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Modelling II

3D Computer Model for Tapered Dissimilar Metal Weld Examination

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ABSTRACT

In 2005, the NDE Program used EPRI Materials Management Initiative funding to develop ultrasonic phased array technology for dissimilar metal pipe weld (DMW) inspection. EPRI and Zetec staff collaborated on the successful qualification of a procedure for ultrasonic phased array examination of DMW from the outside surface using the Omniscan instrument. This initial qualification covered DMW configurations with unobstructed access across the entire weld crown and butter. Thus, only un-tapered weld configurations were covered by the original qualified phased array procedures. This paper describes the extension of the phased array ultrasonic examination procedure for the inspection of dissimilar metal welds to complex configurations (tapered weld surfaces). A consortium of EPRI, utility, and vendor personnel successfully expanded the EPRI phased array procedure to cover two additional complex dissimilar metal weld configurations. The extended procedure also incorporates the Zetec OmniScan phased array portable instrument PA 32P-32R/128. This way, industrial vendors will benefit from additional flexibility in selecting the hardware to implement this procedure. The report outlines the qualification examination procedure, “Zetec_OmniScanPA_03_revD”, for the inspection of dissimilar metal welds according to Appendix VIII (Supplement 10) for use in PWR and BWR nuclear power plants. The paper also illustrates an application of the EPRI 3D computer model for tapered dissimilar metal welds.

INTRODUCTION

EPRI phased array NDE technologies, initiated in 2001 for piping applications. In late 2001, the EPRI NDE Program qualified a procedure through Performance Demonstration Initiative (PDI) and extended the scope of that qualification in 2002. Commercialization was accomplished by coordinating with an NDE services vendor. The first field application of the procedure took place in September 2002. The application was a success, producing high-quality data. The 2003 phased array NDE technologies scope had two objectives. First, the qualified piping procedure was made faster by reducing the number of probes from three to only one, and by using a higher-capacity instrument so that the probe could scan faster. Second, a dissimilar metal weld procedure was developed based on valuable experience gained during fingerprint inspections of PDI 's dissimilar metal weld specimen set. For 2004 and 2005, the Materials Executive Oversight Group (MEOG) supported the qualification of the phased array procedure for simple dissimilar metal weld configurations with Materials Management Initiative Funds.

This paper describes the extension of the original procedure qualification [1] to complex dissimilar metal weld configurations and to using a higher-capacity portable phased array instrument. A consortium of EPRI, utility, and vendor personnel successfully expanded the EPRI phased array procedure to cover two additional complex dissimilar metal weld configurations (See Figures 1 and 2). The paper outlines the qualification examination procedure extension to complex dissimilar metal welds according to Appendix VIII (Supplement 10) for use in PWR and BWR nuclear power plants [2]. The extended procedure also incorporates the Zetec OmniScan phased array portable instrument PA 32P-32R/128. This way, industrial vendors will benefit from additional flexibility in selecting the hardware to implement this procedure.

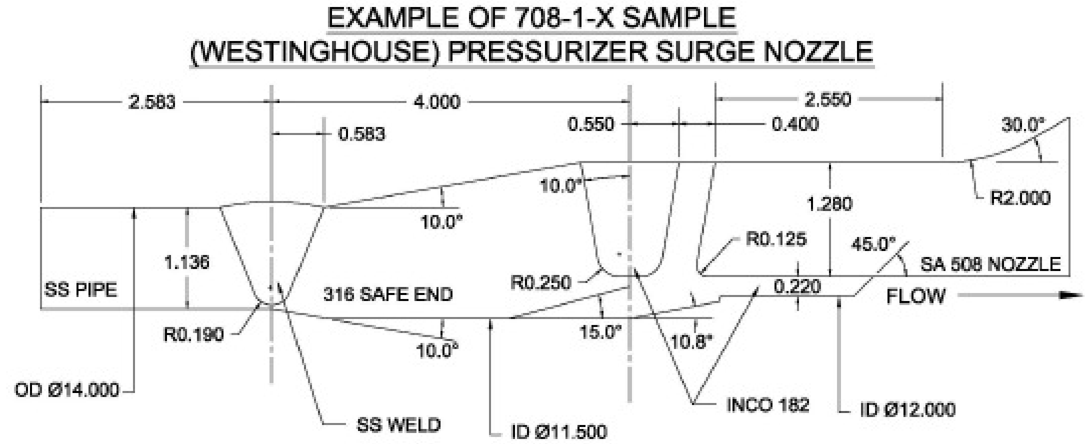

Figure 1 - New PDI Dissimilar Metal Weld Configuration 708-1-X

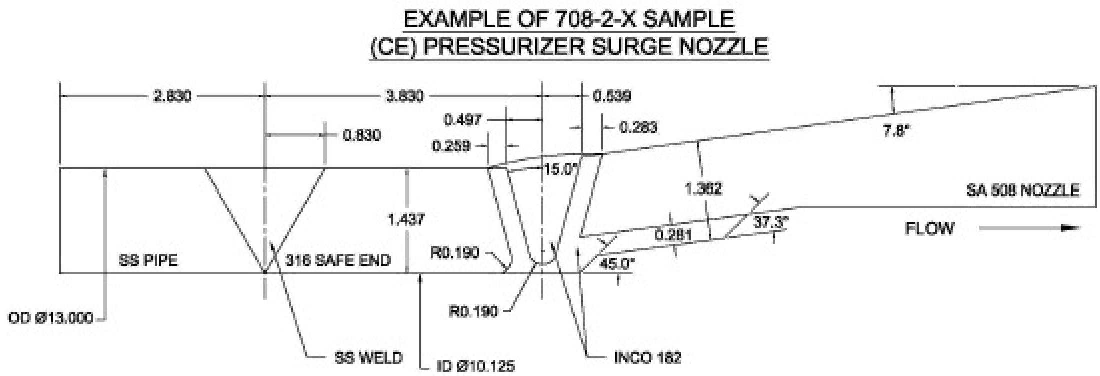

Figure 2 - New PDI Dissimilar Metal Weld Configuration 708-2-X

GENERAL DESCRIPTION OF THE QUALIFIED EXAMINATION PROCEDURE

Zetec qualified a manually driven, encoded, examination procedure inspired by the existing draft EPRI procedures [1]. The qualified phased array ultrasonic examination procedure has the following characteristics:

Scope

This procedure is applicable for encoded, manually driven phased array ultrasonic examination of full penetration dissimilar metal piping butt welds, conducted from the external (OD) surface. This includes dissimilar metal piping systems susceptible to Stress Corrosion Cracking (SCC).

The procedure is applicable to the diameter and thickness ranges as listed in Table 1. Specific pipe thickness and diameters demonstrated along with examination limitations are listed on the PDI Performance Demonstration Qualification Summary (PDQS) for this procedure [2].

If the weld is accessible from both sides, the examination will always be done from both sides. If the weld is not accessible from both sides, the procedure is applicable for single sided weld access.

This procedure is qualified for:

- Detection, length sizing and through-wall sizing of circumferentially oriented flaw indications in dissimilar metal weld configurations where single or dual side access is available.

- Detection and through-wall sizing of axially oriented flaw indications in dissimilar metal weld configurations where dual side access is available, or if the flaw indications are located within an accessible region of a single side access configuration.

This procedure is not qualified for length sizing of axially oriented flaws, regardless of location.

Table 1 - Applicable Ranges of Dissimilar Metal Weld Pipe Diameter and Thickness

	Material	Diameter Range		Thickness Range	
		PDI Demonstration	Field Applicability	PDI Demonstration	Field Applicability
Detection and length sizing	Dissimilar metal	2.0" to 50.0" (60 to 1016 mm)	1.5" NPS and up (48 mm and up)	0.280" to 5.20" (7.1 to 132.1 mm)	0.210" to 6.50" (5.3 to 165.1 mm)
Through-wall sizing	Dissimilar metal	2.0" to 50.0" (60 to 1016 mm)	1.5" NPS and up (48 mm and up)	0.280" to 5.20" (7.1 to 132.1 mm)	0.210" to 6.50" (5.3 to 165.1 mm)

Examination area

The ASME Code Section XI examination is limited to the inner third of the material volume and heat affected zone (HAZ) for a distance of 6.35 mm (1/4") beyond the extent of the weld cap (See Figure 3).

This procedure provides additional coverage of the complete weld volume, butter material, and base material for a distance of 6.35 mm (1/4") inch from each weld toe or butter interface, in order to identify, characterize and size indications originating from the inner surface but extending to mid-wall or higher.

Examination execution

Circumferential flaws

For circumferential flaw examinations, the ultrasonic beam is oriented essentially perpendicular to the weld. The scanning movement of the search unit shall be along the weld, while the increment shall be across the weld.

Longitudinal waves

The search unit position for the first scan line is such that the exit point of the last focal law (closest to the front of the search unit) from the 70 degree beam is located at examination volume point "C" (See Figure 4).

The search unit position for the last scan line is such that the first focal law (closest to the rear of the search unit) from the 60 degree beam intersects the inner surface at examination volume point "A" (See Figure 4).

Shear waves

The search unit position for the first scan line is such that the exit point of the last focal law (closest to the front of the search unit) from the 60 degree beam is located at the interface of base material and weld material (See Figure 5).

The search unit position for the last scan line is such that the first focal law (closest to the rear of the search unit) from the 60 degree beam intersects the inner surface at examination volume point "A" (See Figure 5).

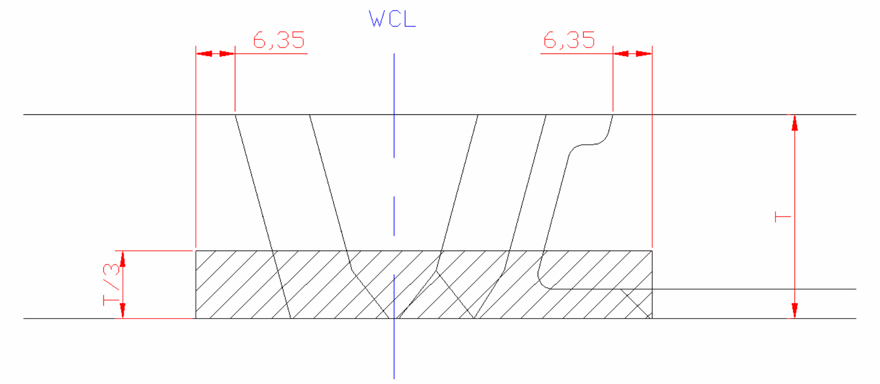

Figure 3 - ASME Section XI Examination Volume (Cross-hatched area)

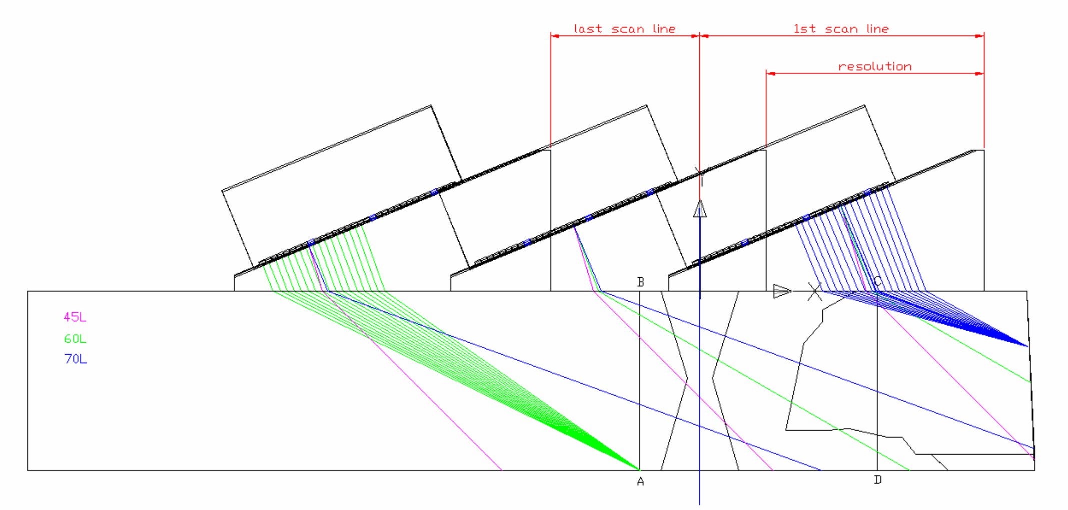

Figure 4 - Index Positions for Longitudinal Wave Circumferential Flaw Examination

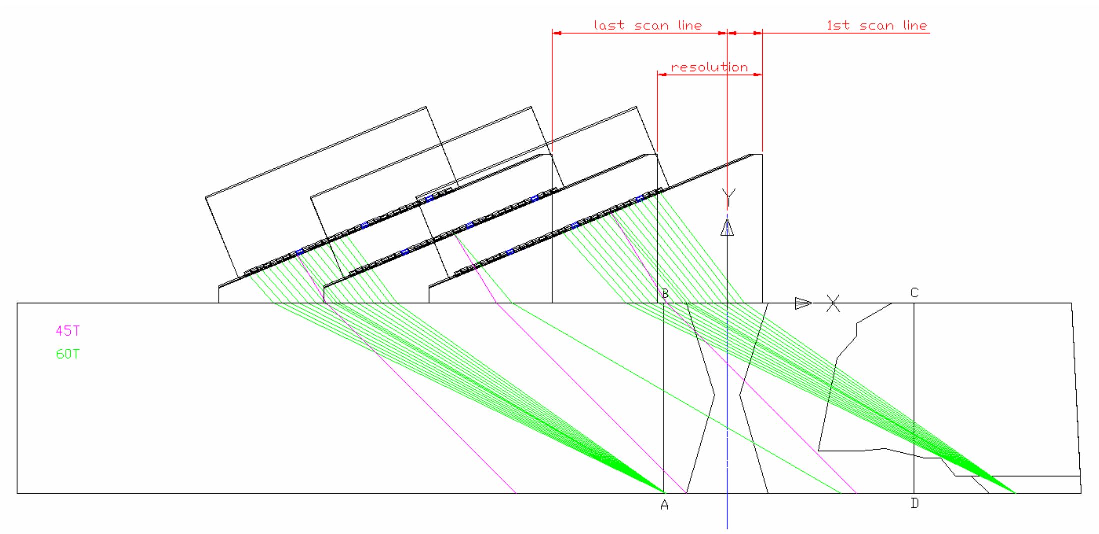

Figure 5 - Index Positions for Shear Wave Circumferential Flaw Examination

Axial flaws

For axial flaw examinations, the search unit is moved on the surface of the examination volume material with the beam looking in both clockwise and counter clockwise directions. The scanning movement of the search unit shall be along the weld, while the increment shall be across the weld.

The scanning sequence shall be sufficient to ensure that the entire weld length is examined. If several scanning sequences are required to cover the complete circumference of the weld, consecutive scanning sequences should overlap by at least 25 mm (1 inch) in the circumferential direction. Additional scan lines may be needed to further interrogate suspect indications or to compensate for geometrical uncertainties (offset weld center, tapers, etc.).

For axial flaw examinations, the search unit position for the first scan line is such that the nominal exit point is located at examination volume point "A" (See Figure 6). The last scan line is such that the nominal exit point of the search unit is located at examination volume point "D" (See Figure 6).

Data collection and analysis

- The external surface, contact examination is performed using side-by-side twin-crystal techniques.
- Detection and reporting threshold are based on the local ultrasonic noise level.
- Flaw indication length sizing is based on amplitude drop techniques.
- Depth sizing is based on tip diffraction techniques

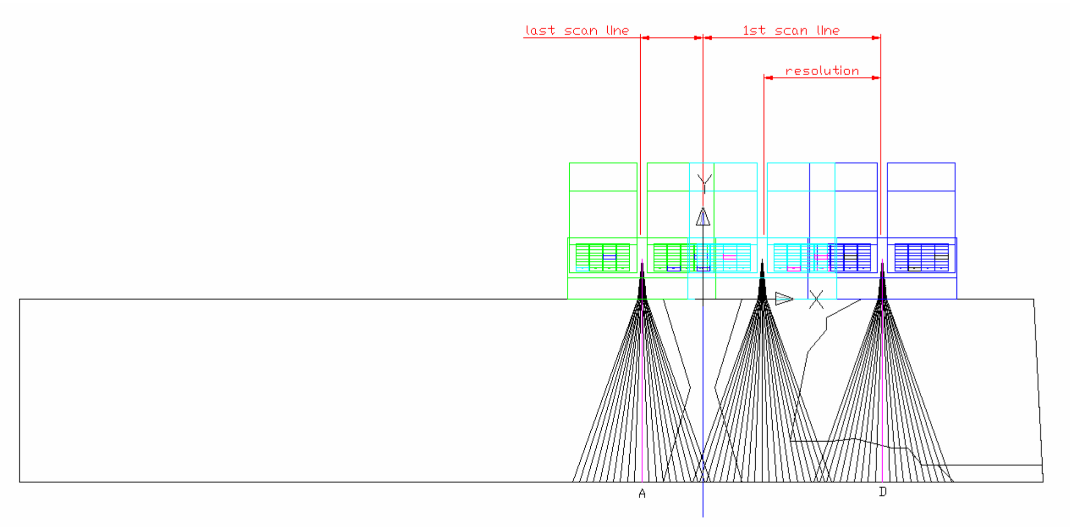

Figure 6 - Index Positions for Axial Flaw Examinations

Summary

- Phased array techniques for the inspection of dissimilar metal piping welds (including certain complex configurations (See Figures 1 and 2) have been developed, with the following characteristics [2]:
  - Dual 2-D phased array methodology, providing very good inspection capability on both circumferential and axial flaws
  - A limited number of array probes are necessary to cover the full range of diameters and thicknesses

    - Encoded, manually driven inspections generating quality UT data, allowing for reliable detection and accurate through-wall sizing
    - Using state-of-the-art portable phased array hardware (both PA 16P-16R/128 and PA 32P-32R/128) and advanced software
- This extension of the phased array examination procedure has been successfully qualified according to Appendix VIII, and applies to [2]:
    - Detection, length sizing, and through-wall sizing of circumferentially oriented flaw indications where single or dual side access is available
    - Detection and through-wall sizing of axially oriented flaw indications where access is available

3D COMPUTER MODEL OF TAPERED DISSIMILAR METAL WELDS

Until the recent qualification of the complex configurations depicted in Figures 1 and 2, the only ultrasonic NDE procedures qualified through the Performance Demonstration Initiative (PDI) required unobstructed access across the entire weld crown and butter [1]. Thus, only un-tapered weld configurations are covered by the qualified procedures. Unfortunately, tapered surfaces are prominent in many installed dissimilar metal welds. In those situations, where qualified NDE is not available, utilities must file for relief or seek alternatives that could even include preemptive measures, such as weld overlay. A method is needed to extend existing qualifications achieved on un-tapered configurations to apply to tapered surfaces. A solid technical basis is needed to do this.

A similar issue existed with qualification of ultrasonic procedures for examination of the inner radius region of reactor vessel nozzles. In that case, the complexity of nozzle configurations made it impractical to include every situation in the qualification sets, yet the geometrical differences from nozzle to nozzle would not allow application of a procedure qualified on a range of configurations to be applied to another nozzle with a different configuration. A 3D computer model was developed to provide the technical basis for extending qualified procedures to other nozzle configurations without the need for additional experiments or qualifications. In fact, this approach was so successful that it became incorporated into ASME Code requirements, i.e., Code Case 552.

A new 3D computer model has been developed and validated for application on tapered dissimilar metal welds. The 3D computer model for tapered DMW could extend the qualifications achieved on un-tapered welds to cover tapered configurations. The 3D model would be used to determine the modifications to the probe beam angle and probe skew angle to compensate for the presence of the taper. Implementation of the 3D computer model of tapered DMW would reduce, or possibly eliminate, the need to build site-specific mockups and conduct qualifications where the only difference between the demonstration welds and the plant welds is the presence of tapers. Figure 7 shows the cross-section of PDI generic pressurizer water reactor (PWR) pressurizer spray nozzle dissimilar metal weld (DMW) design (702/X). The PDI-UT-10 procedure examination volume is also indicated in Figure 7.

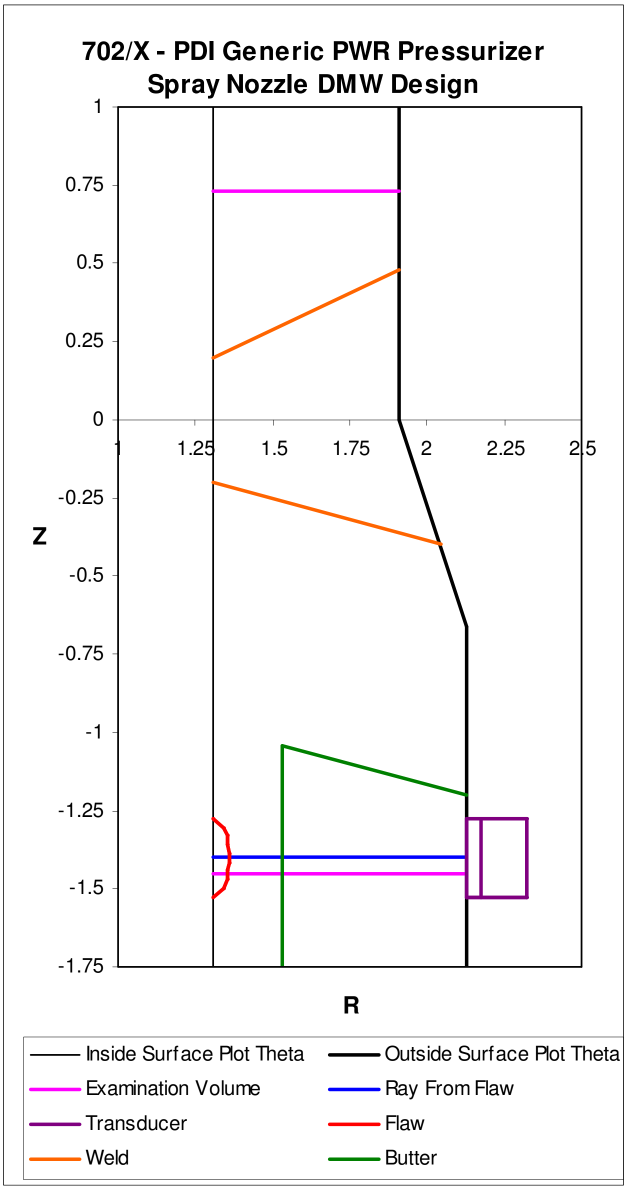

Figure 7 - Cross-Section of 702/X - PDI Generic Pressurizer Spray Nozzle Dissimilar Metal Weld Design

Figure 8 is a plot of the probe beam angle versus probe skew angle to obtain a 45° corner trap for the pressurizer spray nozzle dissimilar metal weld shown in Figure 7. The curve in Figure 8 could be used to design detection techniques for the pressurizer spray nozzle DMW except for the fact that the finite probe size limits the coverage for the ideal probe angles and probe skews indicated in Figure 8. A more realistic technique design curve can be obtained by accounting for the finite probe size while scanning on the available surfaces, 1) pipe side of weld, 2) taper, and 3) nozzle side of weld and allowing the beam angle at the flaw to vary between some limits say 55 degrees to 89 degrees (normal incidence detection). Figure 9 shows the resultant curves for each scan surface that are needed to obtain optimum coverage while accounting for the finite probe size.

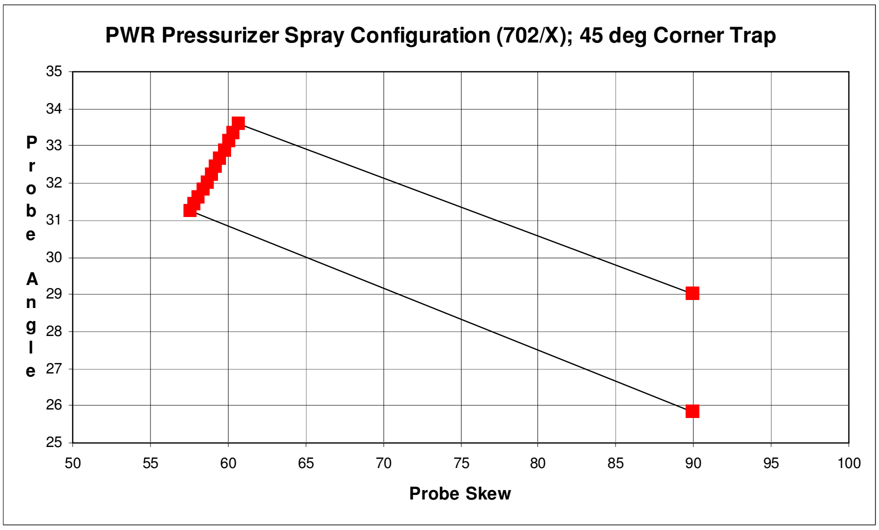

Figure 7 - PDI Generic Pressurizer Spray Nozzle DMW (702/X): Probe Angle versus Probe Skew; 45 Degree Corner Trap, Technique Design Curve

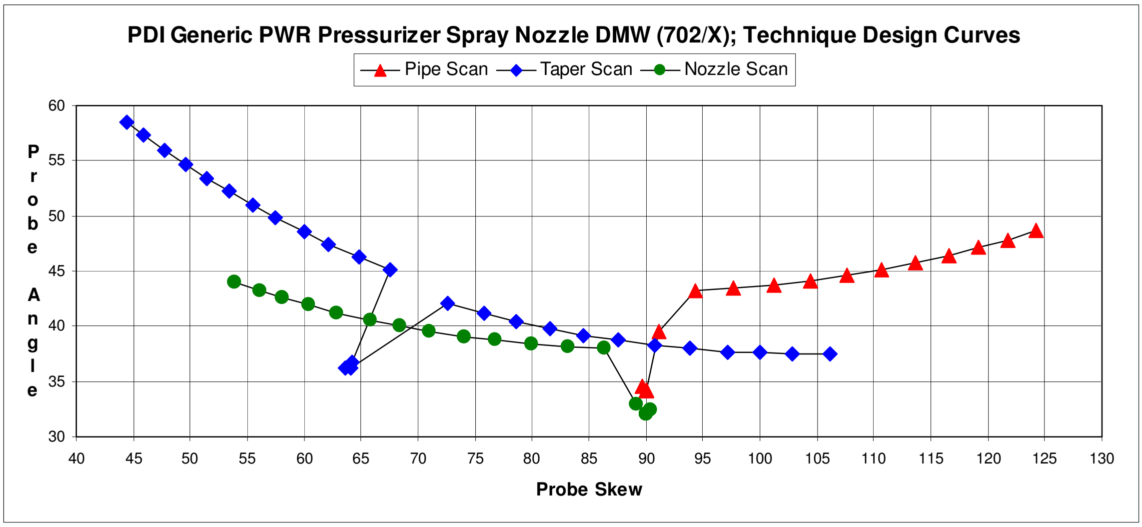

Figure 8 - PDI Generic Pressurizer Spray Nozzle DMW (702/X): Probe Angle versus Probe Skew Technique Design Curves for Finite Sized Probes

The EPRI 3D model detection technique to examine the pressurizer spray nozzle dissimilar metal weld involves scanning from the pipe side of weld, taper, and nozzle side of weld. Table 2 gives the probe beam and skew angles, scan surface, and the mode of propagation. Figure 9 shows these detection techniques in relation to the technique design curves for finite sized probes.

Table 2 - Spreadsheet Model Detection Techniques for Generic Pressurizer Spray Nozzle DMW (702/X)

Probe Angle	**Probe Skew**	**Scan Surface**	**Mode of Propagation**
35	±90	Pipe Side of Weld	Longitudinal Wave
45	±105	Pipe Side of Weld	Longitudinal Wave
39	±66	Taper	Longitudinal Wave
48	±62	Taper	Longitudinal Wave
40	±76	Taper	Longitudinal Wave
40	±80	Nozzle Side of Weld	Longitudinal Wave
35	±90	Nozzle Side of Weld	Longitudinal Wave

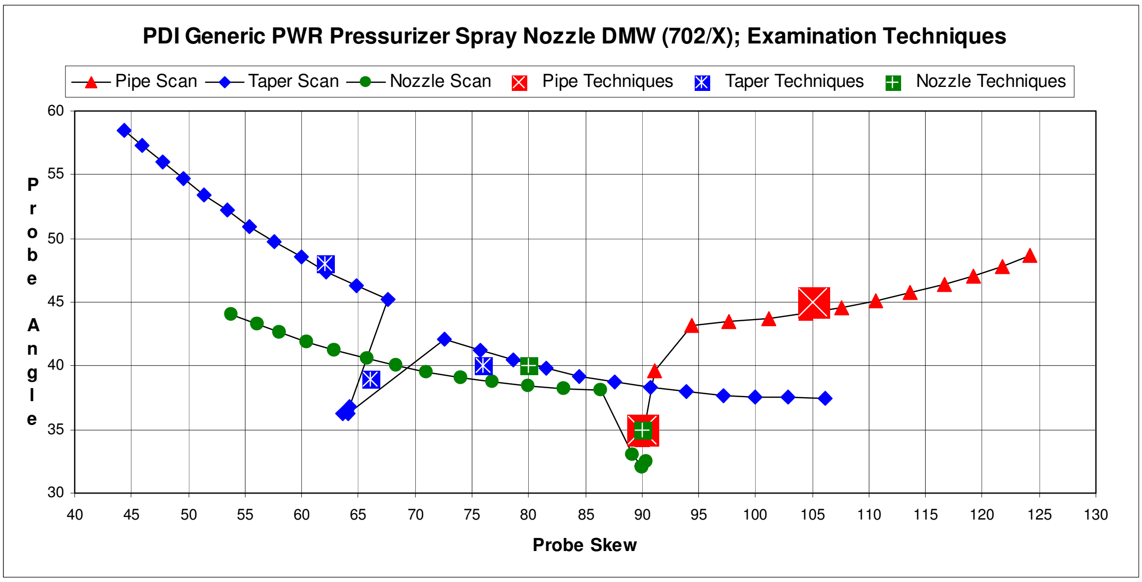

Figure 9 - PDI Generic Pressurizer Spray Nozzle DMW (702/X): Probe Angle versus Probe Skew Technique Design Curves for Finite Sized Probes

Figure 10 shows the maximum and minimum probe axial positions and the portion of the examination volume covered by the pipe side of weld detection technique, 45/105p.

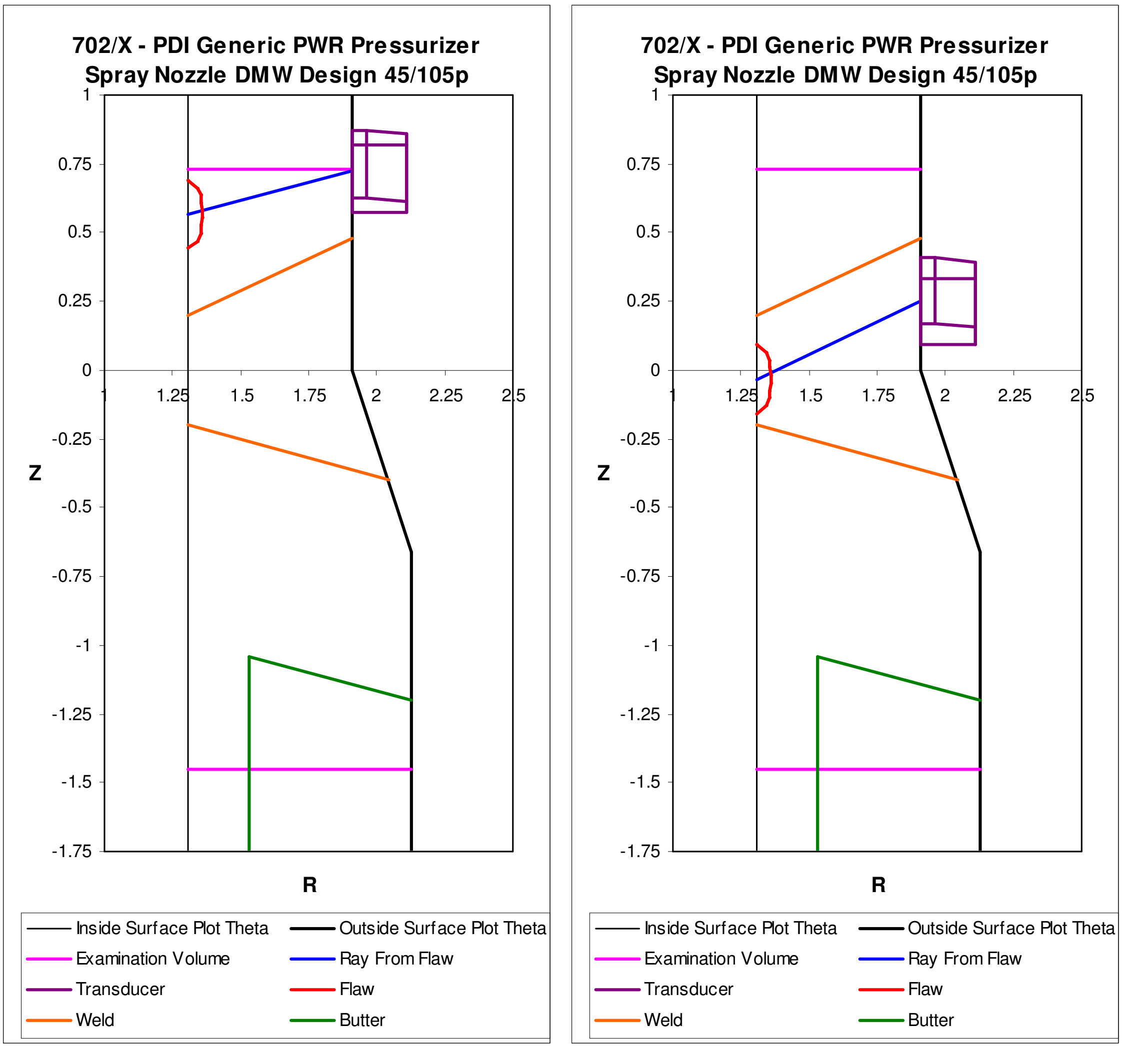

Figure 10 - PDI Generic Pressurizer Spray Nozzle DMW (702/X): Probe Scan Limits and Exam Coverage for Detection Technique 45/105p

Figure 11 shows the maximum and minimum probe axial positions and the portion of the examination volume covered by the taper detection technique, 48/62tp. Figure 10 and Figure 11 illustrate how the 3D computer model for dissimilar metal welds is used to design examination techniques that negotiate the abrupt change in the pipe surface at the initiation of the taper (Z = 0) while providing continuous coverage of the examination volume.

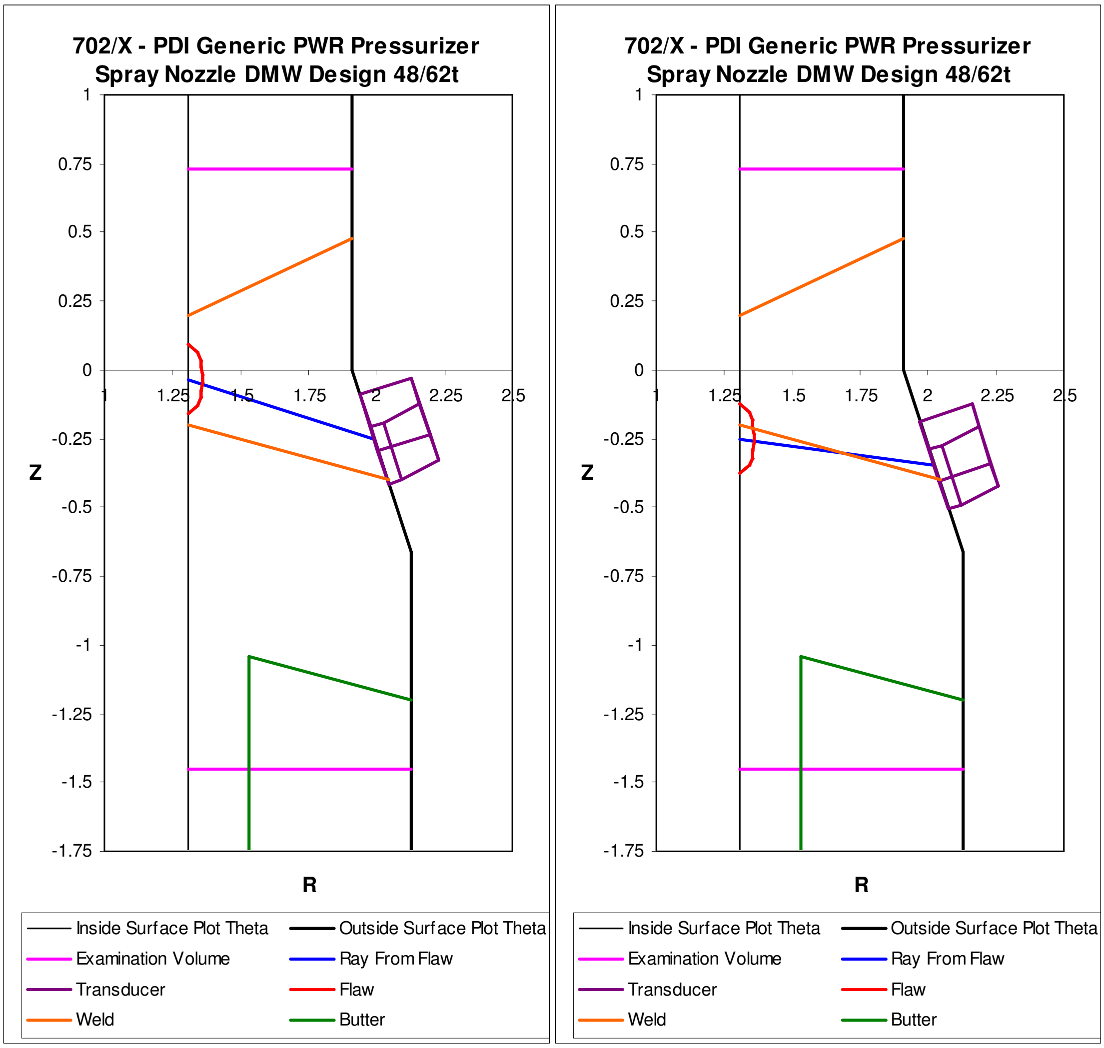

Figure 11 - PDI Generic Pressurizer Spray Nozzle DMW (702/X): Probe Scan Limits and Exam Coverage for Detection Technique 48/62p

Future Plans

Implementation of a 3D computer model for tapered overlays and DMW could be used to extent the qualifications achieved on un-tapered welds to tapered configurations. The 3D model would be used to determine the modifications to the probe beam angle and probe skew angle to compensate for the presence of the taper. Implementation of the 3D computer model of tapered overlays and DMW would reduce or possibly eliminate the need to build site specific mockups and perform qualification extensions where the only difference between the demonstration welds and the plant welds is the presence of tapers.

REFERENCES

1. Ultrasonic Phased Array Examination Procedure for Dissimilar Metal Welds. EPRI, Palo Alto, CA: 2006. 1013703.
2. Procedure for Encoded, Manually Driven, Phased Array Ultrasonic Examination of Dissimilar Metal Piping Welds: Zetec_OmniScanPA_03_revD.doc. EPRI, Palo Alto, CA: 2007. 1015133.