Entergy Operations, Inc.
1340 Echelon Parkway
Jackson, MS 39213
Tel 601-368-5138

Ron Gaston
Director, Nuclear Licensing

10 CFR 50.55a(z)(1)

2CAN112103

November 5, 2021

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

Subject: Relief Request ANO2-RR-21-002, Half-Nozzle Repair of Reactor Vessel Closure Head Penetration #46

Arkansas Nuclear One, Unit 2
NRC Docket No. 50-368
Renewed Facility Operating License No. NPF-6

During the current Arkansas Nuclear One, Unit 2 (ANO-2) refueling outage 2R28, Entergy Operations, Inc., (Entergy) performed ultrasonic (UT) examinations of Reactor Vessel Closure Head (RVCH) penetration nozzles in accordance with American Society of Mechanical Engineers (ASME) Code Case N-729-6. An axial, planar indication was identified in Control Element Drive Mechanism (CEDM) Nozzle 46. The indication was located along the outside diameter of the CEDM nozzle at the toe of J-groove weld and downhill side of the nozzle.

Due to the indication described above, repair of CEDM Nozzle 46 is required. Entergy initially intended to eliminate the indication by performing defect removal in accordance with IWA-4421(a) and IWA-4422.1(a). However, after reassessment of the data, Entergy has determined to perform a "half-nozzle" repair of CEDM Nozzle 46. The proposed alternative is provided in the Enclosure of this letter.

Pursuant to 10 CFR 50.55a(z)(1), Entergy requests NRC approval of the proposed alternative to the ASME Code repair/replacement requirements, on the basis that the proposed alternative provides an acceptable level of quality and safety.

This request for an alternative is required to address an emergent condition at ANO-2. Entergy requests NRC approval as soon as possible but no later than November 10, 2021. This schedule is subject to fluctuation. Relief is requested for the duration of ANO-2 operating cycle 29, currently expected to conclude in the Spring 2023.

There are new regulatory commitments established in this submittal. The new commitments are summarized in the attachment to the enclosure.

If there are any questions or if additional information is needed, please contact Riley Keele, Manager, Regulatory Assurance, Arkansas Nuclear One, at 479-858-7826.

Respectfully,

Ronald W. Gaston Digitally signed by Ronald W. Gaston Date: 2021.11.04 23:08:20 -05'00'

Ron Gaston

RWG/rwc

Enclosure: Relief Request ANO2-RR-21-002

Attachment to Enclosure Commitments

cc: NRC Region IV Regional Administrator

NRC Senior Resident Inspector – Arkansas Nuclear One

NRC Project Manager – Arkansas Nuclear One

Designated Arkansas State Official

Enclosure

2CAN112103

Relief Request
ANO2-RR-21-002

RELIEF REQUEST

ANO2-RR-21-002

1. ASME CODE COMPONENT AFFECTED

Component:	Reactor Vessel Closure Head (RVCH) Penetration #46
Code Class:	1
Exam. Cat.:	American Society of Mechanical Engineers (ASME) Code Case N-729-6
Item No.	B4.20
Unit:	Arkansas Nuclear One, Unit 2 (ANO-2)
Interval:	Fifth (5^{th}) (March 26, 2020 to March 25, 2030)

2. APPLICABLE CODE EDITION AND ADDENDA:

ASME Section XI, 2007 Edition through 2008 Addenda

ASME Section XI, Code Case N-729-6, as amended in 10 CFR 50.55a(g)(6)(ii)(D)

ASME Section III, 1968 Edition through Summer 1970 Addenda (Original Construction Code)

ASME Section III, Subsection NB, 1992 Edition

3. APPLICABLE CODE REQUIREMENTS

The applicable requirements of the following ASME Boiler & Pressure Vessel (B&PV) Code and Code Cases from which relief is requested are as follows:

ASME Code, Section XI, 2007 Edition through 2008 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.

- 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).

ASME Code, Section III, 1992 Edition

- NB-5245, *Partial Penetration Welded Joints*, specifies progressive surface examination of partial penetration welds.

- NB-5330(b) states:

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

Code Case N-638-7, Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique

This Code Case provides requirements for automatic or machine gas tungsten arc welding (GTAW) of Class 1 components without the use of preheat or post-weld heat treatment. The condition imposed on this Code Case by Regulatory Guide (RG) 1.147, Revision 19 is addressed below in paragraph 7.1.

- Paragraph 1(g) states:

  Peening may be used, except on the initial and final layers.

- Paragraph 2(b) permits use of existing welding procedures qualified in accordance with previous revisions of the Code Case. When the existing welding procedure was qualified in accordance with N-638-4, the test coupon base material was post-weld heat treated to comply with paragraph 2.1(a) of the Code Case (N-638-4) which states:

  > The materials shall be post-weld heat treated to at least the time and temperature that was applied to the materials being welded.

4. REASON FOR REQUEST

Entergy Operations, Inc. (Entergy) ANO-2 is presently in Refueling Outage 2R28. While performing ultrasonic (UT) examinations of RVCH penetration nozzles, in accordance with

ASME Code Case N-729-6 (Item No. B4.20)[1], an axial, planar indication was identified in Control Element Drive Mechanism (CEDM) Nozzle 46. The indication was located along the outside diameter, downhill side of the nozzle in the J-groove weld fillet region (see Figure 11). Eddy current (ECT) examination along the outside diameter of the nozzle and J-groove weld confirmed that the indication was surface connected. A supplemental liquid penetrant (PT) examination of the flaw was also performed to confirm the indication's location. The UT leak path assessment on CEDM Nozzle 46 did not provide any evidence of base material degradation along the RVCH nozzle bore. Additionally, the VE bare metal visual examination (Item B4.10) of the RVCH did not identify any evidence of reactor coolant leakage such as boric acid deposits or base material wastage.

The UT examination indicated that the flaw in CEDM Nozzle 46 was 0.204 inch deep and 0.400 inch long. However, the total length of the flaw was estimated to be 1.03 inches based on the UT and supplemental PT examinations. The PT examination also indicated that the flaw extended into the thread relief region of the nozzle while the lower tip of the flaw is approximately 0.7 inch above the bottom of the nozzle. Figure 10 shows the relative location of the nozzles in the RVCH and Figure 11 shows the general location of the axial indication.

The repair technique sometimes referred to as the half-nozzle repair, will be performed to correct the identified condition on CEDM Nozzle 46. The half-nozzle repair involves machining away the lower section of the nozzle containing the flaws, then welding the remaining portion of the nozzle to the RVCH to form the new pressure boundary. The new weld also attaches a replacement lower nozzle that provides a means for re-attaching the guide cone. This technique requires relief from certain aspects of the ASME B&PV Code as described below.

Because of the risk of damage to the RVCH material properties or dimensions, it is not feasible to apply the post weld heat treatment (PWHT) requirements of the original Construction Code. As an alternative to the requirements of the RVCH Code of Construction, Entergy proposes to perform a modification of CEDM Nozzle 46 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 PWHT. The modification described below will be performed in accordance with the 2007 Edition through 2008 Addenda of ASME Section XI, Code Case N-638-7, Code Case N-729-6, and the alternatives discussed in Section 5.

Basic steps for the IDTB repair are:

1. Roll expansion of the nozzle above the area to be modified to stabilize the nozzle and prevent any movement when the nozzle is separated from the nozzle-to-RVCH J-groove weld.

[1] Code Case N-729-6 as amended in 10 CFR 50.55a(g)(6)(ii)(D) and supplemented by Relief Request ANO2-ISI-022 (Reference 4)

2. Machining to remove the lower nozzle to above the J-groove weld eliminating the portions of the nozzle containing the unacceptable indication(s). This machining operation also establishes the weld preparation area (Refer to Figure 1).

3. PT examination of the machined area (Refer to Figure 1).

4. Welding the remaining portion of the nozzle and the new replacement Alloy 690 nozzle using Alloy 52M weld material (Refer to Figure 2).

5. Machining the weld and adjacent nozzle material to provide a surface suitable for nondestructive examination (NDE).

6. PT and UT examination of the weld and adjacent region (Refer to Figure 3).

Note the figures in this request are provided to assist in clarifying the above description. They are not intended to provide design information such as the location of the CEDM nozzle weld relative to the inner and outer spherical radii of the RVCH.

Stresses introduced during the controlled roll expansion process implemented per design and fabrication controls will not create regions that would be more susceptible to Primary Water Stress Corrosion Cracking (PWSCC) than other regions that have been previously evaluated and found acceptable. Two fabrication parameters are controlled to ensure the nozzle roll expansion is effective in performing its design function of mechanical support for the nozzle prior to the application of the IDTB weld. The parameters of interest are tool insertion depth and the torque setting on the assembly tool.

Tool insertion depth, based on tooling setup height, will be controlled so that the rolled region is contained within the RVCH penetration bore. The torque applied to the roll expander is controlled so that the desired amount of plastic deformation occurs. The torque limiter assembly will be set and independently verified with a calibrated torque wrench prior to use.

As noted above, the roll expansion process will be completed for CEDM Nozzle 46 and the two parameters of interest (tool insertion depth and applied torque) that could impact the susceptibility to PWSCC will be validated to be within process specifications. Additionally, rotary peening will be applied to remediate the tensile surface stresses in the roll expanded region. As a result, there is high confidence that adequate measures will be applied in the modification of Nozzle 46 with respect to PWSCC for the life of the repair.

Entergy has determined that modification of CEDM Nozzle 46 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(z)(1).

5. PROPOSED ALTERNATIVE AND BASIS FOR USE

5.1 Welding Requirements

The half nozzle repair on CEDM Nozzle 46 will be performed using the ambient temperature temper bead process of Code Case N-638-7. Paragraph 2(b) of the Code Case permits use of welding procedures qualified in accordance with previous Code Case revisions. Accordingly, the welding procedure to be used on Nozzle 46 was qualified in accordance with N-638-4 (an earlier revision). Code Case N-638-4, paragraph 2.1(a) states:

> The materials shall be post-weld heat treated to at least the time and temperature that was applied to the materials being welded.

Post-weld heat treatment (PWHT) can slightly degrade the fracture (notch) toughness of low alloy steels. Therefore, it is both reasonable and conservative to perform a simulated PWHT of test samples that will be used to evaluate base materials that have received PWHT during fabrication and placed into reactor service. However, it is not conservative to perform a simulated PWHT of welding qualification test plate material that will be compared to the temper bead heat affected zone (HAZ) for acceptance.

The temper bead weld procedure qualification is required to demonstrate that the Charpy V-notch test results from the weld HAZ are no less than the Charpy V-notch test results for the unaffected base material. EPRI Report 1025169, Section 3.0 (Reference 5) documents that simulated PWHT on procedure qualification test plates degrades the notch toughness of the test plate increasing the contrast between the impact properties of the base material test plate and the temper bead weld HAZ. In other words, the simulated PWHT makes passing the impact testing requirements of the temper bead procedure qualification less difficult. Therefore, simulated PWHT on the temper bead test coupon does not provide conservative results when the simulated PWHT time exceeds the actual PWHT time applied to the component during construction.

The RVCH material at ANO-2 has at least 50 hours of PWHT but the weld procedure qualification test plate has 30 hours of simulated PWHT. This condition does not comply with Code Case N-638-4, paragraph 2.1(a) which requires simulated PWHT on the temper bead qualification test plate to be equivalent to or exceed the total aggregate time applied to the component to be welded. There is no maximum limit on the simulated PWHT time.

The simulated PWHT requirement of Code Case N-638 has been recognized by the ASME Code Committee as non-conservative and was changed in Revision 7. Code Case N-638-7, paragraph 2.1(a) now states that simulated PWHT of the "test assembly is neither required nor prohibited. However, if used, the simulated PWHT shall not exceed the time or temperature already applied to the base material to be welded." The welding procedure to be used to implement the half nozzle repair on CEDM Nozzle 46 complies with this requirement.

Code Case N-638-7 has been conditionally approved by the NRC in RG 1.147, Revision 19. The NRC condition, which is unrelated to simulated PWHT, states: "Demonstration of ultrasonic examination of the repaired volume is required using representative samples that

contain construction-type flaws." Therefore, the enhanced and more conservative simulated PWHT requirements in Code Case N-638-7 have also been approved by the NRC.

In conclusion, ambient temperature temper bead welding will be performed on CEDM Nozzle 46 in accordance with Code Case N-638-7 while the welding procedure was qualified in accordance with Code Case N-638-4. The qualified welding procedure does not comply with the simulated PWHT requirements of Revision 4 of the Code Case but does comply with the enhanced and more conservative simulated PWHT requirements in Revision 7 (i.e., N-638-7).

Therefore, Entergy requests approval to apply the simulated PWHT requirements of Case N-638-7, paragraph 2.1(a) when using the temper bead welding procedure on CEDM Nozzle 46.

Code Case N-638-7, paragraph 1(g) states:

> Peening may be used, except on the initial and final layers.

Rotary peening is performed on the final layer to provide further assurance of the modified configuration being resistant to PWSCC. However, peening on the final layer of a temper bead weld is prohibited by ASME Code Case N-638-7, paragraph 1(g). This prohibition is referring to the high cold-work peening that is traditionally used for configuration distortion control during welding, as was interpreted by ASME XI-1-13-19 for Code Case N-606-1. This is not considered applicable to the rotary peening process, which is highly controlled, uniform, and only influences a shallow surface layer (approximately 10 mils at the HAZ and 20 mils at the base metal). The uniform compressive stress layer created by the rotary peening process does not inhibit subsequent NDE. Furthermore, this residual compressive stress layer has been shown to greatly reduce PWSCC initiation. Recognizing these benefits, the ASME Code Committee revised Code Case N-638 (i.e., N-638-8) to allow use of peening processes designed to reduce residual surface tensile stresses on the final layer or surface of the weld.

Upon completion of peening, a visual and surface examination will be performed on the peened surface. However, while the peening operation will provide increased resistance to PWSCC initiation, the inspection frequency of ISI examinations on CEDM Nozzle 46 will comply with that specified in Item B4.20 of Code Case N-729-6 as approved by the NRC in 10 CFR 50.55a(g)(6)(ii)(D).

ASME Code Section III, Nonmandatory Appendix W, W-2140, clearly describes the beneficial nature of compressive stresses for the mitigation of stress corrosion cracking (SCC) susceptibility. It states that shot peening, as a form of stress improvement, can be used to place the inside diameter of piping in a compressive residual stress state to resist SCC. Extensive laboratory testing performed as part of MRP-61, "An Assessment of the Control Rod Drive Mechanism (CRDM) Alloy 600 Reactor Vessel Head Penetration PWSCC Remedial Techniques," indicates that shot peening successfully inhibits PWSCC initiation. With rotary peening, the shot is captured in a flap and regularly spaced such that it uniformly imparts compressive stresses on metal surfaces.

Therefore, Entergy requests relief from Code Case N-638-7, paragraph 1(g).

5.2 IDTB Modification Acceptance Examinations

ASME Section III, 1992 Edition, NB-5245, specifies progressive surface examination of partial penetration welds. The Construction Code requirement for progressive surface examination, in lieu of volumetric examination, was because volumetric examination is not practical for the conventional partial penetration weld configurations. Therefore, the following combination of UT and PT examinations are proposed.

For a modified Vessel Head Penetration (VHP), the weld is suitable for UT examination and the weld is accessible from both the top and bottom sides (Refer to Figure 4 through Figure 8).

UT volumetric examination of the modified configuration will be performed as specified in ASME Code Case N-638-7, 4(a)(2) and 4(a)(4). RG 1.147, Revision 19, has conditionally approved Code Case N-638-7 with the condition that UT volumetric examinations are demonstrated using representative samples which contain construction type flaws. See Section 7.1 for details. The acceptance criteria of NB-5330 of the 1992 Edition of the ASME Section III Code apply to all flaws identified within the examined volume.

The UT examination system is capable of scanning from cylindrical surfaces with inside diameters of approximately 2.82 inch. The scanning is performed using a 0° L-wave transducer, 45° L-wave transducers in two opposed axial directions, and 70° L-wave transducers in two opposed axial directions as well as 45° L-wave transducers in two opposed circumferential directions. The weld receives 100% examination coverage. Additionally, the low alloy steel extending to 0.25 inch beneath the weld into the low alloy steel base material (see Figure 3) will be examined using the 0° L-wave transducer searching for evidence of under bead cracking and lack of fusion in the HAZ. These examinations satisfy ASME Section III, NB-5330 requirements. The repair volume is extended to include 1 inch of Alloy 600 nozzle material above the weld and 1 inch of Alloy 690 material below the weld. UT examination coverage is as shown in Figure 4 through Figure 8 of this submittal.

In addition to the UT examinations, a surface PT examination will be performed on the entire weld as shown in Figure 3. The final examination of the new weld and immediate surrounding region will be sufficient to verify that defects have not been induced in the ferritic low alloy steel RVCH base material, due to welding, to the extent practical. The acceptance criteria of NB-5350 in ASME Section III, 1992 Edition shall apply.

The combination of performing PT and UT examinations depicted in Figure 3 during the IDTB repair provides assurance of structural integrity. Thus, Entergy requests relief from the progressive surface examination requirements specified in NB-5245.

5.3 Triple Point Anomaly

ASME Section III, NB-5330(b) states:

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

An artifact of ambient temperature temper bead welding is an anomaly in the weld at the triple point. There are two triple points in the modification. The upper 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 lower triple point is the point in the repair weld where the low alloy steel RVCH base material, the Alloy 690 replacement nozzle, and the Alloy 52M weld intersect. The locations of the upper and lower triple points for the VHP modification are shown in Figure 2.

The 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 through-wall extent and are assumed to exist, for purposes of analysis, around the entire bore circumference at the triple point elevation.

Detailed finite element based "Life of Repair" analyses performed for similar repairs at other plants resulted in a fatigue crack growth life for the triple point anomaly flaw of over 20 years. Examples of previous "Life of Repair" analyses include those for St. Lucie Unit 2 (NRC Safety Evaluation (SE) ML031700111), Byron and Braidwood contingency (NRC SE ML19136A386), Harris (NRC SE ML18283B544), and Palisades (ML20365A001). The typical process for these types of "Life of Repair" analyses is as follows:

1. The outermost penetration is modeled due to the applied loading conditions being representative and bounding relative to all other locations in the RVCH. The initial flaw size for the triple point anomaly analysis is 0.10 inches. Crack growth analysis determines the future flaw size and concludes that it is acceptable for the stated life. The outermost hillside nozzle is explicitly modeled, meaning that both extremes of interaction between the IDTB weld and the original J-groove weld are considered (i.e., these welds are very close to each other on the uphill side, and are relatively far away from each other on the downhill side).

2. A fracture mechanics analysis is performed for the design configuration to provide justification, in accordance with ASME Section XI, for operating with the postulated triple point anomaly. The anomaly is modeled as a 0.10 inch deep crack-like defect, initiating 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 in Items 3 and 4 below.

3. Circumferential and Axial Flaws: Flaw propagation is across the nozzle wall thickness from the outside diameter to the inside diameter of the nozzle housing for the upper and lower triple points.

    a. The shortest path is through the upper triple point (see Figure 2). By using a fatigue crack growth rate twice that of the rate of in-air austenitic stainless steel

material, that is used to bound the Alloy 600/690 nozzle and Alloy 52M weld materials, it is ensured that another potential path through the HAZ between the new repair weld and the Alloy 600 nozzle material is also bounded.

   b. 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.

4. Cylindrical Flaw: Flaw propagation extends down the outside surface of the repair weld between the upper and lower triple points.

   a. 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.

5. The results of similar prior detailed finite element analysis have demonstrated that a 0.10 inch weld anomaly is acceptable for greater than 20 years of operation following a VHP nozzle inside diameter temper bead weld repair. Acceptable design margins are demonstrated for all flaw propagation paths considered in the analysis. The minimum fracture toughness margin has been shown to be greater than the required margin of $\sqrt{10}$ (3.16) for normal operating conditions per ASME Section XI, IWB-3612. Fatigue crack growth is minimal. A limit load analysis was also performed for similar prior repairs considering the ductile Alloy 600/Alloy 690 materials along flaw propagation path lines. This analysis showed a limit load margin greater than the required margin per ASME Section XI, IWB-3644.

6. Since the postulated outside diameter flaw in the weld anomaly at the upper triple point is 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. The crack-like defects due to the weld anomaly at the lower triple point are exposed to primary coolant; however, the materials at the lower triple point are Alloy 52M, Alloy 690, and low alloy steel and, therefore, are only subject to fatigue crack growth.

7. Prior analyses of similar repair configurations have demonstrated that fatigue crack growth is acceptable and the crack-like indications remain stable, satisfying the ASME Section XI criteria.

Given the emergent nature of the ANO-2 CEDM Nozzle 46 repair, there is not sufficient time to perform the detailed "Life of Repair" finite element analysis for the triple point anomaly during the outage. Instead, a one cycle justification will be developed based on a comparative analysis between the nozzle repair associated with a similar previously performed triple point anomaly analysis and the ANO-2 RVCH Nozzle 46 repair. This

comparative analysis will be performed against a prior triple point analysis performed for the "Life of Repair" that is most representative and bounding relative to the ANO-2 Nozzle 46 repair considering; geometry, materials and transient loading conditions as well as a conservative crack growth prediction for one fuel cycle of operations. This qualitative justification will show that the weld anomalies postulated in the ANO-2 repair will meet the acceptance criteria of IWB-3612 for normal/upset and emergency/faulted operating conditions during one fuel cycle of operation. This one cycle justification will be submitted to the NRC.

The key parameters at ANO-2 relative to a similar repair (where "Life of Repair" analysis has been performed) were reviewed. The NRC SE for this previous RVCH penetration IDTB repair is ML20365A001 (Palisades). These parameters include IDTB weld toughness, IDTB weld wall thickness, and the key transients driving fatigue crack growth (including heat-up/cooldown transients). The ANO-2 repair IDTB weld toughness is equivalent, the wall thickness is greater (which is favorable to provide an increased repair life), and the key transients are representative. Since the "Life of Repair" analysis for the similar repair resulted in over 20 years of life, there is confidence that the one cycle justification for the ANO-2 repair will show acceptance.

Entergy requests relief from the acceptance criteria specified in NB-5330(b) of ASME Section III to permit anomalies, as described herein, at the triple point area to remain in service for a single nominal 18-month fuel cycle of operation.

5.4 Flaw Characterization and Successive Exams - RVCH Original J-Groove Weld

The assumptions of IWB-3600 of ASME Section XI are that cracks are fully characterized in accordance with IWB-3420 in order to compare the calculated parameters to the acceptable parameters addressed in IWB-3500. There are no qualified UT examination techniques for examining the original nozzle-to-RVCH J-groove welds. Therefore, since it is impractical to characterize the flaw geometry that may exist therein, it is conservatively assumed the "as-left" condition of the remaining J-groove weld includes flaws extending through the entire Alloy 82/Alloy 182 J-groove weld and buttering. 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/Alloy 182 weld would propagate by PWSCC through the weld and buttering to the interface with the low alloy steel RVCH material. Any growth of the postulated "as-left" flaw into the low alloy steel would be by fatigue crack growth under cyclic loading conditions.

"Life of Repair" analyses performed for similar repairs has resulted in a fatigue crack growth life for the "as-left" J-groove flaw of 14 years or more (linear elastic fracture mechanics (LEFM) only). Examples of previous "Life of Repair" analyses include those for St. Lucie Unit 2 (NRC SE ML031700111), Byron and Braidwood contingency (NRC SE ML19136A386), Harris (NRC SE ML18283B544), and Palisades (ML20365A001). The typical process for these types of "Life of Repair" analyses is as follows:

1. The outermost penetration was modeled due to the applied loading conditions being the same or worse than all other locations in the RVCH. The initial flaw size for the J-groove weld is conservatively assumed to include all of the weld and buttering. This is highly

conservative since the buttering sees PWHT, which would tend to reduce welding residual stresses, making it less susceptible to PWSCC. While the analysis considers crack growth on both uphill and downhill sides, the weld on the downhill side of the outermost nozzle has the largest area. Therefore, the largest possible initial flaw size on the downhill side is considered.

2. The transients applicable for the “as-left” J-groove weld are those due to normal and upset conditions only. The controlling loading condition was identified to be during normal cooldown, 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 was less than the J-integral of the low alloy steel head material at a crack extension of 0.1 inch. Flaw stability during ductile flaw growth was easily demonstrated using safety factors of 3.0 for primary stress intensity factors and 1.5 for secondary stress intensity factors. The applied tearing modulus was less than the material tearing modulus of the low allow steel head material.

3. The J-groove flaws were evaluated using worst-case CEDM outermost nozzle penetration configuration with postulated flaw sizes on uphill and downhill sides of the J-groove weld. Fatigue crack growth for cyclic loading conditions using operational stresses from pressure and thermal loads and crack growth rates from ASME Section XI, Non-mandatory Appendix A, Sub-article A-4300 for ferritic material in a primary water environment was calculated. Based on the results of LEFM analysis only or a combination of LEFM and elastic-plastic fracture mechanics (EPFM) analyses, a postulated flaw remaining in the original Alloy 82/Alloy 182 J-groove weld and buttering for the modified RVCH nozzle was shown to be acceptable.

Given the emergent nature of the ANO-2 CEDM Nozzle 46 repair, there is not sufficient time to perform the detailed “Life of Repair” finite-element based analysis for the "as-left" J-groove flaw during the outage. Instead, a one cycle justification will be developed based on a comparative analysis between the nozzle repair associated with a previously performed "as-left" J-groove flaw analyses and the ANO-2 CEDM Nozzle 46 repair. This comparative analysis will be performed against a prior "as-left" J-groove flaw analysis performed for the "Life of Repair" that is most representative and bounding relative to the ANO-2 Nozzle 46 repair considering; geometry, materials and transient loading conditions as well as a conservative crack growth prediction for one fuel cycle of operations. This qualitative justification will show that the "as-left" J-groove weld for the ANO-2 repair will meet the acceptance criteria of IWB-3612 for normal/upset and emergency/faulted operating conditions during one fuel cycle of operation. In addition, the one cycle justification will confirm that the primary stress limits considering reinforcement requirements of NB-3330 are met, considering a local area reduction of the pressure retaining membrane that is equal to the area of the J-groove weld and a conservatively bounding flaw size for one fuel cycle of operation. This one cycle justification will be submitted to the NRC.

The key parameters at ANO-2 relative to a similar repair (where “Life of Repair” analysis has been performed) were reviewed. The NRC SE for this previous RVCH penetration IDTB repair is ML031700111 (St. Lucie Unit 2). These parameters include RVCH toughness, RVCH wall thickness, and the key transients driving fatigue crack growth (including heat-up/cooldown transients). The ANO-2 RVCH toughness is higher, the wall thickness is equivalent, and the key transients are equivalent. Since the “Life of Repair” analysis for the similar repair resulted in 14 years of life, there is confidence that the one cycle justification

for the ANO-2 repair will show acceptance. Note that the 14-year life was using LEFM and a longer life can be achieved using EPFM analysis.

Relief is requested from flaw characterization specified in IWB-3420 for a single nominal 18-month fuel cycle of operation.

In addition, the potential for debris from a cracked J-groove weld remnant was considered. Radial cracks (relative to the nozzle) were postulated to occur in the J-groove weld due to the dominance of higher hoop stresses relative to axial stresses. The possibility of transverse cracks occurring that could subsequently intersect the radial cracks is considered remote as there are minimal driving forces for cracks in the transverse direction. The radial cracks would relieve the driving forces for any potential transverse cracks. There are no known service conditions that could drive radial cracks and transverse cracks to intersect to produce a loose part. There is extensive operating experience with remnant J-groove welds for which there are no known cases of debris generation (loose parts) due to PWSCC of the remnant J-groove weld. Therefore, cracking of the J-groove weld resulting in debris (loose parts) is not expected.

5.5 Preservice Inspection (PSI) and Inservice Inspection (ISI) of VHPs

Code Case N-729-6 as approved by the NRC in 10 CFR 50.55a specifies requirements for performing PSI and ISI examinations of RVCHs with nozzles having partial penetration welds. Code Case N-729-6 Table 1, Item B4.20, permits either volumetric or surface examination. Item B4.20 examination requirements are specified in Figure 2 of Code Case N-729-6. The post-weld examination volume shown in Figure 9 will be used for the PSI examinations required by Code Case N-729-6, paragraph -2220.

Pending submittal of a follow-on relief request (see section 6), ISI examination of CEDM Nozzle 46 will be performed using a volumetric examination method. The repair proposed by this relief request modifies the examination volume depicted in Figure 2 of Code Case N-729-6. Figure 9 of this submittal will be used to establish the examination volume for future ISI examinations. The examination volume also includes the rotary peened surfaces. Successive examinations required by Code Case N-729-6 will be performed on CEDM Nozzle 46 during each subsequent refueling outage.

All other ANO-2 RVCH CEDM and ICI nozzles will continue to be examined in accordance with Code Case N-729-6 as modified by 10 CFR 50.55a(g)(6)(ii)(D) and other NRC approved alternatives.

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

5.6 General Corrosion Impact on Exposed Low Alloy Steel

The IDTB nozzle modification leaves a small portion of low alloy steel in the RVCH exposed to primary coolant. An evaluation was performed for similar prior repairs for the potential

corrosion concerns at the RVCH low alloy steel wetted surface. NRC SEs for previous RVCH penetration IDTB repairs that included small areas of exposed low alloy steel include ML031700111 (St. Lucie Unit 2), ML19136A386 (Byron and Braidwood contingency), and ML18283B544 (Harris). Galvanic corrosion, hydrogen embrittlement, SCC, and crevice corrosion are not expected to be a concern for the exposed low alloy steel base metal. General corrosion of the exposed low alloy steel base metal will occur in the area between the IDTB weld and the original J-groove weld. Due to the depletion of oxygen, tight geometry, and lack of Primary Coolant System (PCS) flow at the exposed low alloy steel, general corrosion will significantly decrease after a period of time. As the surface of the low alloy steel passivates, the long-term corrosion rate is expected to be negligible. However, a conservative, sustained, corrosion rate will be applied and the resultant increase in bore diameter will be considered in the reinforcement calculation (per NB-3330) as part of the ASME Section III analysis one cycle justification. The corrosion evaluation and the ASME Section III analysis one cycle justification will be submitted to the NRC.

Galvanic Corrosion

The results of the NRC's boric acid corrosion program have shown that the galvanic difference between the SA-533, Grade B, Alloy 600, Type 308 stainless steel (nominal chemistry of RVCH cladding) is not significant enough to consider galvanic corrosion as a strong contributor to the overall boric acid corrosion process (NUREG-1823). Therefore, it was judged that galvanic corrosion between the exposed RVCH low alloy steel, Alloy 600, Alloy 690, or their weld metals is not a concern for this repair configuration. This is supported by studies documented in EPRI Report 1000975 in which low alloy steel specimens were coupled and uncoupled to stainless steel exposed to a borated water environment at various temperatures. The corrosion rates for the coupled and uncoupled conditions were determined to be similar. Additionally, galvanic corrosion of carbon steel coupled to stainless steel in boric acid solution in the absence of oxygen should be quite low. The results of this study are also applicable to nickel-based alloys as austenitic stainless steels have approximately the same corrosion potential as nickel-based alloys such as Alloy 600 and Alloy 690.

Hydrogen Embrittlement

Hydrogen embrittlement occurs when a material property is degraded due to the presence of the hydrogen. This type of damage usually occurs in combination with an acting stress. The hydrogen concentration in the RVCH will be greatest at the exposed surface and decreases across the thickness of the RVCH to the trace concentration of hydrogen in the low alloy steel. Hydrogen concentrations in the reactor coolant system are deemed insufficient to induce hydrogen cracking in the low alloy steel of the RVCH. Therefore, it was determined that hydrogen embrittlement is not a concern for the exposed RVCH low alloy steel in the repaired configuration. This conclusion is supported by many cases of low alloy steels being exposed to primary coolant without any observed cracking due to hydrogen embrittlement.

Stress Corrosion Cracking

There is extensive Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) operating experience related to low alloy steels being exposed to the reactor coolant

environment. This operating experience has not identified any known occurrence of stress corrosion cracking of the low alloy steel of RVCHs. Likewise, there are no existing ASME Section XI Code rules or NRC regulations addressing this issue in RVCH low alloy steels in PWR reactor coolant environment. Therefore, it has been determined that stress corrosion cracking of the low alloy steel of the RVCH is not a concern for this repair configuration.

Crevice Corrosion

The geometry of the gap between the RVCH and replacement nozzle could create conditions for crevice corrosion. However, operating experience for PWRs shows that crevice corrosion of low alloy steels associated with these half nozzle repairs is not a problem in PWR systems due to expected low oxygen contents. Furthermore, the surface of the low alloy steel material will passivate with time, decreasing the rate of corrosion within the crevice. Therefore, it was determined that crevice corrosion of the low alloy is not a concern.

General Corrosion

Corrosion of the exposed low alloy steel is not expected to be a concern based on existing operating experience. The surface of the low alloy steel material will passivate with time, decreasing the rate of general corrosion. As corrosion products fill this gap, they will isolate the low alloy steel surface from the reactor coolant system, thereby, impeding the transport of oxygen which is necessary to sustain continued general corrosion. Due to the depleted oxygen, passivated surface, tight geometry, and lack of appreciable reactor coolant flow at the exposed low alloy steel, general corrosion will decrease significantly after a period of time.

5.7 Conclusions

Implementation of an IDTB repair to RVCH CEDM Nozzle 46 will produce an effective repair that will restore and maintain the pressure boundary integrity of the VHP. Other IDTB modifications have been performed successfully (see Section 8) and have been in service for several years without any known degradation [e.g., Shearon Harris (2012, 2013, 2015, 2016 and 2018) and Palisades (2004, 2018, and 2020)]. This alternative provides improved structural integrity and reduced likelihood of leakage for the primary system. Detailed finite element based “Life of Repair” analyses performed for similar repairs at other plants resulted in a fatigue crack growth life for the triple point anomaly flaw of over 20 years. Likewise, "Life of Repair" analyses performed on the "as-left" J-groove flaw has resulted in a fatigue crack growth life of 14 years or more. Corrosion of the exposed low alloy steel base material is not a concern due to lack of oxygen, tight geometry, and lack of reactor coolant system flow in the exposed region. A one cycle justification will also be developed and submitted to the NRC within 14 days of the end of the 2R28 refueling outage. Finally, a separate relief request will be submitted to justify continued use of the nozzle repair for the life of the plant. Accordingly, the use of the alternative provides an acceptable level of quality and safety in accordance with 10 CFR 50.55a(z)(1).

6. DURATION OF PROPOSED ALTERNATIVE

The duration of the proposed alternative is for one cycle of operation. The upcoming operating cycle is currently scheduled to start in in the fourth quarter of 2021, coincident with startup from the current refueling outage. The operating cycle is currently scheduled to be complete in the second quarter of 2023.

A separate relief request will be submitted to justify continued use of the nozzle repair for the life of the plant. This permanent relief request will contain the appropriate analyses and justification for the remainder of the plant operating life and will be submitted prior to the end of the upcoming operating cycle.

7. ADDITIONAL INFORMATION

7.1 VHP Weld Qualification Mockup UT Acceptance

Volumetric examination is required by Code Case N-638-7. NRC RG 1.147, Revision 19 imposes a condition for this code case that requires UT demonstration on representative samples which contain construction type flaws. Framatome, in support of many similar modifications, has performed demonstrations using IDTB weld repair mockups since VHP modifications at Oconee Nuclear Station in 2001. The most recent procedure demonstration took place during the 2010 Davis Besse control rod drive mechanism (CRDM) repair campaign which included review of recorded automated data showing UT responses obtained from an IDTB weld mockup for the half-nozzle repair. This is the same mockup used for the procedure demonstration for Shearon Harris VHP nozzle modifications listed in Section 8.

To satisfy this requirement, an IDTB weld half-nozzle repair mockup containing reflectors to simulate construction type flaws applicable to this weld process has been used. 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 outside diameter so that the hole face is normal to the nozzle surface to simulate under-bead cracking, and lack of bond, or lack of fusion throughout the weld volume. The examination procedure has demonstrated the ability to detect a linear weld fabrication triple point anomaly extending 0.05 inch and greater into the weld.

A Nickle-Chromium-Iron (NiCrFe) alloy calibration block is used and contains a series of EDM notches at nominal depths of 10%, 25%, 50%, and 75% deep from both inside diameter and outside diameter surfaces in both the axial and circumferential orientation. The block also contains 1/4T, 1/2T, and 3/4T deep end-drilled holes and side-drilled holes that are used for calibration.

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. Prior to examination of the repair

welds at ANO-2, UT personnel will practice using the data files from the demonstration described above.

8. PRECEDENTS

1. Nuclear Management Company (NMC) letter to the NRC, "Request for Relief from ASME Section XI Code Requirements for Repair of Reactor Pressure Vessel Head Penetrations," dated October 11, 2005, ADAMS Accession Number ML052870321.

2. FirstEnergy Nuclear Operating Company (FENOC) letter to the NRC, "10 CFR 50.55a Request for Alternate Repair Methods for Reactor Pressure Vessel Head Penetration Nozzles," dated April 1, 2010, ADAMS Accession Number ML100960276.

3. Constellation Energy letter to the NRC, "Relief Request for Modifications to Pressurizer Heater Sleeves and Lower Level Nozzle Penetrations (RR-PZR-01)," dated January 31, 2011, ADAMS Accession Number ML110340059.

4. Progress Energy letter to the NRC, "Relief Request I3R-09 Reactor Vessel Closure Head Nozzles Inservice Inspection Program – Third Interval," dated May 3, 2012, ADAMS Accession Number ML12131A663.

5. Progress Energy letter to the NRC, "Relief Request I3R-11 Reactor Vessel Closure Head Nozzles Inservice Inspection Program – Third Interval," dated May 22, 2013, ADAMS Accession Number ML13143A167.

6. Progress Energy letter to the NRC, "Relief Request I3R-13 Reactor Vessel Closure Head Nozzle 37, Inservice Inspection Program – Third Ten-Year Interval," dated November 22, 2013, ADAMS Accession Number ML13329A354.

7. Progress Energy letter to the NRC, "Relief Request I3R-15, Reactor Vessel Closure Head Nozzle Repair Technique, Inservice Inspection Program – Third Ten-Year Interval," dated April 2, 2015, ADAMS Accession Number ML15092A236.

8. Progress Energy letter to the NRC, "Relief Request I3R-16, Reactor Vessel Closure Head Nozzle Repair Technique, Inservice Inspection Program – Third Ten-Year Interval," dated October 19, 2016, ADAMS Accession Number ML16294A218.

9. Progress Energy letter to the NRC, "Relief Request I3R-18, Reactor Vessel Closure Head Nozzle Repair Technique, Inservice Inspection Program – Fourth Ten-Year Interval," dated April 18, 2018, ADAMS Accession Number ML18108A094.

10. Entergy letter to the NRC, "Relief Request Number RR 5-7 *Proposed Alternative to ASME Section XI Code Requirements for Repair of Reactor Pressure Vessel Head Penetrations*," dated November 26, 2018, ADAMS Accession Number ML18330A142.

11. Entergy letter to the NRC, "Relief Request Number RR 5-8 *Proposed Alternative to ASME Section XI Code Requirements for Repair of Reactor Pressure Vessel Head Penetrations*," dated September 23. 2020, ADAMS Accession Number ML20267A387.

12. Florida Power & Light Company letter to the NRC, "Unit 1 Relief Request 21 and Unit 2 Relief Request 31 Request for Additional Information Response," dated April 14, 2003, ADAMS Accession Number ML031060268.

9. <u>REFERENCES</u>

1. ASME Code Case N-638-7, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, Section XI, Division 1".

2. NRC Regulatory Guide 1.147, Revision 19, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1", ADAMS Accession Number ML19128A244.

3. ASME Code Case N-729-6 "Alternative Examination Requirements for PWR Reactor Vessel Upper Heads With Nozzles Having Pressure-Retaining Partial- Penetration Welds, Section XI, Division 1".

4. Entergy letter to the NRC, "Request for Alternative to 10 CFR 50.55a(g)(6)(ii)(D) Examination Requirements – Relief Request ANO2-ISI-022," dated November 24, 2020, ADAMS Accession Number ML20329A202

5. EPRI Report 1025169, "Welding and Repair Technology Center: Welding and Repair Technical Issues in ASME Section XI".

Figure 1

Nozzle Machining

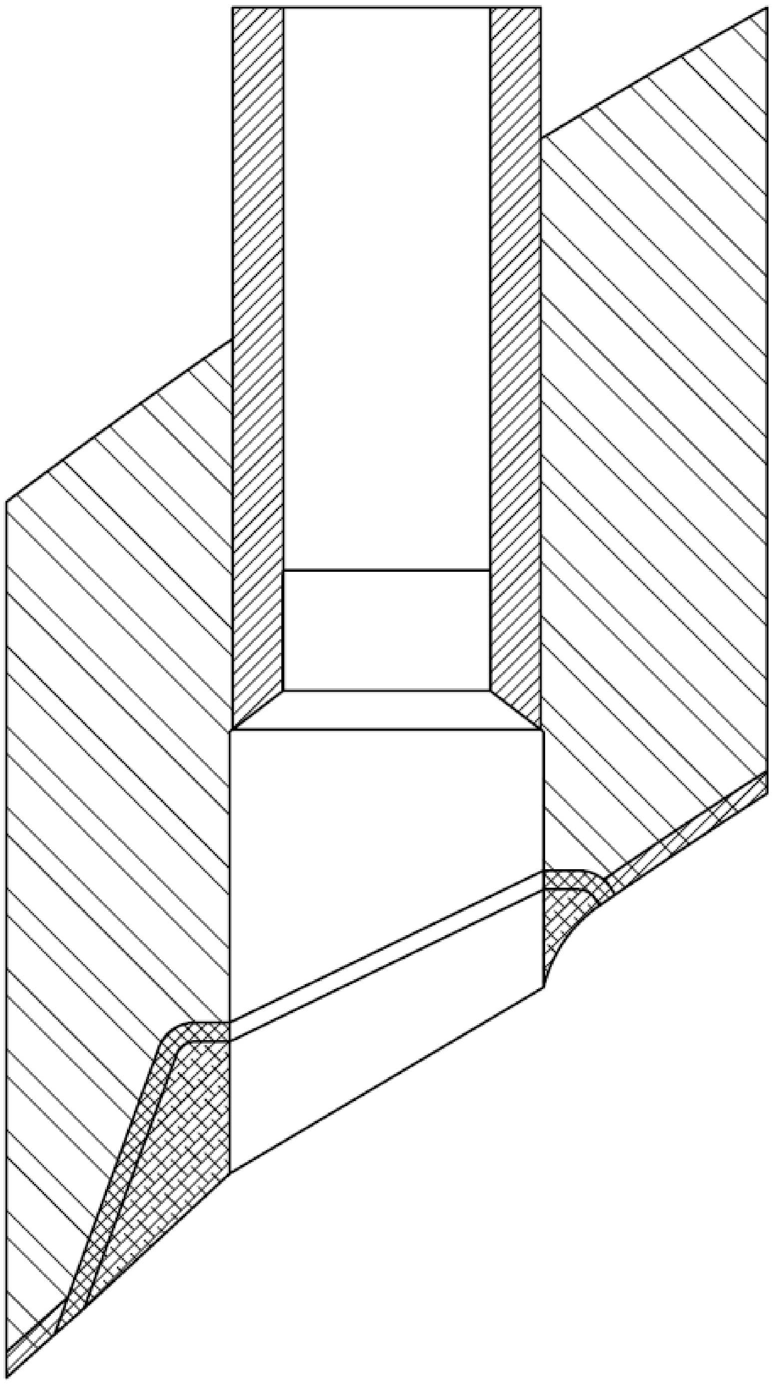


Figure 2

Nozzle Weld

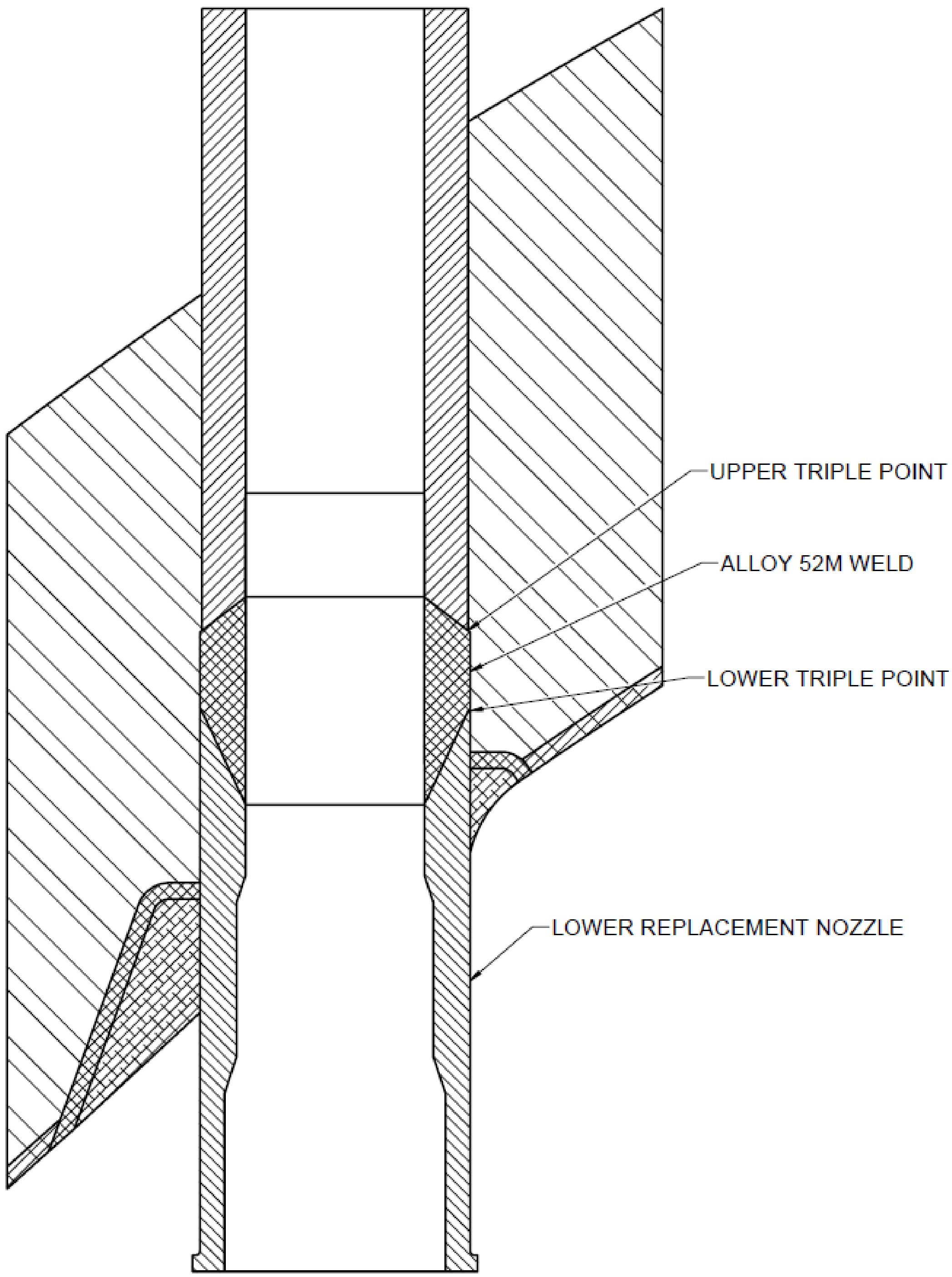
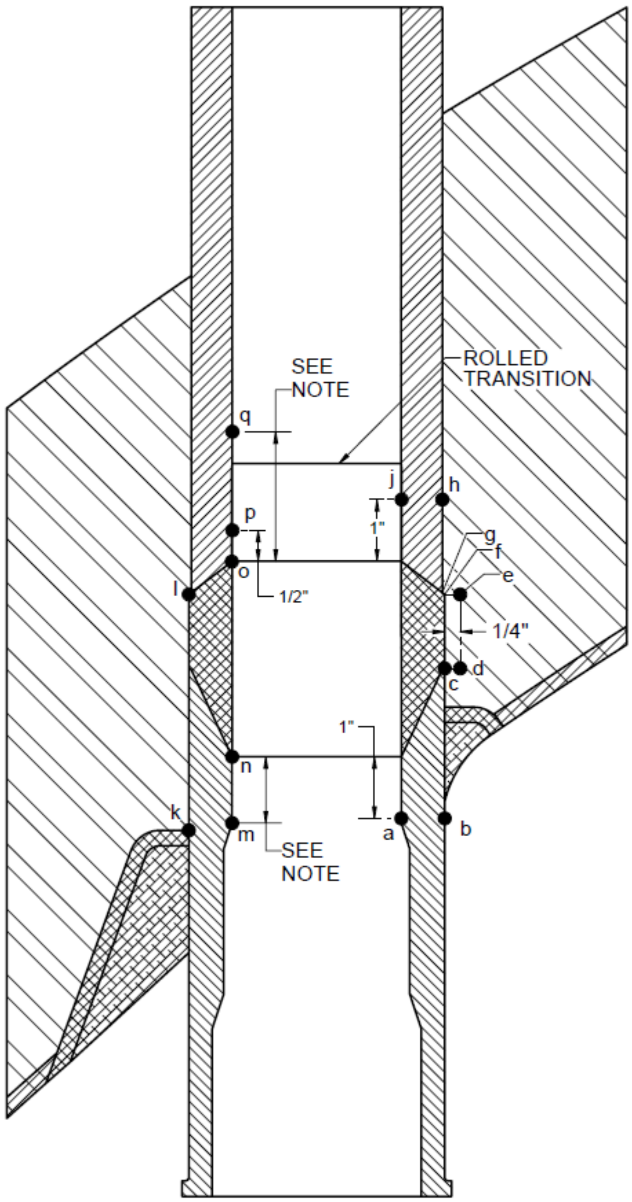


Figure 3

Nozzle Examination



Pre – Weld PT	k-l-o-p
Post – Weld PT	m-n-o-p-q
Post – Weld UT	a-b-c-d-e-f-g-h-j-a

NOTE: For Post – Weld PT, extent of examination above and below the weld is 1 inch for Nozzle 46. In addition, the examination shall include a minimum of 0.81 inch above the rolled transition area.

Figure 4

Nozzle 0° and 45°L UT Beam Coverage Looking Clockwise and Counter-Clockwise

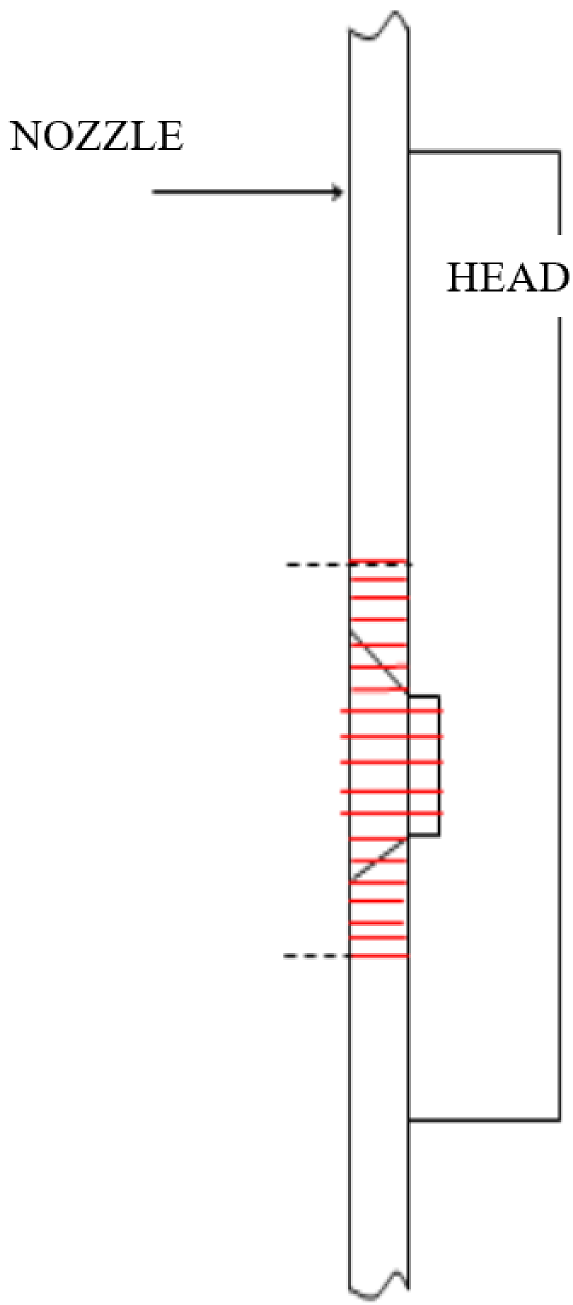


Figure 5

Nozzle 45°L UT Beam Coverage Looking Down

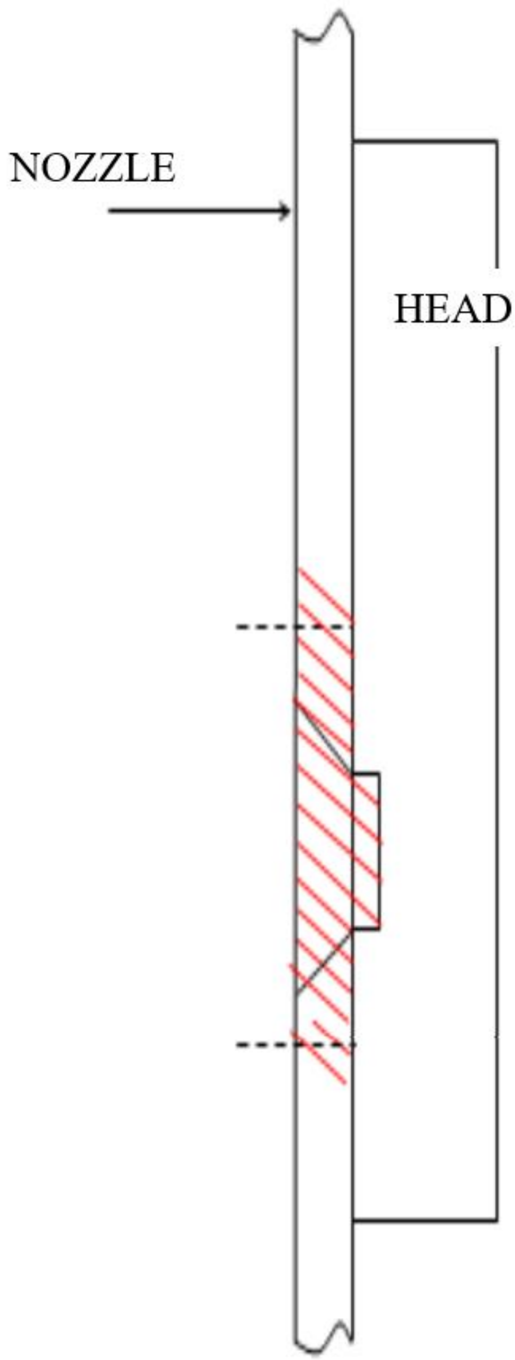


Figure 6

Nozzle 45°L UT Beam Coverage Looking Up

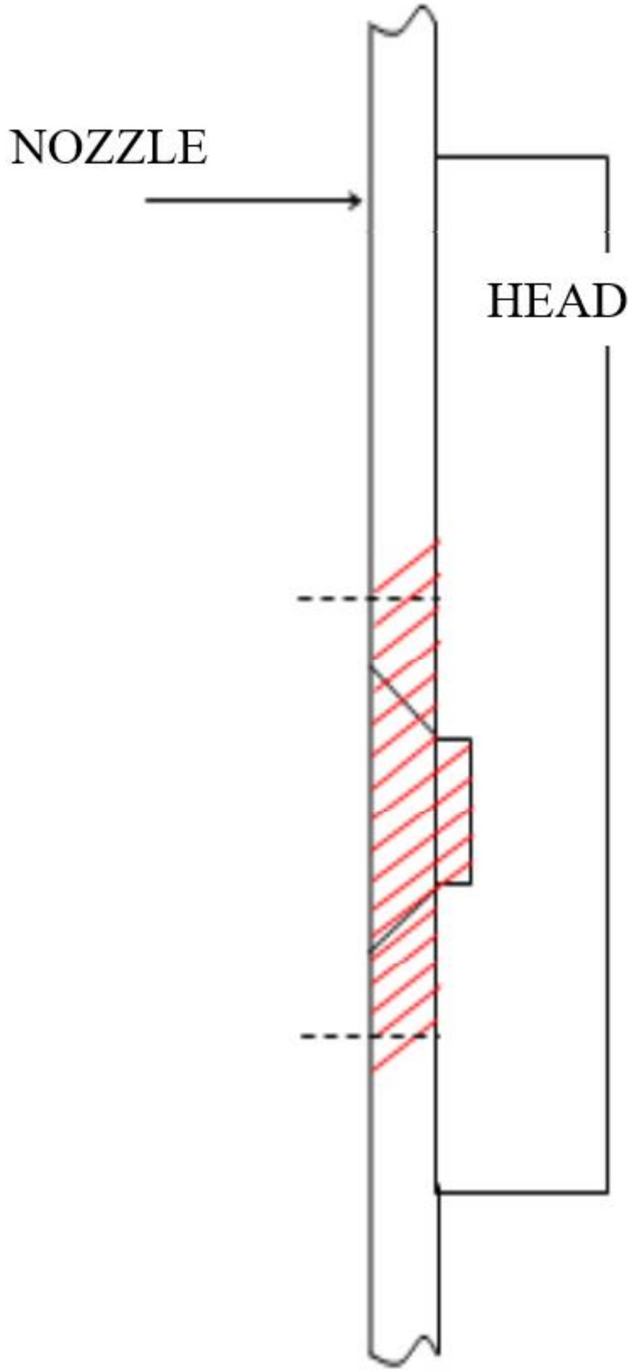


Figure 7

Nozzle 70°L UT Beam Coverage Looking Down

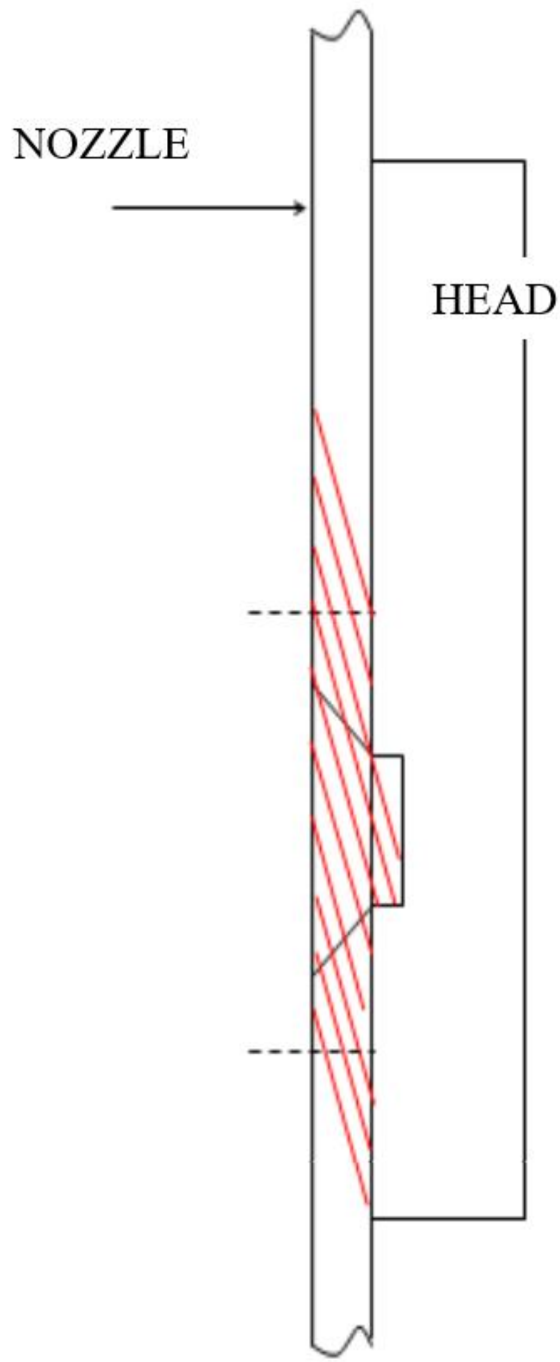


Figure 8

Nozzle 70°L UT Beam Coverage Looking Up

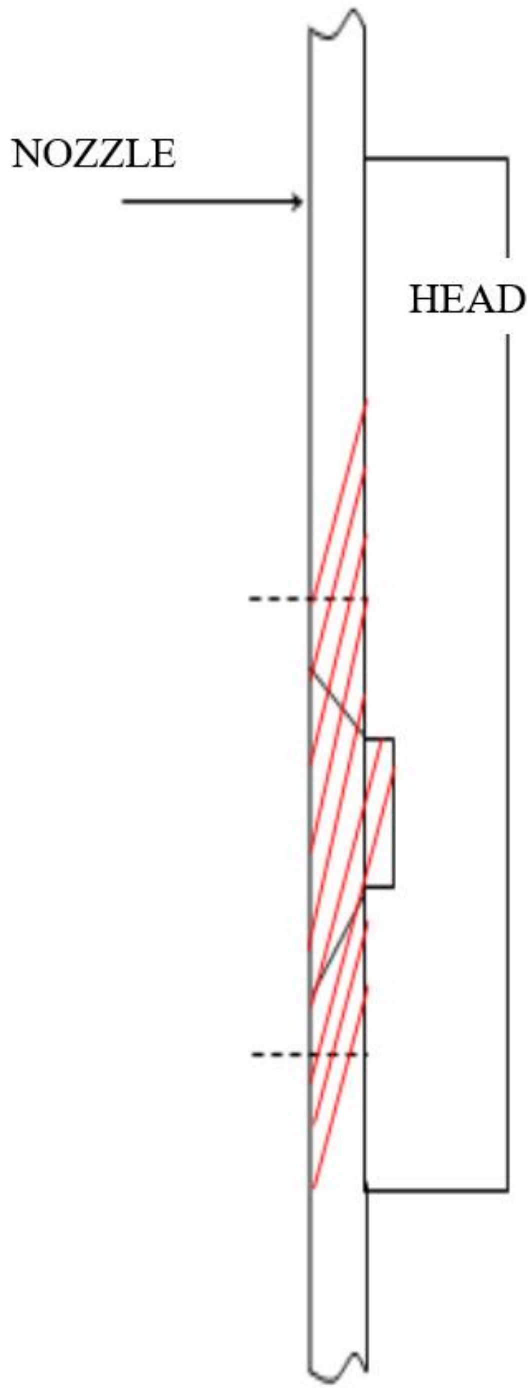
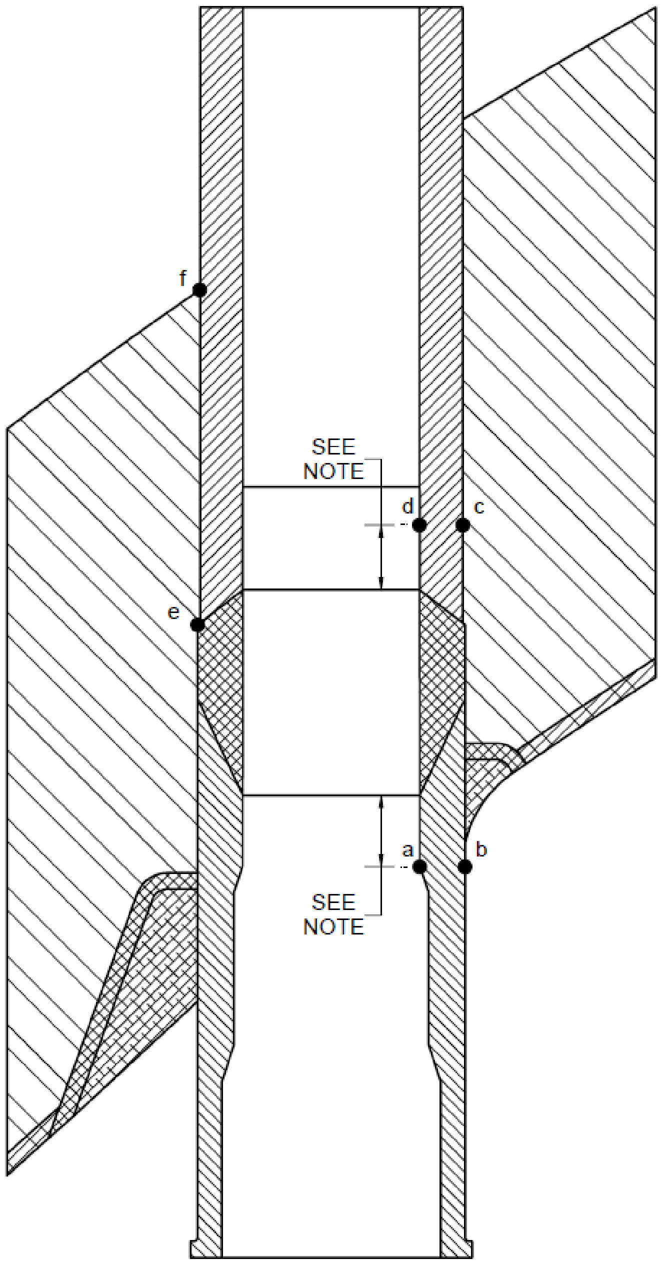


Figure 9

Nozzle PSI/ISI UT Examination

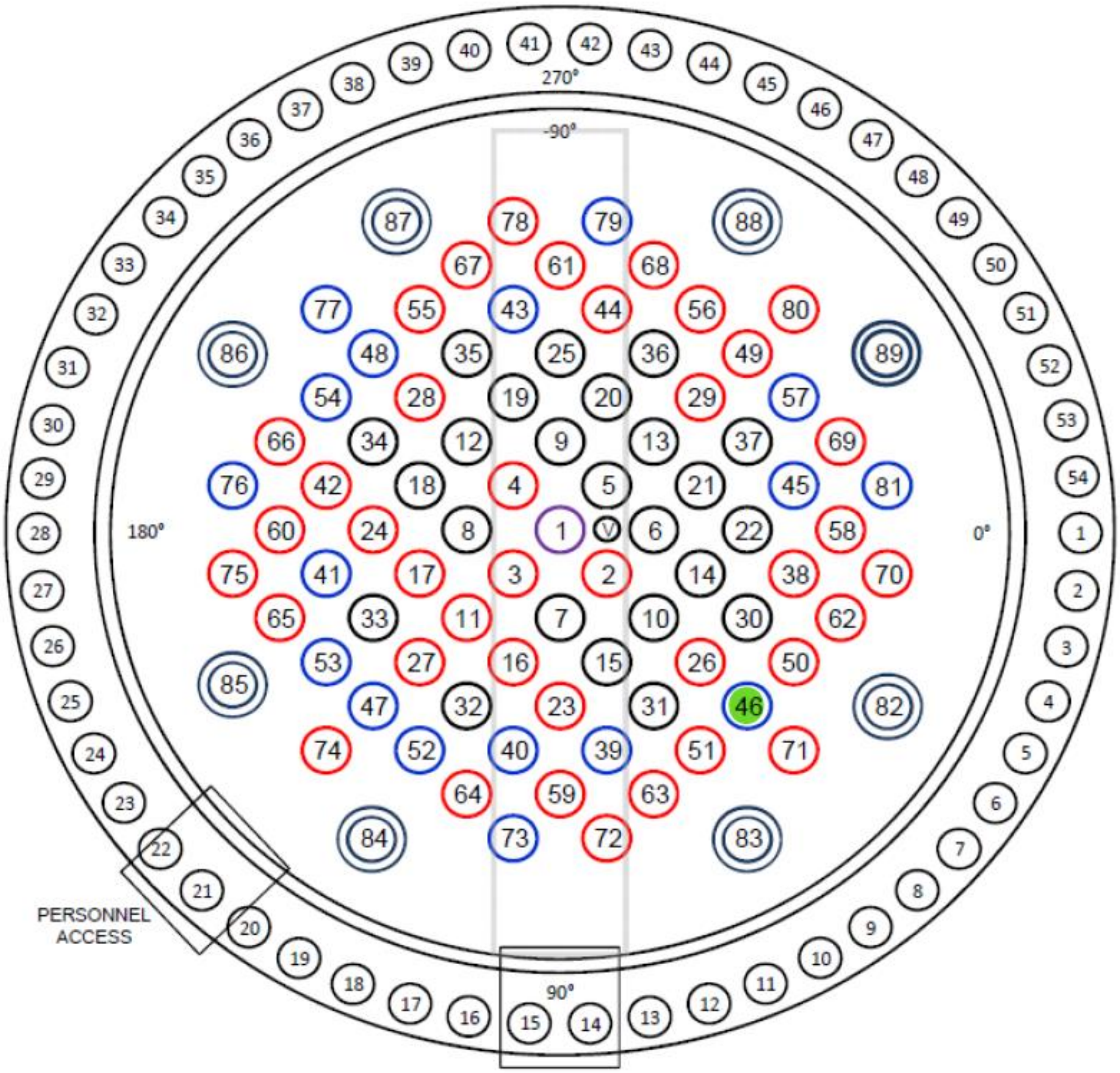


UT	a-b-c-d-a
UT	e-f (leak path)

Note: Extent of examination above and below the weld is 1 inch for Nozzle 46.

Figure 10

Reactor Vessel Head Penetration Locations



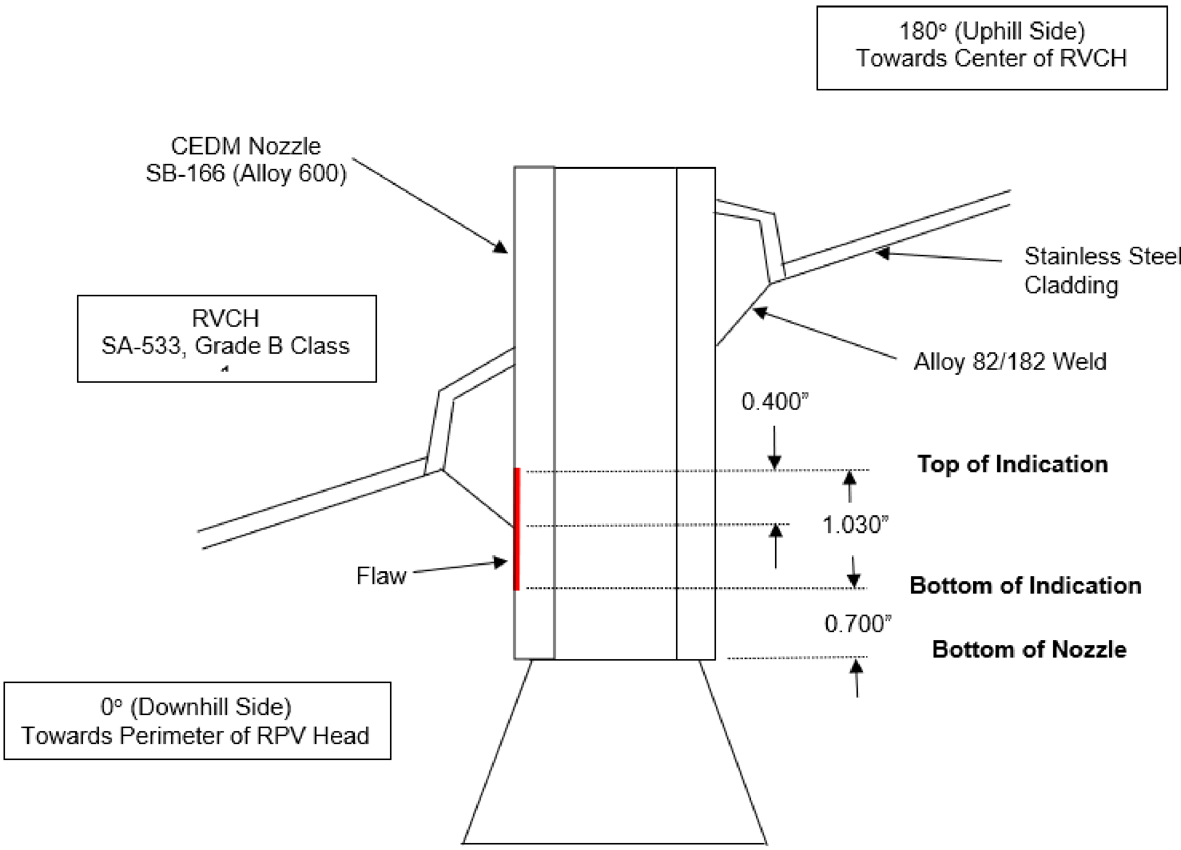
Notes:

1. Figure 10 shows the locations of the RVCH penetrations. There are 81 CEDM penetrations, eight In-core Instrument penetrations, and one Vent line.

2. CEDM Penetration 46 is highlighted.

Figure 11

Indication Location



Enclosure, Attachment

2CAN112103

Commitments

This table identifies actions discussed in this letter for which Entergy commits to perform. Any other actions discussed in this submittal are described for the NRC's information and are **not** commitments.

COMMITMENT	TYPE (Check one)		SCHEDULED COMPLETION DATE (If Required)
	ONE-TIME ACTION	CONTINUING COMPLIANCE	
A one cycle justification will also be developed and submitted to the NRC.	X		Within 14 days of the end of the 2R28 refueling outage.
A revised relief request will be submitted to extend design life of the repair for at least one-interval	X		To support ANO's return to service following 2R29.