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October 4, 2002

Mr. Terrance Chan
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2739

SUBJECT: Nozzle-to-shell weld coverage issues

Dear Terrance:

As you may remember the PDI introduced the subject of examination coverage of the RPV nozzle-to-shell welds, at our September 13th meeting. We are fast approaching the November implementation date for this application and we need clarification on this subject.

The PDI has worked closely with NRC staff and consultants to establish an effective program for implementing performance demonstration requirements. The NRC staff and consultants have been active participants in these activities as well as the effort to codify the program in the ASME Code and assure that it did not conflict with the concerns of the NRC. However, we now appear to be at an impasse regarding interpretation of the Code of Federal Regulations, the ASME Code and utility requirements for effective implementation of the required examinations.

A white paper, which details the PDI position, is attached. The PDI Program and samples do not currently address flaws perpendicular to the weld centerline; in the outer 85% of the nozzle to shell weld. Implementation of an examination, according to the NRC staff member's interpretation, would result in the application of an examination that is not qualified for its' intended task nor warranted according to our interpretation of The Code of Federal Regulations and the ASME Code. We believe that PDI has made substantial progress in the effectiveness and reliability of RPV and piping examinations and would not encourage the application of ineffective examinations nor the additional radiation burden that would be involved.

Correspondence to the PDI Committee should be directed to:
Mike Bratton • Entergy Nuclear South • 17265 River Road • Killona, LA 70066-0751

We would greatly appreciate a letter clarifying this situation as soon as possible.

Sincerely,

***Signature on File**

Mike Bratton
PDI Steering Committee Chairman

cc: Don Naujock, NRC
PDI Steering Committee
PDA Staff

MB/ja
Attachments: 1

White Paper

RPV Nozzle-to-Shell Examination Coverage and Scan Directions

September 27, 2002
Larry Becker
EPRI NDE Center

Objective

The objective of this White Paper is to clarify a difference of opinion regarding the scanning and coverage requirements for reactor pressure vessel (RPV) nozzle-to-shell welds.

Problem Statement

In discussions with the U.S. NRC staff, an opinion has been stated that the outer 85% of the nozzle-to-shell weld must be examined for flaws perpendicular to the weld centerline. The position is based on an interpretation of the Final Rule 10CFR50.55a(b)(2)(xv)(K), September 22, 1999. This position is based on the interpretation that Paragraph (K) states that radial scan procedures shall be qualified to Appendix VIII Supplement 6 (1) as modified by Paragraph G.

The Performance Demonstration Initiative (PDI) disagrees with this interpretation based on the following premise:

- Previous agreements and understandings with the NRC
- Supplement 6 is not appropriate for the detection of flaws perpendicular to the weld
- Paragraph K of the Rule is specifically directed at the complex geometry of the nozzle-to-shell welds.
- Paragraph K of the Rule only specifies Appendix VIII, Supplement 5 qualifications and scans for the inner 15% of the examination volume but not the outer 85%.
- Appendix VIII, Supplement 5 (2) more appropriately references circumferential scans to detect flaws perpendicular to the weld.

The 85% coverage interpretation would place an undue burden on the industry as well as increase personnel radiation exposure with no technical benefit realized nor increase in safety. The orthogonal scans required by Paragraph G would not detect flaws perpendicular to the weld in the outer 85%, due to the complex geometry of the weld. Supplement 6 procedures are qualified for

examination directions parallel and perpendicular to the axial and circumferential welds of the RPV. However, Supplement 6 procedures are not appropriate for the complex geometry presented by flaws perpendicular to the nozzle-to-shell weld. Procedures qualified to Supplement 6 are appropriate for the radial inward scans, to detect flaws parallel to the weld, from the vessel surface.

The PDI believes the recent interpretation by NRC staff is not consistent with previous NRC positions and agreements with PDI. The technical basis for the PDI interpretation is provided below. Several instances where NRC has taken a position on this subject are also listed.

Background

Coverage issues regarding nozzle-to-shell welds have been a topic of discussion since 1994. Several actions are listed below that indicate NRC agreement with that of the PDI Program.

Organization of the ASME Code Section XI

- **IWA-2232** states, "Ultrasonic examinations shall be conducted in accordance with Appendix I".
- **IWB-2500** lists the examination requirements by component category.
- **IWB-3500** lists the acceptance criteria for flaw indications.
- **Appendix I** describes the extent of examination and coverage requirements, as well as personnel and procedures required to be qualified to Appendix VIII. Appendix I describes scanning of the outer 85% is required in one radial direction.
- **Appendix VIII** describes the qualification requirements for procedures, personnel, and equipment to be used in examinations required by Appendix I. However, Appendix VIII does not address examination of components, including requirements for scanning directions and coverage.

Technical Basis

Code Case N-622

The NRC requested that the contents of the PDI Program be incorporated into the ASME Code Section XI in order to preclude the need to include all the differences contained in the PDI Program into 10CFR50.55a. A concerted effort by PDI staff, members of the ASME Code, NRC staff, and NRC consultants came to agreement on a version of the document, and Code Case N-622 was approved February 29, 1999 (3). Unfortunately, it was not published until September of that year.

Code Case N-622, A-1300 (b)(2) requires that the outer 85% be examined in at least one radial direction. PDI met with the NRC on several occasions to assure the Final Rule would incorporate the provisions of the PDI Program and the Code Case. Until recently, PDI was under the assumption that an agreement with the NRC was in place.

10CFR50.55a Rule dated September 22, 1999

Paragraph 10CFR50.55a(b)(2)(xv)(G) discusses the application of Appendix VIII Supplements 4 and 6. Supplements 4 and 6 are applicable to RPV plate-to-plate welds. The wording in (G) is the same as in other paragraphs, i.e., ". . . when applying Supplement "X" the following additional provisions must be used." This is interpreted to mean that the application is within the Scope of the procedure to be applied. Both Code Case 622 and Appendix I, 2002 Addenda (4) require the use of a procedure qualified to Supplement 6 in one radial inward direction for the outer 85% of the weld. The NRC has participated in the formulation of both the Code Case and the Code revisions without objections to this point.

Paragraph 10CFR50.55a(b)(2)(xv)(K) discusses in detail the qualification of procedures, personnel, and equipment for the examination of reactor pressure vessel (RPV), nozzle-to-vessel welds.

Nozzle-to-Shell Welds Scanned from Inside of the Vessel

Subparagraph (K)(1)(*i*) specifically states that for examinations performed from the bore, scanning for flaws perpendicular to the weld centerline are not required. Subparagraph (K)(4) references Table VIII-S7-1, which excludes flaws perpendicular to the weld centerline in the outer 85% of the weld. Subparagraph (K)(2)(*iii*) addresses the outer 85% of the weld and requires that the examination be performed either from the bore using a procedure and personnel qualified in accordance with Subparagraph (K)(1) or from the vessel shell using procedures and personnel qualified to Supplement 6 as modified by paragraphs (D), (E), (F) and (G). Subparagraph (K)(1) states that scanning for flaws perpendicular to the weld are not required. Supplement 6 qualifications are performed on scanning for flaws both parallel and perpendicular to the weld and meet the requirements of paragraphs (D), (E), (F) and (G). It is clear that for examinations performed from the bore it is not required to search for flaws perpendicular to the weld, except in the inner 15%. All pressurized water reactor (PWR) vessels are examined from the bore; therefore, would not require scanning for flaws perpendicular to the weld centerline in the outer 85% of the weld.

Nozzle-to-Shell Welds Scanned from Outside of the Vessel

All boiling water reactor (BWR) vessels are normally scanned from the outside surface, and Subparagraph (K)(3) addresses the examination from the outside surface. Specifically (K)(3)(*ii*) addresses the outer 85% of the weld and requires:

1. Examination in at lest one radial direction
2. Personnel and Procedures are to be those that have been qualified to the requirements of Appendix VIII, Supplement 6.
3. Table VIII-S7-1 removes from consideration flaws that are perpendicular to the weld in the outer 85% of the weld.

The PDI procedures used are qualified to the requirements of Supplement 6 for the single radial direction. Those procedures are not qualified to detect flaws at large deviations relative to the scan direction. Supplement 5 and Code Cases N-622 and N-552 (5) address these conditions. If the NRC desired scanning in the circumferential direction for the outer 85%, the industry would expect that the NRC would have included the same words that are included in (K)(3)(*i*), which does include circumferential scanning and qualifications to Supplement 5 for the inner 15%. As stated earlier in this paper, the argument still holds that procedures qualified to Supplement 6 are not appropriate for circumferential scanning of the nozzle to detect flaws perpendicular to the weld. Such examinations would increase personnel radiation exposures since these examinations are conducted in a high radiation zone and would require an additional six to eight scans. Therefore, performing these examinations result in increased cost burden with no benefit to quality or safety.

Failure to perform circumferential scans would not require a notation of limited scanning nor a request for relief, as the examination meets the coverage requirements of (K)(3)(ii). The staff interpretation, in effect, requires more stringent requirements for BWR nozzle-to-shell welds while PWR units are exempt. It is recognized that the BWR have considerable more margin than PWR units.

Code Case N-613 and N-613-1

Code Case N-613 (6) approved July 30, 1998, has been published. However, the NRC has objected to the Case, as it only requires the examination to search for flaws parallel to the weld over the entire weld thickness. PDI and the ASME Code have agreed with the NRC that the inner 15% of the weld should be examined in four orthogonal directions. The NRC made an alternative proposal, (N-613-1) in a letter from Wallace E. Norris to Ken Thomas, chairman of the ASME Code, Water Cooled Systems, dated October 30, 2000. The alternative Case required coverage from four directions for the inner 15% of the volume. The proposed Case also specifies that only scanning for flaws parallel to weld were required for the outer 85% of the weld. If the NRC had wished to achieve coverage for flaws perpendicular to the weld in the outer 85%, then the question

must be asked why would they specify only flaws parallel to the weld. This action has passed Main Committee but has not yet been published.

ASME Code Section XI, 2002 Addenda, Appendix I

Appendix I provides instructions for examination coverage. After issuance of the September 22,1999 Rule, the Code resolved to clarify scanning and coverage requirements. The revisions completed the required review process, including NRC participation, and have now been published in the 2002 Addenda. I-3400 describes the requirements for examination of RPV nozzle-to-shell welds. I-3410 and I-3420 (4) describe examination requirements from the inside and outside surfaces. In both cases, examination is required in one radial direction for the outer 85% of the weld.

Supplement 6 Qualification Limitations

Supplement 6 procedures are qualified on vessel shell plates. These plates represent the vessel curvature and thickness. The procedures are qualified for single- or dual-side access. To be applicable for nozzle-to-shell examinations, the procedure must be qualified for single-side access conditions.

Supplements 6, single-side procedures, are appropriate for nozzle-to-shell radial inward scans from the vessel surface. There is little difference in curvature as compared to vessel plate qualification. A transducer oriented perpendicular to the radial-inward scan direction is not qualified to detect flaws oriented perpendicular to the centerline of the nozzle-to-shell weld below 0.5 to 1 inch from the incident surface. The discussion below provides an explanation of the effectiveness of the perpendicular beam direction (qualified to Supplement 6) for the detection of flaws perpendicular to the nozzle-to-shell weld centerline.

The simple case of a nozzle welded into a flat plate is shown in plan view in Figure 1.

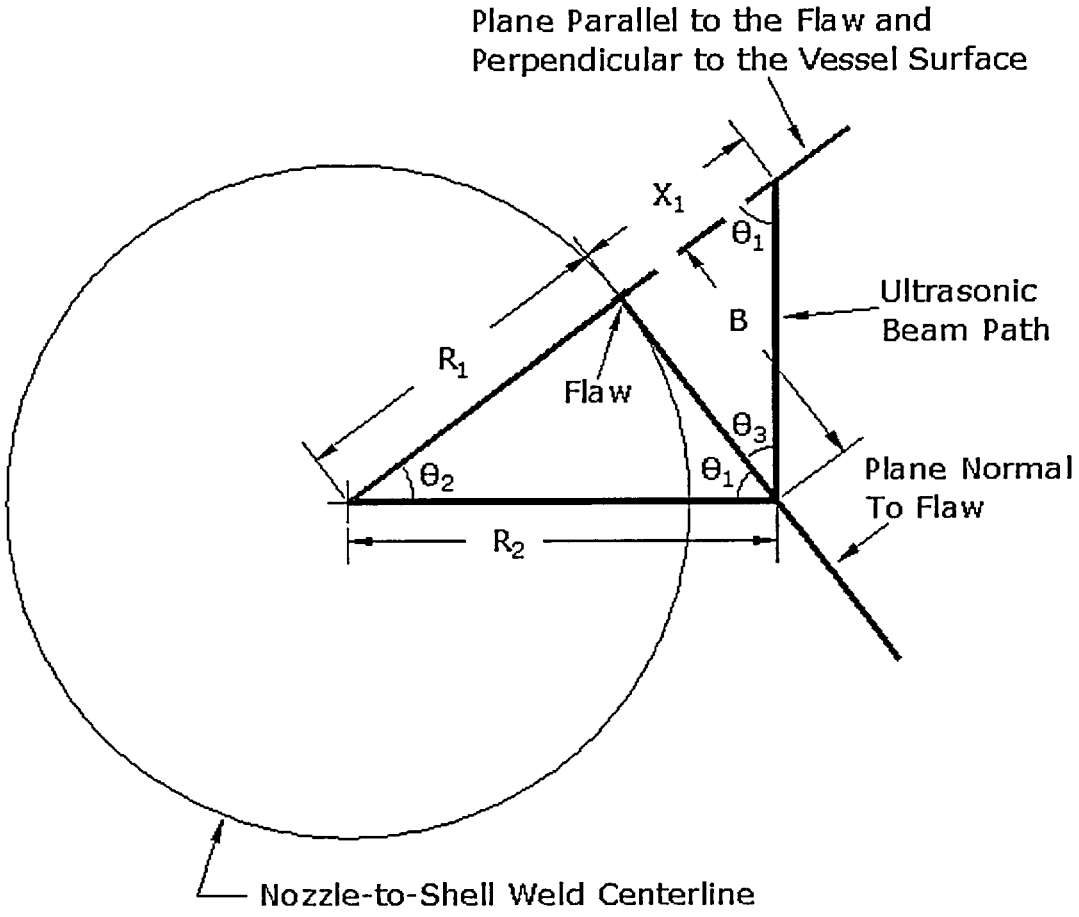

Figure 1. Plan View of the Nozzle-to-Shell Weld Examination Geometry for a Circular Weld in a Flat Plate

Where:

- R_1 is the radial distance from the center of the nozzle to the target flaw
- R_2 is the radial distance from the center of the nozzle to the plane that is normal to the flaw and perpendicular to the surface.
- Θ_i is the Beam propagation or incident angle of the ultrasonic beam.
- X_1 is the displacement of the beam from the target flaw location on the plane parallel to the flaw.
- "t" is the distance from the outside surface to the target flaw location.

- "Θ_3" is the angle between the flaw normal and the ultrasonic beam direction. This angle is also defined as the angle of misorientation.

If Θ_3 is reduced to zero the beam propagation angle would lie in the Plane normal to the flaw and the beam path projected on the surface "B" is given by:

$$B = t \text{ Tan } \Theta_i \quad (1)$$

The angle between R_1 and R_2, "Θ_2", is given by:

$$\Theta_2 = \text{Arctangent } [(t/R_1) \text{ Tangent } \Theta_i] \quad (2)$$

$$\Theta_1 = 90° - \Theta_2 \quad (3)$$

The displacement distance X_1 is given by:

$$X_1 = t(\text{Tangent } \Theta_i)(\text{Tangent } \Theta_2) \quad (4)$$

$$R_2 = R_1 \text{Cosine } \Theta_2 \quad (5)$$

In the case where the ultrasonic beam is perpendicular to R_2 (the case qualified under Appendix VIII Supplement 6) Θ_3 is equal to Θ_2. Both the displacement X_1 and the misorientation angle Θ_3 are equal to zero at incident surface (t = 0) and increase with the distance of the target flaw location below the incident surface.

The effect is more pronounced for smaller nozzles than for larger nozzles. The misorientation angle and the displacement distance for 60° angles and weld radii of 4, 12, and 20 inches are shown in Figures 2 and 3. These radii are approximately equivalent to the radius of nozzle-shell welds for 4, 12 and 28-inch nozzles in a BWR RPV. A 45° incident angle for a 12-inch weld radius is also included for reference.

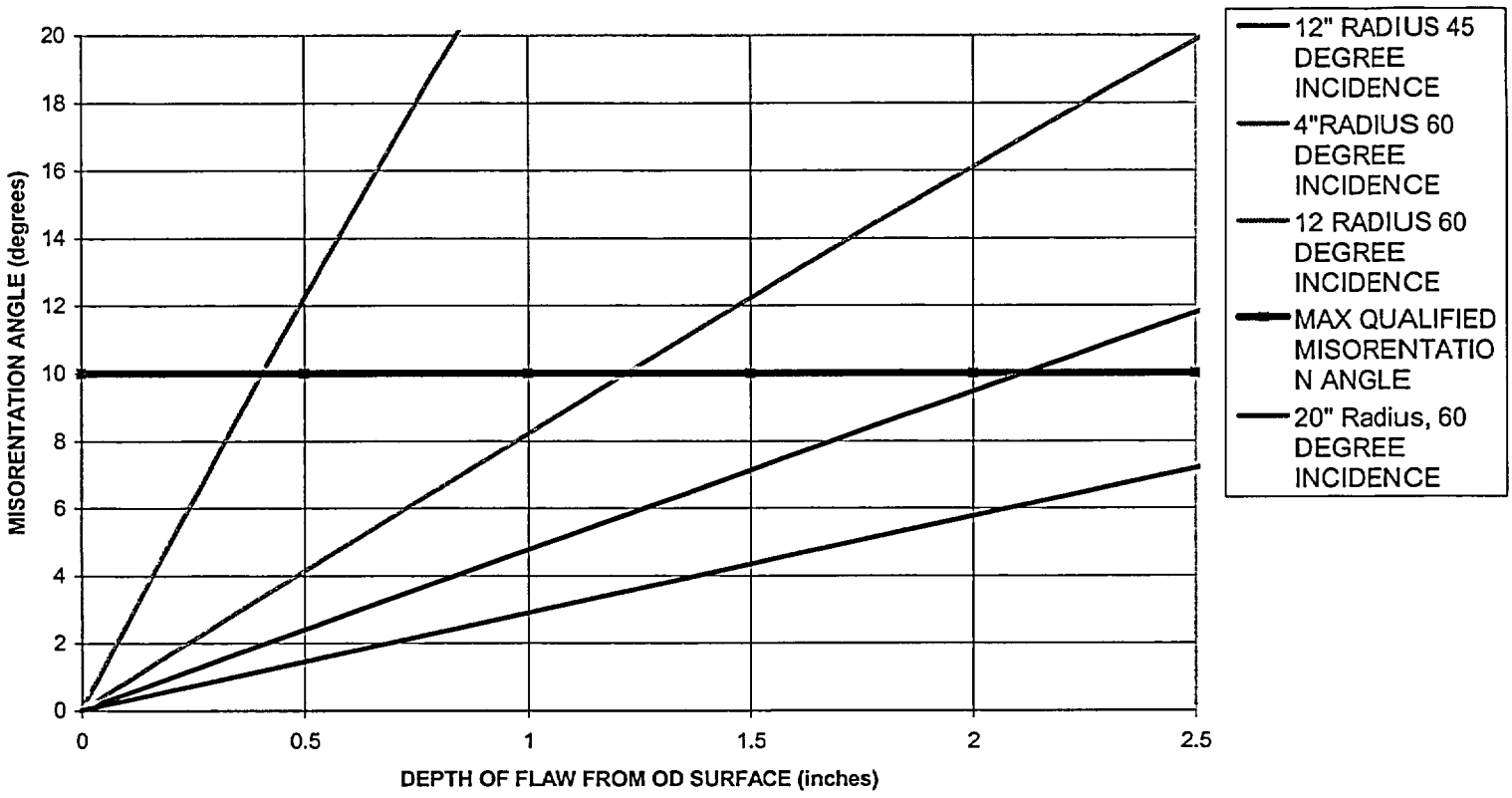

Figure 2 Misorientation Angle As Function Of Depth For Nozzle Weld Radii Of 4, 12 And 20 Inches And 60° And 45° Incident Angles.

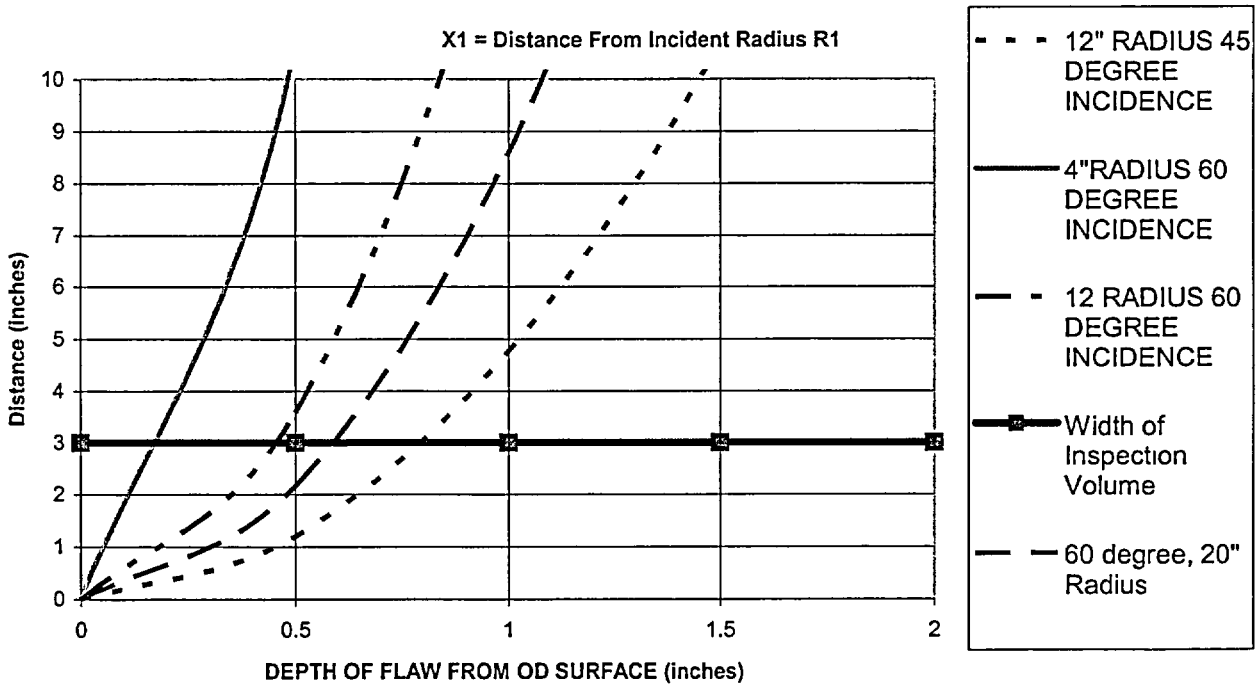

Figure 3. Displacement Distance Versus Depth as a Function of the Weld Radius and the Incident Angle "Θ_I.

Supplement 6 procedures from the outside surface of the RPV are qualified for an incident angle "Θ_i" of 60° and a misorientation angle Θ_3 of up to 10°. Displacements of greater than 3 to 4 inches would place the beam outside of the weld and the inspection volume.

Figure 3 illustrates that for the 60° incident angle, the inspection beam would fall outside the inspection volume at a depth of slightly more than 0.5 inch for the 28-inch nozzle. The misorientation angle effect, shown in Figure 2, is less than that of the displacement shown in Figure 3. However, if the beam is outside the inspection volume, the misorientation angle is of little concern.

In order to have a reasonable expectation of detecting flaws in the outer 85% of the weld, it would be necessary to adjust the radial position and the skew angle of the transducer relative to the radial direction. To accomplish this, the transducer radial position would be adjusted to R_2 as in equation (5). The skew angle (the beam propagation direction relative to the radial direction) would need to be adjusted to Θ_3 as in equation (2). Both R_2 and Θ_3 vary with the depth of the target flaw below the surface, requiring a number of scans in addition to the radial inward scans. The number of additional scans would depend on the slope of the curves shown in Figures 2 and 3. This optimization process is not within the Scope of Appendix VIII Supplement 6. The case presented here is for a flat plate; the case for a cylindrical nozzle intersecting a curved plate would be more extreme.

The closest approach to demonstrating an effective procedure for this application would be the ASME Code, Section XI, Appendix VIII, Supplement 5, which is only applicable to the inner 10% of the vessel thickness. Extending Supplement 5 qualifications to the outer 85% would require modifications to Section XI Appendix VIII Supplement 5, Appendix I, and 10CFR50.55a. The ASME Code, Section XI, Appendix I, 2001 Edition, 2002 Addenda (4) currently states that the examination for flaws perpendicular to the nozzle-to-shell weld centerline is not required in the outer 85% of the weld volume.

The addition of circumferential scans for the outer 85% of the nozzle-to-shell weld would add approximately 40 hours to a PWR examination. BWR plans have even more nozzles and would require even more examination time. Another consideration is that BWR examinations are performed from the outside surface, which would result in increased personnel radiation exposure. A study by the EPRI Boiling Water Reactor Vessel Internals Program (BWR VIP) has demonstrated that for the limiting case of a transverse flaw at the inside surface perpendicular to the weld centerline, the total failure probability was on the order of $2.5\ 10^{-11}$ per year. For flaws in the outer 85%, of the nozzle-to-shell weld, the failure probability would be much smaller.

Summary

The PDI Program requests that the NRC confirm its previous positions as stated in the Final Rule of September 22, 1999:

1. The contents of Table VIII-S7-1, 10CFR50.55a(b)(2)(xv)(K)(4) and proposed Code Case N-613-1 are the target flaws of interest in the outer 85% of the nozzle-to-shell weld.
2. The scanning and coverage requirements for the outer 85% of the nozzle-to-shell weld are as a minimum one radial direction, as per the requirements of 10CFR50.55a(b)(2)(K)(3)(ii).
3. The requirements of 10CFR50.55(b)(2)(xv)(G)(3) and (4) address the qualification of procedure, personnel, and equipment. They do not require circumferential scanning of the outer 85% of the nozzle-to-shell weld.
4. Subparagraph (K)(4) modifies the qualification requirements of Supplement 6 to remove from consideration flaws perpendicular to the weld, in the outer 85% of the weld.

The orthogonal scans of Supplement 6 are not qualified for the detection of flaws perpendicular to the nozzle-to-shell weld without mounting a new performance demonstration program that is currently not described in Appendix VIII. The new program would require additional samples and modifications to Appendix VIII and 10CFR50.55a. It would also require that Appendix I and the NRC proposed Code Case N-316-1 be changed to include the requirement for the detection of flaws perpendicular the nozzle to shell weld in the outer 85% of the weld.

The application of an unqualified technique in the hope that it might detect something in an area of little interest is not prudent. Performance demonstration has greatly improved the effectiveness of RPV examinations. Performing examinations that are ineffective degrades the credibility of the overall program of examinations. Thank you for your consideration of our request.

N-613-1

References

1. ASME Code, Section XI, 1995 Edition, 1996 Addenda and beyond, Appendix VIII "Performance demonstration for Ultrasonic Examination Systems", Supplement 6 "Qualification Requirements for Reactor Vessel Welds Other than Clad/Base metal Interface".

2. ASME Code, Section XI, 1995 Edition, 1996 Addenda and beyond, Appendix VIII "Performance demonstration for Ultrasonic Examination Systems", Supplement 5 "Qualification Requirements for Nozzle Inside Radius section".

3. ASME Code Case N-622 "Ultrasonic Examination of RPV and Piping, Bolts and Studs, Section XI, Div 1, A-1300 (b)(2), Approved February 26, 1999.

4. ASME Code, Section XI, 2001 Edition, 2002 Addenda, Appendix I " Examination Requirements", I-3000 Examination Coverage, I-3420 (b).

5. ASME Code Case N-552, "Alternative Methods – Qualification for Nozzle Inside Radius Section from the Outside Surface", Section XI, Div 1, approved December 12, 1995.

6. ASME Code Case N-613-1, "Ultrasonic Examination of Full Penetration Nozzles in Vessels, Category B-D, Item No's B3.10 and B3.90, Reactor Vessel-To-Nozzle Welds Fig.-2500-7(a), (b), and (c) Section XI, Division 1, Passed Main Committee.

7. *Technical Basis for Reduction of Inspection Requirements for the Boling Water Reactor Nozzle-to-Vessel Shell Welds and Nozzle Blend Radii,* EPRI, Palo Alto, CA 2001. 1003020, September 2002.