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919-362-2502

10 CFR 50.55a

November 22, 2013
Serial: HNP-13-119

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Shearon Harris Nuclear Power Plant, Unit No. 1
Docket No. 50-400

Subject: Relief Request I3R-13, Reactor Vessel Closure Head Nozzle 37, Inservice Inspection Program – Third Ten-Year Interval

Ladies and Gentlemen:

Pursuant to 10 CFR 50.55a(a)(3)(i), Duke Energy Progress, Inc., hereby requests NRC approval of the attached relief request for the Shearon Harris Nuclear Power Plant, Unit 1 (HNP) inservice inspection program, third ten-year interval. On November 18, 2013, while HNP was shut down for a scheduled refueling outage, the reactor vessel closure head penetrations were being examined in accordance with Inservice Inspection Program. Ultrasonic examinations identified a flaw in head penetration nozzle 37. Bare metal visual inspection of the outer surface of the reactor vessel head revealed no indications of leakage. HNP plans to perform a repair to reactor vessel closure head nozzle penetration 37 utilizing the inside diameter temper bead welding method. HNP has determined that repair of the nozzle penetration, utilizing the alternatives specified in this request, would provide an acceptable level of quality and safety. The request describes one nozzle to be repaired and is similar to relief requests I3R-09 and I3R-11 previously approved by the NRC staff (ADAMS Accession Numbers ML12270A258 and ML13238A154). Relief is requested in accordance with 10 CFR 50.55a(a)(3)(i). The provisions of this relief are applicable to the third ten-year inservice inspection interval for HNP which commenced on May 2, 2007 and will end on May 1, 2017.

HNP requests approval of this request by December 3, 2013, to support restart from the current outage.

This document contains no new regulatory commitments.

Please refer any questions regarding this submittal to John Caves at (919) 362-2406.

Sincerely,

Enclosure: Relief Request I3R-13 Reactor Vessel Closure Head Nozzle 37

cc: Mr. J. D. Austin, NRC Sr. Resident Inspector, HNP
Mr. A. Hon, NRC Project Manager, HNP
Mr. V. M. McCree, NRC Regional Administrator, Region II

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Relief Request I3R-13
Reactor Vessel Closure Head Nozzle 37
Inservice Inspection Program – Third Ten-Year Interval

Proposed Alternative
in Accordance with 10 CFR 50.55a(a)(3)(i)
Alternative Provides Acceptable Level of Quality and Safety

1. ASME Code Components Affected

Components:	Reactor Vessel Closure Head Penetration Nozzle 37
Code Class:	Class 1
Examination Category:	B-P
Code Item Number:	B4.20 (Code Case N-729-1, Alternative Examination Requirements for PWR Reactor Vessel Upper Heads with Nozzles Having Pressure-Retaining Partial-Penetration Welds, Section XI, Division 1)
Description:	Reactor Vessel Closure Head Penetration Nozzles
Size:	4 Inch Nominal Outside Diameter
Material:	Inconel SB-167

2. Applicable Code Edition and Addenda

Shearon Harris Nuclear Power Plant, Unit No. 1 (HNP), Inservice Inspection Program (ISI) – Third Interval	American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI, 2001 Edition through 2003 Addenda
Shearon Harris Nuclear Power Plant, Unit No. 1, Reactor Vessel Closure Head Code of Construction	American Society of Mechanical Engineers Boiler and Pressure Vessel Code Section III, 1971 Edition through Winter 1971 Addenda

3. Applicable Code Requirements

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWA-4221(b) states:

> An item to be used for repair/replacement activities shall meet the Construction Code specified in accordance with (1), (2) or (3) below.

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWA-4221(c) states in part:

> As an alternative to (b) above, the item may meet all or portions of the requirements of different Editions and Addenda of the Construction Code, or Section III…provided the requirements of IWA-4222 through IWA-4226, as applicable, are met…..

ASME Code, Section XI, 2001 Edition through 2003 Addenda, IWA-4400 provides welding, brazing, metal removal, and installation requirements related to repair/replacement activities.

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWA-4411 states:

> Welding, brazing, and installation shall be performed in accordance with the Owner's Requirements and, except as modified below, in accordance with the Construction Code of the item.

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWA-4411(a) states in part:

> Later editions and addenda of the Construction Code, or a later different Construction Code, either in its entirety or portions thereof, and Code Cases may be used, provided the substitution is as listed in IWA-4221(c).

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWA-4610(a) states in part:

> Thermocouples and recording instruments shall be used to monitor the process temperatures.

Code Case N-638-1, *Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique,* provides requirements for automatic or machine gas tungsten arc welding (GTAW) of Class 1 components without the use of preheat or postweld heat treatment.

Code Case N-638-1 paragraph 3.0(d) states:

> The maximum interpass temperature for field applications shall be 350° F regardless of the interpass temperature during qualification.

Code Case N-638-1 paragraph 4.0(b) states:

> The final weld surface and the band around the area defined in paragraph 1.0(d) shall be examined using a surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours. The ultrasonic examination shall be in accordance with Appendix I.

Code Case N-729-1, *Alternative Examination Requirements for PWR Reactor Vessel Upper Heads with Nozzles Having Pressure-Retaining Partial-Penetration Welds* Section XI, Division 1, Fig. 2, "Examination Volume for Nozzle Base Metal and Examination Area for Weld and Nozzle Base Metal", is applicable to the RVCH nozzle penetrations.

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWA-4611.1(a) states:

> Defects shall be removed in accordance with IWA-4422.1. A defect is considered removed when it has been reduced to an acceptable size.

ASME Code, Section XI, 2001 Edition through 2003 Addenda, IWA-3300 specifies requirements for characterization of flaws detected by inservice examination.

ASME Code, Section XI, 2001 Edition through 2003 Addenda, IWB-3420 states:

> Each detected flaw or group of flaws shall be characterized by the rules of IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of IWB-3500.

ASME Code, Section XI, 2001 Edition through 2003 Addenda IWB-3132.3 states:

> A component whose volumetric or surface examination detects flaws that exceed the acceptance standards of Table IWB-3410-1 is acceptable for continued service without a repair/replacement activity if an analytical evaluation, as described in IWB-3600, meets the acceptance criteria of IWB-3600. The area containing the flaw shall be subsequently reexamined in accordance with IWB-2420 (b) and (c).

4. Reason for Request

An indication requiring repair was detected during an Inservice Inspection Program ultrasonic (UT) examination of the HNP Reactor Vessel Closure Head (RVCH) nozzle penetrations. Nozzle 37 will be repaired under this request. Figure 10 shows the location of the axial indication and Figure 11 shows the relative location of the nozzle on the RVCH. Table 1 provides sizing and characterization information on the flaw leading to the repair activity. The flaw is in the tube outside diameter (OD) surface extending inward toward the tube inside diameter (ID) and is axially oriented at the lower toe side of the weld.

Because of the risk of damage to the RVCH material properties or dimensions, it is not feasible to apply the post welding heat treatment requirements of the original Construction Code. As an alternative to the requirements of RVCH Code of Construction, ASME Section III, 1971 including Addenda through Winter 1971, HNP proposes to perform the repair of the RVCH nozzle penetration utilizing the Inside Diameter Temper Bead (IDTB) welding method to restore the pressure boundary of the degraded nozzle penetration. The IDTB welding method is performed with a remotely operated weld tool, utilizing the machine GTAW process and the ambient temperature temper bead method with 50° F minimum preheat temperature and no post weld heat treatment. The repair will be performed in accordance with the 2001 Edition through the 2003 Addenda of ASME Section XI, Code Case N-638-1, Code Case N-729-1, and the alternatives discussed below.

Basic steps for the IDTB repair are:

1. Removal of lower portion of existing Thermal Sleeve Assembly at applicable penetration to provide access for IDTB weld repair.
2. Roll expansion above the area of repair. This stabilizes the nozzle to prevent any movement when the nozzle is separated from the nozzle to RVCH J-groove weld.
3. Machining to remove the nozzle to above the J-groove weld eliminating the portions of the nozzle containing the unacceptable indication. This machining operation also establishes the weld prep area (Refer to Figure 1).

4. Liquid penetrant (PT) examination of the machined area (Refer to Figure 3).
5. Welding the remaining portion of the nozzle to the RVCH using primary water stress corrosion cracking (PWSCC) resistant Alloy 52M weld material (Refer to Figure 2). Alloy 82 weld material may be used at the interface between the Alloy 182 existing weld and the Alloy 52M new weld if necessary.
6. Machining the weld and nozzle to provide a surface suitable for nondestructive examination (NDE).
7. PT and UT examination of the weld and adjacent area (Refer to Figure 3).
8. Abrasive water jet machining (AWJM) remediation on the portion of the remaining nozzle most susceptible to PWSCC. The AWJM process removes a small amount of material thickness while imposing compressive residual stress on the nozzle surface.
9. PT examination of the weld and adjacent area.
10. Welding of new Lower Thermal Sleeve Assembly.

Note that the figures included in this request are provided to assist in clarifying the description above. The location of the weld relative to the inner and outer radii of the head, and the existing J-groove weld will vary depending upon the location of the nozzle and as-found dimensions.

HNP has determined that repair of the RVCH nozzle penetration utilizing the alternatives specified in this request will provide an acceptable level of quality and safety. Relief is requested in accordance with 10 CFR 50.55a(a)(3)(i).

5. Proposed Alternative and Basis for Use

a. Monitoring of Interpass Temperature

Code Case N-638-1 paragraph 3.0(d) states:

> The maximum interpass temperature for field applications shall be 350° F regardless of the interpass temperature during qualification.

Code Case N-638-1 states that all other requirements of IWA-4000 must be met when using this Case. IWA-4610(a) requires that thermocouples and recording instruments be used to monitor process temperatures. Direct interpass temperature measurement is impractical to perform during welding operations from inside the RVCH nozzle penetration bore. The maximum interpass temperature will be determined by one of the following methods:

(1) Heat-flow calculations, using at least the variables listed below.

   (a) Welding heat input
   (b) Initial base material temperature
   (c) Configuration, thickness, and mass of the item being welded
   (d) Thermal conductivity and diffusivity of the materials being welded

  - (e) Arc time per weld pass and delay time between each pass
  - (f) Arc time to complete the weld

(2) Measurement of the maximum interpass temperature on a test coupon that is no thicker than the item to be welded. The maximum heat input of the welding procedure shall be used in welding the test coupon.

This methodology is consistent with the associated requirements specified in Code Case N-638-2 and subsequent versions. Alternatives to Code Case N-638-1 interpass temperature monitoring requirements have been previously approved by the NRC for dissimilar metal weld overlays in HNP Inservice Inspection Relief Request I3R-1, ADAMS Accession Number ML072760737.

HNP requests relief from using thermocouples and recording instruments to verify process temperatures.

Method 1, the use of heat flow calculations, will be used to determine a conservative maximum anticipated interpass temperature to ensure interpass temperature limits are not exceeded. In the IDTB repair scenario, the maximum heat input of 32,200 Joules per inch with an average time of 1 minute between subsequent weld passes results in a calculated base material temperature increase of approximately 6° F. Based on AREVA’s experience with over 128 IDTB reactor vessel head nozzle repairs, the typical time between weld passes will be significantly greater than a minute as a result of weld sequencing, viewing previously deposited weld passes, completing paperwork, independent verifications, and routine equipment maintenance including tungsten electrode replacement.

b. Acceptance Examination Area

Code Case N-638-1 paragraph 4.0(b) states in part:

> The final weld surface and the band around the area defined in paragraph 1.0(d) shall be examined using a surface and ultrasonic methods …

Code Case N-638-1 paragraph 1.0(d) defines the area requiring preheat, and therefore examination, as the area to be welded and the band around the area of at least 1.5 times the component thickness or five inches, whichever is less.

The band includes an annular area extending five inches around the penetration bore on the inside surface of the RVCH. The purpose for the examination of the band is to ensure all flaws associated with the weld repair area have been removed, or addressed, since these flaws may be associated with the original flaw and may have been overlooked. For this modification, the repair welding is performed remote from the known flaw.

The band around the area defined in paragraph 1.0(d) cannot be examined due to the physical configuration of the partial penetration weld. The alternative final examination of the new weld and immediate surrounding area within the bore will be sufficient to verify that defects have not been induced in the low alloy steel RVCH material due to the welding process and will assure integrity of the nozzle and the new weld. Figure 3 identifies the areas for PT and UT examination of the modified nozzle penetration. UT examination will be performed by scanning from the inner diameter surface of the weld. The UT examination is qualified to detect construction type flaws in the new weld and base metal interface beneath the new weld. UT examination acceptance criteria will be in accordance with ASME Section III, 2001 Edition, including Addenda through 2003, NB-5330. The extent of the examination is consistent with Construction Code requirements.

Scanning is performed from the inside surface of the new weld and the adjacent portion of the nozzle, excluding the weld taper. The volume of interest for UT examination extends from at least one inch above the new weld and into the RVCH low alloy steel base material beneath the weld, to at least one-quarter inch depth. The PT examination area includes the weld surface and extends upward on the nozzle inside surface to include the area required by Code Case N-729-1, Figure 2, and at least one-half inch below the new weld. Figure 3 of this request identifies the area for PT examination of the modified nozzle penetration after machining and before welding.

ASME Section III, 2001 Edition including Addenda through 2003, NB-5245, specifies progressive surface examination of partial penetration welds. The original Construction Code requirement for progressive PT examination, in lieu of volumetric examination, was because volumetric examination is not practical for the conventional partial penetration weld configurations. For this modification the weld, except for the taper transition, is suitable for UT examination and a final surface PT examination can be performed as shown in Figure 3. Liquid penetrant examination will be performed on the entire weld, including the taper transition. In addition, 70˚L and 45˚L axial UT examination scans looking down (see Figures 5 and 7) will interrogate the taper transition volume. The performance of the surface and UT examinations provides assurance of structural integrity.

Code Case N-638-1, paragraph 4.0(b) requires that the specified volumetric examination be in accordance with Section XI, Appendix I. Paragraph 4.0(e) specifies acceptance criteria to be in accordance with IWB-3000.

ASME Code, Section XI, 2001 Edition through 2003 Addenda, IWB-3000 does not have any acceptance criteria that directly apply to the partial penetration weld configuration. Regulatory Guide 1.147, Rev. 15, has conditionally approved Code Case N-638-1 with the condition that UT volumetric examinations be performed with personnel and procedures qualified for the repaired volume and qualified by demonstration using representative samples which contain construction type flaws. The acceptance criteria of NB-5330, in ASME Section III, 2001 Edition through 2003 Addenda, will apply to all flaws identified within the repaired volume.

ASME Section III, 2001 Edition including Addenda through 2003, NB-5245 requires incremental and final surface examination of partial penetration welds. Due to the welding layer deposition sequence (i.e., each layer is deposited parallel to the penetration centerline), the specific requirements of NB-5245 cannot be met. The Construction Code requirement for progressive surface examination is because volumetric examination is not practical for conventional partial penetration weld configurations. For this modification, the repair weld is suitable, except for the taper transition, for UT examination and a final surface examination.

The final examination of the repair weld and immediate surrounding area will be sufficient to verify that defects have not been induced in the ferritic low alloy steel RVCH base material due to the welding process. PT examination coverage is shown in Figure 3. UT examination will be performed scanning from the inside surface of the weld, excluding the transition taper portion at the bottom of the weld, and adjacent portion of the nozzle bore. The UT examination is qualified to detect flaws in the new weld and base metal interface in the repair region, to the maximum practical extent.

The UT transducers and delivery tooling are capable of scanning from cylindrical surfaces with inside diameters near 2.75 inches. The UT equipment is not capable of scanning from the face of the weld taper. The scanning is performed using 0° L-wave, 45° L-wave, and 70° L-wave transducers. Approximately 70% of the weld surface will be scanned by UT. Approximately 83% of the RVCH ferritic steel heat affected zone will be covered by UT. The UT examination coverage volumes are shown in Figures 4 through 8 for the various scans.

The repair weld produces a region that limits the examination volume. The downward aimed angle beam transducers (45˚L and 70˚L) are used to interrogate this area for defects (planar defects normal to the beam, cracking, lack-of-fusion, etc.). The UT is being performed in addition to the surface examinations. There is no portion of the repair volume that does not receive at least single direction UT coverage. The actual volume examined will be calculated after the as-built dimensions of the weld are known and the examination is performed. It is anticipated that greater than 80% of the examination volume will obtain two-directional coverage.

PT examination will be performed on the entire surface area. In addition, the volume in question will be examined to the extent practical using the 70˚L and 45˚L (see Figures 5 and 7) axial UT examination scans (looking down). There is no portion of the repair that does not receive surface liquid penetrant examination and at least single-direction UT coverage of the volume.

Examination of the area depicted in Figure 3 will assure that all unacceptable flaws associated with the weld repair area have been removed.

HNP requests relief from examination of the area defined in Code Case N-638-1, paragraph 1.0(d).

c. 48 Hour Hold

Code Case N-638-1 paragraph 4.0(b) states in part:

> The final weld surface and the band around the area defined in paragraph 1.0(d) shall be examined using a surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours…

Hydrogen cracking is a form of cold cracking. It is produced by the action of internal tensile stresses acting on low toughness heat affected zones. The internal stresses are produced from localized build-ups of monatomic hydrogen. Monatomic hydrogen forms when moisture or hydrocarbons interact with the welding arc and molten weld pool. The monatomic hydrogen can be entrapped during weld solidification and tends to migrate to transformation boundaries or other microstructure defect locations. As concentrations build, the monatomic hydrogen recombines to form molecular hydrogen – thus generating localized internal stresses at these internal defect locations. If these stresses exceed the fracture toughness of the material, hydrogen induced cracking occurs. This form of cracking requires the presence of hydrogen and low toughness materials. It is manifested by intergranular cracking of susceptible materials and normally occurs within 48 hours of welding.

The machine GTAW process is inherently free of hydrogen. Unlike the shielded metal arc welding process, GTAW filler metals do not rely on flux coverings that may be susceptible to moisture absorption from the environment. Conversely, the GTAW process utilizes dry inert shielding gases that cover the molten weld pool from oxidizing atmospheres. Any moisture on the surface of the component being welded is vaporized ahead of the welding torch. The vapor is prevented from being mixed with the molten weld pool by the inert shielding gas that blows the vapor away before it can be mixed. Furthermore, modern filler metal manufacturers produce wires having very low residual hydrogen. This is important because filler metals and base materials are the most realistic sources of hydrogen for the automatic or machine GTAW temper bead welding. Therefore, the potential for hydrogen-induced cracking is greatly reduced by using the machine GTAW process. Extensive research has been performed by EPRI. EPRI Report 1013558, *Temperbead Welding Applications, 48 Hour Hold Requirements for Ambient Temperature Temperbead Welding* (ADAMS Accession Number ML070670060), provides justification for starting the 48-hour hold after completing the third temper bead weld layer rather than waiting for the weld to cool to ambient temperature.

HNP requests relief from commencing the 48 hour hold period when the weld reaches ambient temperature. The 48 hour hold period will commence upon completion of the third weld layer. This approach has been previously considered by the NRC staff in the conditional approval of N-638-4 in Rev. 16 of Regulatory Guide 1.147 when using austenitic materials and for dissimilar metal weld overlays in the approval of HNP Relief Request I3R-1, ADAMS Accession Number ML072760737.

d. Triple Point Anomaly

ASME Section III, 2001 Edition including Addenda through 2003, NB-5330(b) states:

> Indications characterized as cracks, lack of fusion, or incomplete penetrations are unacceptable regardless of length.

An artifact of ambient temperature temper bead welding is an anomaly in the weld at the triple point. The triple point is the point in the repair weld where the low alloy steel RVCH base material, the Alloy 600 nozzle, and the Alloy 52M weld intersect. The location of the triple point anomaly is shown in Figure 2. This anomaly consists of an irregularly shaped very small void. Mock-up testing has verified that the anomalies are common and do not exceed 0.10 inches in length and are assumed to exist, for purposes of analysis, around the entire bore circumference at the triple point elevation.

A fracture mechanics analysis has been performed for the design configuration to provide justification, in accordance with Section XI, for operating with the postulated triple point anomaly. The anomaly is modeled as a 0.10 inch, circular crack-like defect, extending 360 degrees around the circumference at the triple point location, considering the most susceptible material for propagation. Postulated flaws could be oriented within the anomaly such that there are two possible flaw propagation paths, as discussed below.

Path 1: Flaw propagation is across the nozzle wall thickness from the OD to the ID of the nozzle housing (analysis paths 1 & 2).

> This is the shortest path through the new Alloy 52M weld material. By using a fatigue crack growth rate twice that of the rate of Alloy 600 material, it is ensured that another potential path through the heat affected zone between the new repair weld and the Alloy 600 nozzle material is also bounded.
>
> For completeness, two types of flaws are postulated at the outside surface of the nozzle IDTB repair weld. A 360 degree continuous circumferential flaw, lying in a horizontal plane, is considered to be a conservative representation of crack-like defects that may exist in the weld triple point anomaly. This flaw is subjected to axial stresses in the nozzle. An axially oriented semi-circular outside surface flaw is also considered since it

would lie in a plane normal to the higher circumferential stresses. Both of these flaws would propagate toward the inside surface of the nozzle.

Path 2: Flaw propagation extends down the outside surface of the repair weld between the weld and the RVCH (analysis paths 3 through 6).

A cylindrically oriented flaw is postulated to lie along this interface, subjected to radial stresses with respect to the nozzle. This flaw may propagate through either the new Alloy 52M weld material or the low alloy steel RVCH base material.

The results of the analyses demonstrate that the 0.10 inch weld anomaly is acceptable for a 40 year design life of the HNP nozzle repair. The minimum fracture toughness margins for flaw propagation Paths 3 through 6 have been shown to be acceptable compared to the required margins of $\sqrt{10}$ for normal/upset conditions and $\sqrt{2}$ for emergency/faulted (and test) conditions per Section XI, IWB-3612. A limit load analysis was performed considering the ductile weld repair material along flaw propagation Path 1 & 2. The analysis showed that for the postulated circumferential flaw the minimum margin on allowable stress is 1.43. For the axial flaw the minimum margin on allowable flaw depth is 3.9. Fracture toughness margins have also been demonstrated for the postulated cylindrical flaws. For the cylindrical flaws, it is shown that the applied shear stress at the remaining ligament is less than the allowable shear stress per NB-3227.2.

The final crack size (length and depth) in the axial and circumferential direction at the end of 40 years is:

- Axial flaw: final depth (a_f) is 0.1008 inch, since length/depth is 2, length = 0.202 inch.
- Circumferential flaw: the final flaw depth of the 360° circumferential flaw is 0.1002 inch.

The final crack sizes are acceptable based on ASME Code, Section XI, IWB-3640 flaw evaluations which demonstrate that the final flaw sizes satisfy the applicable Code acceptance criteria, as discussed below.

For flaws in the IDTB weld, the applicable section is IWB-3640. Following the procedures in IWB-3641 and acceptance criteria of IWB-3642 the flaw evaluation based on Appendix C is performed.

For the circumferential flaw, the stress margin is calculated per Article C-5000 of ASME Code Section XI.

The stress margin:

$S_t/\sigma_m = 1.43$ where σ_m is the membrane stress,
$S_t = \sigma_m{}^c/SF_{m,}$ where $\sigma_m{}^c$ is the critical membrane stress, and
SF_m is the safety factor of 2.7 per C-2620

For axial flaws, the calculated stress ratio ($SF_m\ \sigma_h/\sigma_f$) is 0.519 and the nondimensional flaw length is 0.211. Thus the allowable flaw size (a/t) determined from Table C-5410-1 of ASME Code Section XI is 0.75 and allowable flaw depth is 0.395 inch. Thus the allowable flaw size margin, a_{allow}/a_f= 3.9.

The margins of 1.43 for circumferential and 3.9 for axial flaws exceed the required margins of the ASME Code; therefore, the flaw evaluations demonstrate that the required margins of IWB-3600 are satisfied.

The fracture margin calculation includes the required safety factors and hence the required margin is only 1.0. Thus the calculated margins, 1.43 for circumferential flaws and 3.9 for axial flaws, are acceptable.

This evaluation is prepared in accordance with ASME Section XI and demonstrates that for the intended service life of the repair, the fatigue crack growth is acceptable and the crack-like indications remain stable. This satisfies the ASME Section XI criteria but does not include considerations of stress corrosion cracking such as PWSCC. Since the crack-like defects due to the weld anomaly are not exposed to the primary coolant and the air environment is benign for the materials at the triple point, the time-dependent crack growth rates from PWSCC are not applicable.

Relief is requested to permit anomalies, as described herein, at the triple point area to remain in service.

e. Flaw Characterization and Successive Examinations - RVCH Original J-Groove Weld

The assumptions of IWB-3600 are that cracks are fully characterized in order to compare the calculated parameters to the acceptable parameters addressed in IWB-3500. The original nozzle-to-RVCH J-groove weld is extremely difficult to examine with UT due to the compound curvature and fillet radius around the nozzle circumference. These conditions preclude UT coupling and control of the sound beam needed to perform flaw sizing with reasonable confidence in the measured flaw dimensions. Therefore, it is impractical to characterize the flaw geometry that may exist therein. As these J-groove welds have not been fully examined with qualified techniques, they are assumed to have unacceptable flaws.

A flaw in the J-groove weld cannot be sized by currently available nondestructive examination techniques. It is conservatively assumed that the “as-left” condition of the remaining J-groove weld includes flaws extending through the entire Alloy 82/182 J-groove weld and butter material. It is further postulated that the dominant hoop stresses in the J-groove weld would create a situation where the preferential direction for cracking would be radial. A radial crack in the Alloy 82/182 weld metal would propagate by PWSCC, through the weld and butter, to the interface with the low alloy steel head material, where it would blunt, or arrest. Any growth of the postulated as-left flaw into the low alloy steel head would be by fatigue crack growth under cyclic loading conditions.

The J-groove flaws have been evaluated for acceptance in accordance with the analytical evaluation requirements of IWB-3132.3 using worst-case postulated flaw sizes. The results of this evaluation show that, based on a combination of linear elastic and elastic-plastic fracture mechanics analysis of a postulated remaining flaw in the original Alloy 182 J-groove weld and butter material, the HNP RVCH nozzle repair design configuration is considered to be acceptable for 30 years of operation following an IDTB weld repair.

Linear-elastic (LEFM) and elastic-plastic (EPFM) fracture mechanics analyses were used to demonstrate that the remaining worst-case as-left J-groove flaw would be acceptable for 30 years of service. Although the postulated flaw did not satisfy ASME Code Section XI IWB-3612 for all transient loading conditions, LEFM analysis

- determined that the uphill side of the reactor head penetration was the worst case position for the postulated flaw,
- calculated the final flaw size by fatigue crack growth, and
- identified the controlling service conditions for evaluation by EPFM.

For normal and upset conditions, the controlling loading condition was identified to be a reactor trip, for which it was shown, using safety factors of 1.5 on primary loads and 1.0 on secondary loads, that the applied J-integral (0.785 kips/in) was less than the J-integral of the low alloy steel head material (2.473 kips/in) at a crack extension of 0.1 inch. For emergency and faulted conditions, the controlling loading condition was a large loss of coolant accident, for which it was shown that with safety factors of 1.5 on primary loads and 1.0 on secondary loads that the applied J-integral (2.359 kips/in) was less than the J-integral of the low alloy steel head material (2.474 kips/in) at a crack extension of 0.1 inch. Flaw stability during ductile flaw growth was easily demonstrated for both loading conditions using safety factors of 3.0 and 1.5 for the reactor trip and 1.5 and 1.0 for the large loss of coolant accident.

It is believed that the flaws that have been detected by UT examination have been removed when the lower portion of the nozzle was machined away from the J-groove weld. However, as discussed above, flaws are postulated to exist in the remaining portion of the J-groove weld and shown in the evaluation to be acceptable for 30 years of service.

Successive examinations required by IWB-3132.3 will not be performed because analytical evaluation of the worst-case postulated flaw is performed to demonstrate the acceptability of continued operation. A reasonable assurance of the RVCH structural integrity is maintained without the successive examination by the fact that evaluation has shown the worst case flaw to be acceptable for continued operation.

Relief is requested from flaw characterization and subsequent examination requirements.

The potential for debris from a cracking J-groove partial penetration weld was considered. Radial cracks were postulated to occur in the weld due to the dominance of hoop stresses at this location. This possibility of occurrence of transverse cracks that could intersect the radial cracks is considered remote. There are no forces that would drive a transverse crack. The radial cracks would relieve the potential transverse crack driving forces. Hence it is unlikely that a series of transverse cracks could intersect a series of radial cracks resulting in any fragments becoming dislodged.

f. Inservice Inspections

Code Case N-729-1 provides requirements for the inservice inspection of RVCHs with nozzles having partial penetration welds. Code Case N-729-1 Table 1, Item 4.20, permits either volumetric or surface examination. Item 4.20 examination requirements are specified in Figure 2 of Code Case N-729-1. The repair proposed by this relief request removes much of the examination area depicted in this figure at several locations. Figure 9 of this relief request will be used to establish the examination area for the preservice inspection following repair and for future inservice inspections. This examination area is equivalent to that required by Figure 2 in Code Case N-729-1, as it examines the nozzle weld and the same area above the nozzle weld as would be required by Figure 2 in the Code Case.

Therefore, inservice inspection will comply with Code Case N-729-1 as modified by 10 CFR 50.55a(g)(6)(ii)(D) and as depicted in Figure 9.

g. General Corrosion Impact on Exposed Low Alloy Steel

The IDTB nozzle repair leaves a small portion of low alloy steel in the RVCH exposed to primary coolant. An evaluation was performed for the potential corrosion concerns at the RVCH low alloy steel (LAS) wetted surface. Galvanic corrosion, hydrogen embrittlement, SCC, and crevice corrosion are not expected to be a concern for the exposed LAS base metal. General corrosion of the exposed LAS base metal will occur in the area between the IDTB weld and the J-groove weld. The general corrosion rate is conservatively estimated to be 0.0036 inch/year. The corrosion of the exposed base metal has negligible impact on the RVCH and is acceptable for 40 years from the time the modification is installed.

CONCLUSIONS

Implementation of an IDTB repair to the RVCH nozzle penetration will produce an effective repair that will restore and maintain the pressure boundary integrity of the HNP RVCH. Similar repairs have been performed successfully and have been in service for several years without any known degradation. The alternative provides improved structural integrity and reduced likelihood of leakage for the primary system. Accordingly, the use of the alternative provides an acceptable level of quality and safety in accordance with 10 CFR 50.55a(a)(3)(i).

6. Duration of Proposed Alternatives

The analyses described above and others in the modification that will be implemented under 10 CFR 50.59 support a design life expectancy of 14.8 effective full power years. The analysis results are based upon expected repair parameters which may vary during implementation. The design lifetime is sensitive to the length of the Alloy 52M weld ligament, and the actual limiting ligament length may vary depending upon the as-found and as-left conditions. The design life will be re-evaluated if necessary using as-built data and incorporated into the modification, future NDE inspection schedules, and asset management plans. HNP plans to replace the RVCH prior to exceeding the design life of the repair.

The 14.8 EFPY life is based on PWSCC of the remaining Alloy 600 nozzle. AWJM will create a compressive stress layer (at least 0.003 inches thick) on the surface of the Alloy 600 nozzle in areas adjacent to the IDTB weld and at the roll transition location where elevated tensile stresses may be present. AWJM is applied from the top of the weld (elevation of points p and h on Figure 3), to two inches above the top of the weld.

Since the stresses created by the AWJM process are compressive, PWSCC is not expected in this layer. An undetected flaw 0.002 inches deep (twice the maximum particle depth of the AWJM abrasive material) was assumed, which leaves a compressive stress layer 0.001 inches thick. General corrosion of a 0.001 inch thick compressive layer was estimated to take 12.5 EFPY. Once the compressive stress layer is removed by general corrosion, it was assumed that PWSCC would initiate immediately. It was estimated to take 2.3 EFPY for the PWSCC crack to propagate to 75% of the original Alloy 600 nozzle wall thickness. Therefore, the total estimated life of the repair is 14.8 EFPY.

The 30 year life is predicted based on the as-left J-groove flaw evaluation. The 14.8 EFPY is based on a separate PWSCC evaluation in the exposed original Alloy 600 nozzle. The overall acceptable life of the repair design is based on the most limiting life predicted amongst the weld anomaly analysis, the as-left J-groove analysis and the PWSCC evaluation of the original Alloy 600 nozzle, which is 14.8 EFPY.

The provisions of this relief are applicable to the third ten-year inservice inspection interval for HNP which commenced on May 2, 2007 and will end on May 1, 2017. The repairs installed in accordance with the provisions of this relief shall remain in place for the design life of the repair, until another alternative is approved by the NRC, or until the RVCH is replaced.

7. Additional Information

a. Mockup

AREVA, in support of over 128 similar repairs, has performed many qualifications using mockups since the IDTB control rod drive mechanism nozzle repairs at Oconee Nuclear Station in 2001. During these repair evolutions, the site crew performs training on mockups for each of their respective specialties, i.e., machinists train on machining mockups, welders train on welding mockups, and NDE personnel train on NDE mockups.

An IDTB weld repair NDE mockup was fabricated to replicate the expected configuration. It contains a series of electrical-discharge machining (EDM) notches at the triple point to simulate the triple point anomaly at various depths into the nozzle wall and cracking at the IDTB weld to low alloy steel interface. It also contains flat bottom holes drilled from the mockup outer diameter so that the hole is normal to the surface to simulate under bead cracking, lack of bond, and lack of fusion.

An Inconel calibration block is used and contains a series of EDM notches at nominal depths of 10%, 25%, 50%, and 75% deep from both ID and OD surfaces in both the axial and circumferential orientation. The block also contains 1/4T, 1/2T, and 3/4T deep end holes and side drilled holes that are used for calibration.

This is the same mockup used for the procedure qualification for the Davis Besse CRDM nozzle repairs in 2010.

b. ASME Code Case N-638-1

HNP adopted ASME Code Case N-638-1 in the Third Interval Inservice Inspection Program submittal to the NRC as HNP-08-038 (ADAMS Accession No. ML081330463). Later revisions of the code case have not been adopted.

8. <u>Precedents</u>

1. Davis-Besse Nuclear Power Station Relief Request RR-A34, April 1, 2010, ADAMS Accession Number ML100960276.
2. Calvert Cliffs Nuclear Power Plant Relief Request RR-PZR-0 1, January 31, 2011, ADAMS Accession Number ML110340059
3. Shearon Harris Nuclear Power Plant, Unit 1 -Relief Request I3R-09, October 2, 2012, ADAMS Accession Number ML12270A258
4. Shearon Harris Nuclear Power Plant, Unit 1 -Relief Request I3R-11, September 13, 2013, ADAMS Accession Number ML13238A154

9. References

1. EPRI Report 1013558, Temperbead Welding Applications, 48 Hour Hold Requirements for Ambient Temperature Temperbead Welding, EPRI, Palo Alto, CA and Hermann & Associates, Key Largo, FL, December 2006.
2. ASME Code Case N-638-1 Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, Section XI, Division 1.
3. NRC Regulatory Guide 1.147, Revision 15, Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1.
4. NRC Regulatory Guide 1.147, Revision 16, Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1
5. ASME Code Case N-729-1 Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial-Penetration Welds, Section XI, Division 1.

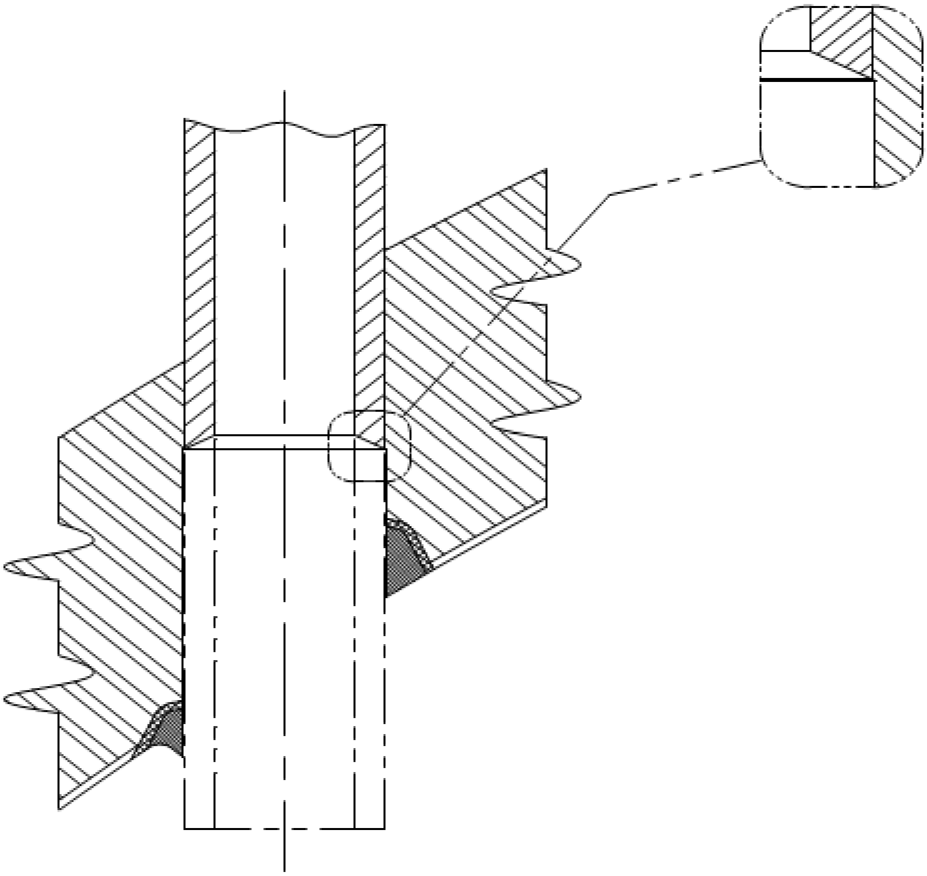


Figure 1. Machining

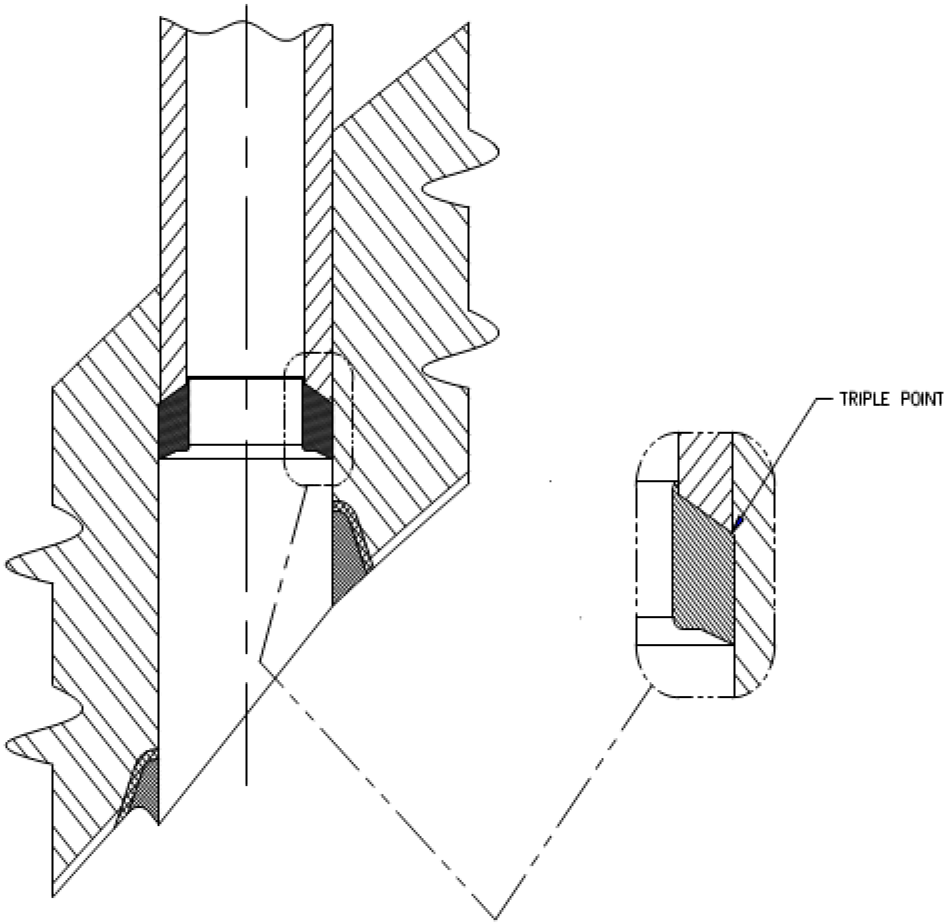
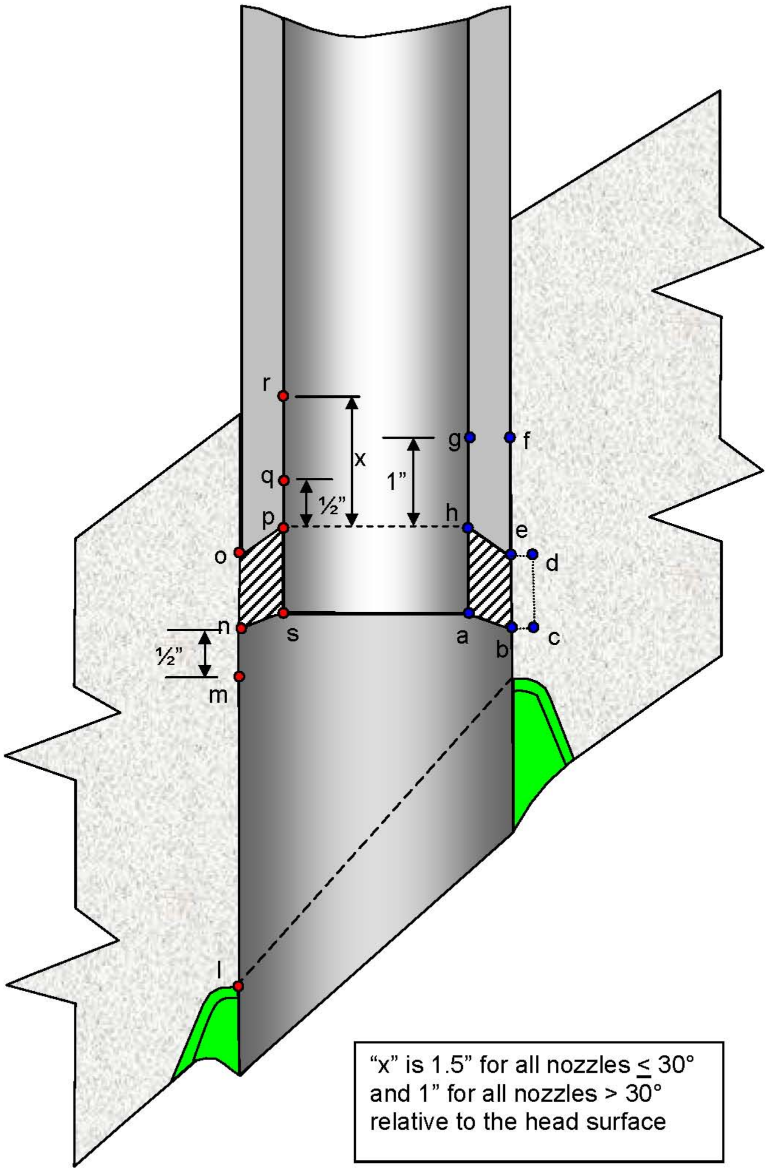


Figure 2. Welding



"x" is 1.5" for all nozzles ≤ 30° and 1" for all nozzles > 30° relative to the head surface

Figure 3. Examination Areas

Pre-Weld PT	l-m-n-o-p-q
Post-Weld PT	m-n-s-p-q-r
Post-Weld UT (Weld)	a-b-c-d-e-h
Post Weld UT (Nozzle Material)	e-f-g-h

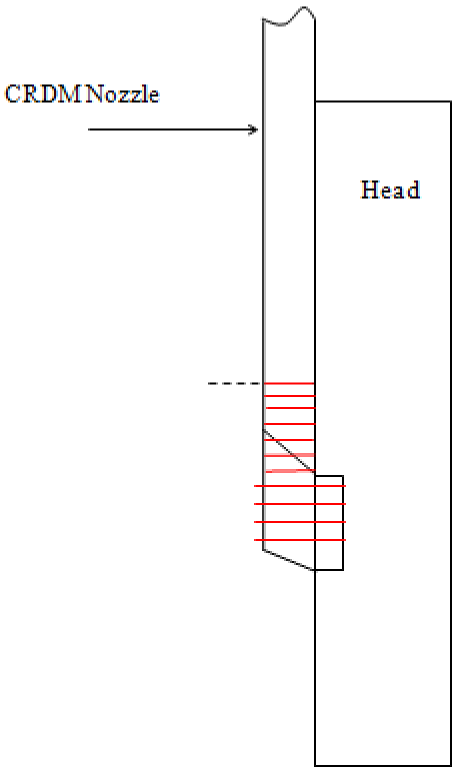


Figure 4. UT 0° and 45° L-wave Beam Coverage Looking

Clockwise and Counter-clockwise

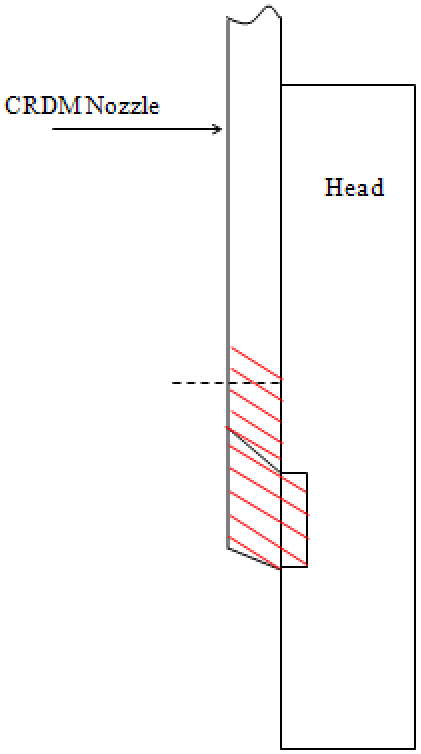


Figure 5. UT 45° L-wave Beam Coverage Looking Down

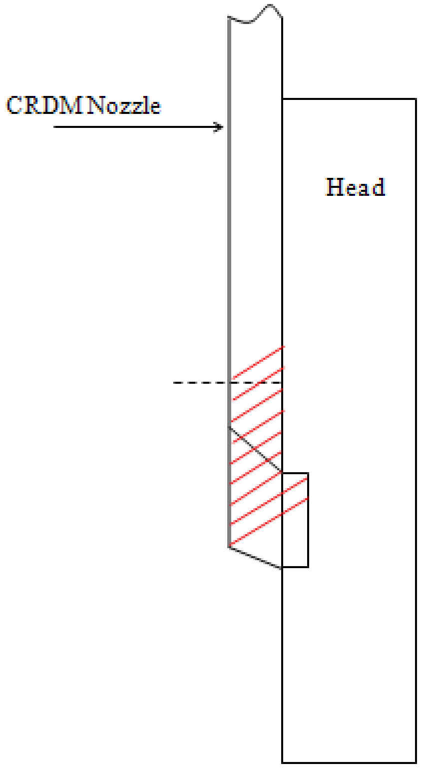


Figure 6. UT 45° L-wave Beam Coverage Looking Up

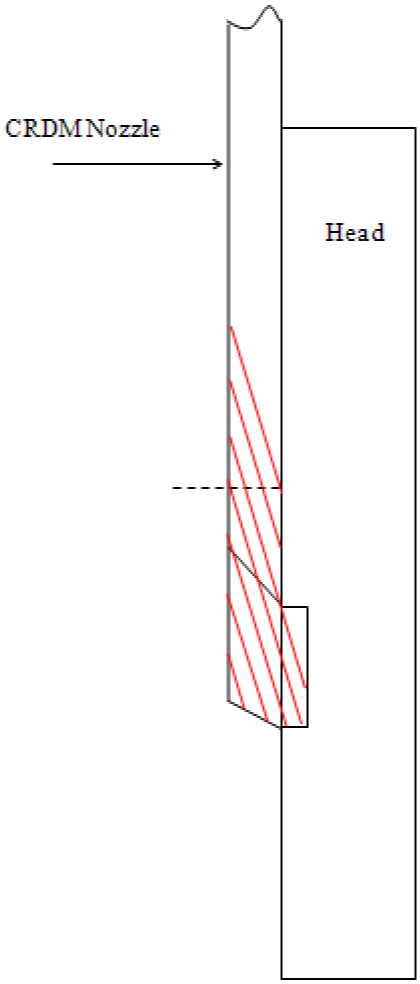


Figure 7. UT 70° L-wave Beam Coverage Looking Down

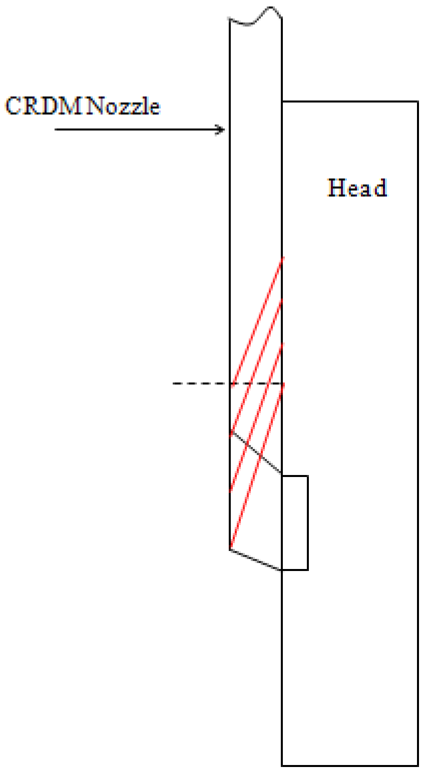
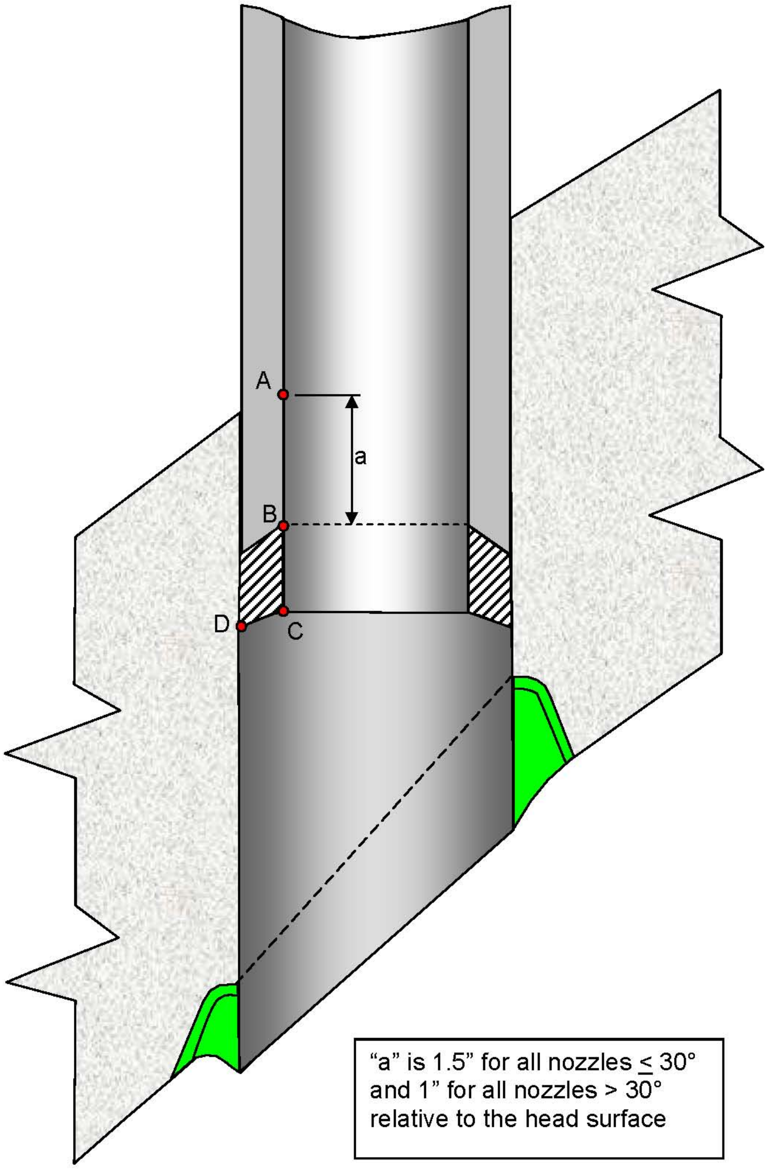


Figure 8. UT 70° L-wave Beam Coverage Looking Up



"a" is 1.5" for all nozzles ≤ 30° and 1" for all nozzles > 30° relative to the head surface

Figure 9. PSI and ISI Weld and Nozzle Base Metal

Surface Examination Area (A-B-C-D)

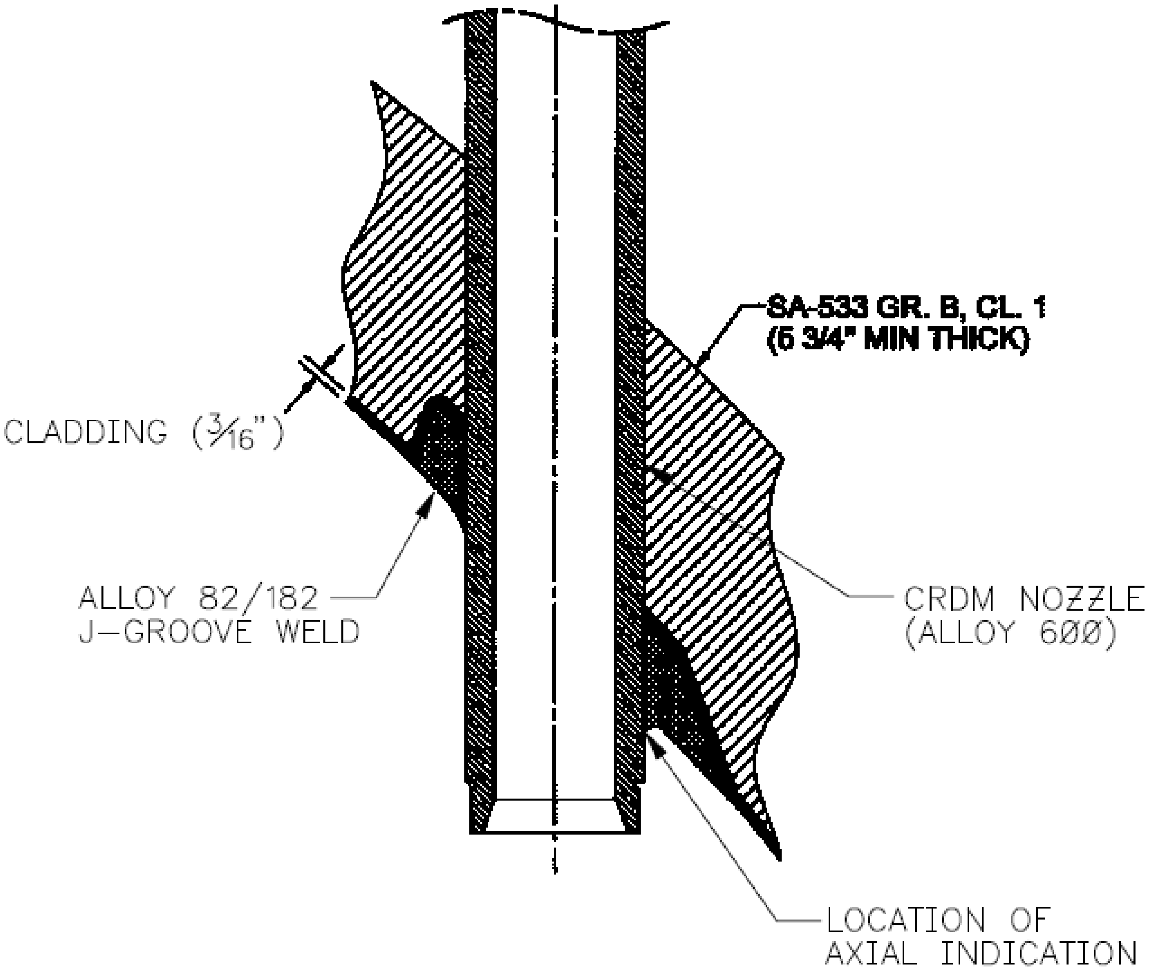


Figure 10. Location of Axial Indication

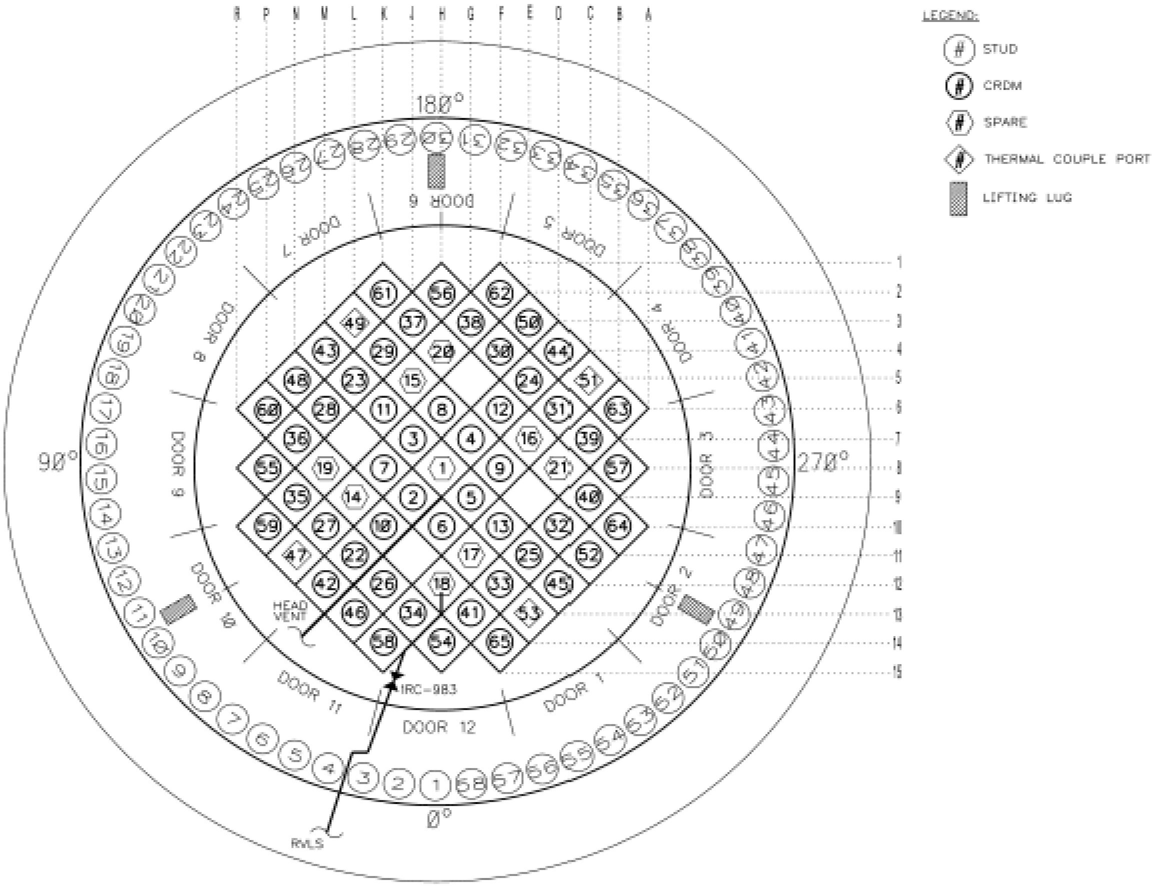


Figure 11. Reactor Vessel Head Penetration Locations

Table 1. Flaw Characteristics

Nozzle	Ind. No.	ID/OD	Depth to Ind. (inches)	Thru Wall (inches)	Length (inches)	Azimuth (degrees)	Orientation Ax/Circ	Type
37	1	OD	0.495	0.131	0.46	12	Ax	PWSCC

Notes:

1. The flaw is in the tube outside diameter (OD) extending inward toward the tube inside diameter (ID) and approximately parallel with the nozzle axis (axially oriented) at the lower toe side of the weld.
2. 0° Azimuth is the lowest point (downhill) on the nozzle. Progression is CCW looking up.
3. Tube diameter, OD 4.002", ID 2.750". Thickness, 0.626" Nom.
4. Dimensions are in inches.
5. Scans performed from the tube ID. Flaw is located at the OD.