were more important than others. There was no identified logic for how the factors are to be systematically considered.

To illustrate this point of vague guidance, it was stated in Section XII.D.1.a (1) of the LMT, Inc. procedure that the indication should have a good signal to noise ratio. Nowhere does the procedure define what is meant by "good." Is 6dB considered good? Is 20dB considered good? In another location, the procedure states that the indication is to provide a substantial and unique echo-dynamic curve. What is a substantial and unique echo-dynamic curve? There is no guidance given as to what this means. In a like manner, the procedure states that an indication should have several areas of unique amplitude peaks observed throughout the indication length. What is a unique amplitude peak?

In Section E of the LMT, Inc. procedure there were a number of points made for classifying an indication as non-relevant, but it is left up to the inspector's judgment for how to consider these points and make a decision. The problem with this approach is that multiple operators using this procedure could arrive at substantially different decisions based on the very loose guidance provided. In contrast, Appendix C of the procedure provided a very nice flow chart for guiding data collection. PNNL believes that similar guidance should be provided for directing the analysis of inspection data (see recommendation below).

As a result of the poor coupling issues observed in the 2005 examination data, PNNL checked the LMT, Inc. procedure to determine what guidance was listed to address coupling. The procedure specifies that ULTRAGELL II®, mixed with de-mineralized water, or alternative couplant approved by the plant owner, should be used. Therefore, unless specified by the licensee, LMT, Inc. would have used this gel-based couplant as required by the procedure.

Even with the poor quality of 2005 data, the crack responses can be intermittently observed. It is unclear whether these were simply misinterpreted as ID geometry, embedded fabrication flaws, or poor coupling signals, however, in hindsight, it seems that a more detailed analysis (and possibly further examination with supplemental scans) should have been investigated at that time. A re-scan due to poor data quality would have been at the discretion of the LMT, Inc. analyst, however, PNNL believes there was sufficient indication to cause further analysis, and potentially, supplemental scans (if only manual) to assess whether a flaw was present in this weld, or conclusively determine if the intermittent signals could be associated with ID geometry. Table 4.1 shows a comparison of PNNL flaw evaluations; the 2007 flaw evaluation performed by EPRI is also included.

The phased array data acquired in 2007 is of very good quality and the crack responses are easily detected in the high resolution images. The phased array technology enables electronic raster scanning and multiple propagation angles to be performed simultaneously, which allows simple line scans along the direction of the weld to be made (as opposed to mechanical raster)

and significantly reduces examination time on the component. In addition, LMT, Inc. chose to use a manually driven, encoded scanning device, which provides instant feedback to the inspector if a condition such as surface roughness, or poor couplant, is experienced. The examination can be started or stopped anywhere along the scan length, and re-scanned, because encoders keep track of the circumferential position of the probe, and data can be easily re-acquired for the affected area.

However, during the PNNL review of the 2007 phased array data it was noted that, while electronic scans were performed for a range of preset angles, not all inspection angles could fully interrogate the desired inspection volume. It was also unclear how much of the inspection volume should be credited for each angle.

Recommendation: PNNL recommends that a method be established to ensure that coverage of the required ASME Code inspection volume is adequately performed, and this method be fully documented in all UT procedures, including those that are qualified through performance demonstration.

**Table 4.1 Comparison of EPRI and PNNL Flaw Evaluations**

| | Flaw Length (inches) | Through-wall Depth (inches) | Through-wall Penetration | Circumferential Location (inches from TDC) |
|---|---|---|---|---|
| **Weld RRF-F002** | | | | |
| EPRI Assessment (2007 Exam) | 5.8 | 0.79 | 71.8% | 17.3 to 24.3 |
| PNNL Assessment (1999 Exam) | 4.7(1) | 0.59 | Approx. 54% | 5.5 to 10.2 |
| PNNL Assessment (2005 Exam) | 11 | Indeterminate | Indeterminate | 12.5 to 23.5 |
| LMT Assessment (2007 Exam) | 5.84 | 0.59 | 54% | Approx. 17 to 23 |
| PNNL Assessment (2007 Exam) | 6.8 | 0.69 | 63% | 17 to 23.8 |
| **Weld RRC-F002** | | | | |
| EPRI Assessment (2007 Exam) | 6.3 | 0.35 | 33% | Not reported |
| PNNL Assessment (1999 Exam) | 11 | 0.78 | 70% | 14 to 25 (centered at 6:00) |
| PNNL Assessment (2005 Exam) | N/A(2) | N/A | N/A | N/A |
| LMT Assessment (2007 Exam) | 6.3 | 0.79 | 72% | Unknown |
| PNNL Assessment (2007 Exam) | 11 | 0.81 | 74% | 12 to 23 |

Notes: (1) This flaw has different circumferential location than others evaluated for Weld RRF-F002.
(2) No examination on RRC-F002 in 2005.

Recently, through discussions with personnel at EPRI-NRC-Industry Performance Demonstration Initiative (PDI) and ASME Code meetings, it has been determined that somewhat vague directions are included, to some extent, in nearly all PDI-qualified procedures. A review of the phased array procedure[4] used in 2007 has shown that generic information for analysts to consider in discriminating between flaws, metallurgical and geometrical reflections has been included. However, the information simply appears to be provided as a list of “reminders”, or “significant points of influence”, for analysts to consider when making judgment calls of UT responses. While PNNL recognizes that a certain level of skill and subjectivity is

inherent in all UT data analyses, a clear set of rules and decision points should be developed to guide flaw characterization, minimize subjectivity and help to ensure consistent application.

Recommendation: It is recommended that all PDI-qualified procedures for examination of DMWs be reviewed and, as needed, revised to provide detailed and clear guidance for how to analyze data. The procedures need to be improved by incorporation of detailed characterization guidance along with a flow chart showing how to classify indications, and what steps should be taken when data indicate potential flaws that should be further investigated, or when the quality of the data is questionable.

To summarize, the cracks discovered in 2007 appear to have been present in 1999. Scanning limitations due to the weld crowns being in-place, and the use of non-performance demonstrated procedures, were the primary contributors to these cracks remaining undetected at that time. In 2005, although the weld crowns had been removed, coupling problems and poor quality of UT data were the most likely causes of the cracks being missed. However, the analyst should have noted that the data quality was poor and that intermittent indications were present in the images. This should have triggered repeat or supplemental scans to have been made, which may have provided more interpretable data in the cracked weld region. If re-scans could not be performed, the impact, or limitations, to the required inspection volume should have been assessed and reported. The phased array data from 2007 is of good quality and the cracks are easily detected in the high resolution images.

The failure of the 2005 UT examinations to detect the substantial cracks in the nozzles at DAEC merits a brief discussion on field reliability of PDI-qualified UT procedures. The fundamental premise of performance demonstration is that candidate equipment, personnel and procedures should be tested under realistic conditions, i.e., mock-ups that mimic as-built components, containing flaws that produce UT responses similar to actual service degradation, should be used for qualification. Of course, it is not feasible to fabricate specimens, or test sufficiently, to simulate the full range and complexity of DMWs for all plant configurations; the specimens at PDI represent generic configurations applicable to most plants. The PDI specimens should also be considered as “optimized” for UT examinations in that surface features, geometries and metallurgy do not preclude acceptable volumetric examination. This approach provides a practical and cost effective way to generically test the capabilities of the candidate UT systems under optimum conditions.

However, UT examinations are seldom performed under optimum conditions, and PDI-qualified personnel, procedures and equipment may be confronted with adverse field conditions that challenge system capabilities. The poor quality of the 2005 data at DAEC was attributable to field deployment issues, and it is believed that similar problems are encountered at other facilities. Therefore, questions concerning the realism of PDI qualifications may be justified. For instance, are the candidate systems being confronted with a sufficient range of adverse conditions to ensure they will perform robustly when applied in the field? Are analysts being tested to determine whether data quality is adequate to make detection and characterization of flaws possible?

The procedures used for UT examinations at DAEC in 2005[3] and 2007[4] contain limited guidance for determining the quality of data, and briefly state that examinations should be repeated when poor quality of data impacts the analysis. Yet, the poor 2005 data quality, due to coupling problems and other issues, significantly degraded the examination at DAEC.

Recommendation: PNNL recommends that industry augment the current application of

performance demonstration to include a range of adverse conditions (simulating those that may be encountered in the field). In addition, it is recommended that industry develop testing methods to apply during performance demonstration that challenge data analysts to display appropriate and correct decision-making on the acceptability of UT data.

A final note concerns the overall reliability of UT to detect and characterize crack-like indications in DMWs. The assumed cracks in the subject nozzles were very large, and it had been expected that PDI-qualified procedures should detect these size flaws (50-70% through-wall) quite easily. However, in light of the DAEC findings, it is presently unclear how reliable these methods may be for flaw detection, especially for shallower flaws. NRR recently asked PDI to work with PNNL to establish probability of detection (POD) curves for the procedures qualified, which would provide insights to this issue. The pass/fail data (for flaws of varied through-wall extent) in DMWs reside in a PDI database maintained by EPRI. Until one is able to use this database to establish POD curves, the reliability of UT for DMWs will remain essentially unknown.

*Open Item: POD for UT in DMWs, based on current performance demonstration tests, is unknown. NRR has formally asked for access to this information, but PDI has not yet responded.*

## 6.0 REFERENCES


1. *Evaluation of Dissimilar Metal Weld Examinations Performed at Duane Arnold Unit 1 during Refueling Outage 20 (RF020)*. EPRI, Palo Alto, CA: 2007. IR-2007-265.

2. Procedure GE-UT-209V7, Revision, DRR#DAEC-99-04, *Procedure for Automated Examination of Similar and Dissimilar Metal Welds, Including Nozzle-to-Safe End Welds*, GE Nuclear Energy, October 21, 1999.

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4. Zetec OmniScanPA 03, Revision D, *Procedure for Encoded, Manually Driven, Phased Array Ultrasonic Examination of Dissimilar Metal Piping Welds*, EPRI, January 25, 2007.