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Proprietary Information – Withhold from Public Disclosure Under 10 CFR 2.390

RS-15-236

10 CFR 50.55a

September 11, 2015

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

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Requests for Relief for Alternate Requirements for Repair of Reactor Vessel Head Penetrations with Nozzles Having Pressure-Retaining Partial-Penetration J-Groove Welds

In accordance with 10 CFR 50.55a, "Codes and standards," paragraph (z)(1), Exelon Generation Company, LLC (EGC), requests approval of the attached relief request for Braidwood Station, Units 1 and 2 and Byron Station, Units 1 and 2 Inservice Inspection Program, Third Ten-Year Interval on the basis that the proposed alternatives would provide an acceptable level of quality and safety.

Specifically, a relief request is being proposed to perform an alternative repair technique using the Areva Inside Diameter Temper Bead (IDTB) welding method to restore the pressure boundary of a degraded nozzle. The IDTB welding method is performed with a remotely operated weld tool utilizing the machine gas tungsten arc welding (GTAW) process and the ambient temperature temper bead method. The modification will be performed in accordance with the 2001 edition, including Addenda through 2003, of ASME section XI, Code Case N-638-4, Code Case N-729-1 and the alternatives as discussed in section 5 of Attachment 1.

Note, this relief request is being submitted as a contingency effort to support repair of potential indications requiring repair as detected during an Inservice Inspection (ISI) Program ultrasonic (UT) examination of the affected vessel head penetrations (VHPs). This relief request is being submitted on a preemptive basis to ensure a timely repair and minimize impact on NRC resource's on an emergent basis should Braidwood Station or Byron Station discover a flaw that requires a repair in the upcoming outages. The need for a repair could be determined as early as during the Byron Station refueling outage in Fall 2015 (B1R20).

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In accordance with 10 CFR 50.55a(z)(1), the proposed alternatives may be approved by the NRC provided an acceptable level of quality and safety are maintained. EGC concludes the proposed alternatives meet this requirement.

Attachment 1 includes the Relief Request. Attachment 2 contains the proprietary calculation, "IDTB RVCH Repair Weld Anomaly Fracture Mechanics Stress Analysis (32-9237284-000)." Attachment 3 provides the non-proprietary version of Attachment 2. Attachment 4 contains the proprietary calculation, "IDTB RVCH Repair Fracture Mechanics Stress Analysis (As-Left J-Groove Weld) (32-9236713-000)." Attachment 5 provides the non-proprietary version of Attachment 4.

Attachment 2 and Attachment 4 contain proprietary information as defined by 10 CFR 2.390, "Public inspection, exemption, requests for withholding." Areva, Inc,(Areva) as the owner of the proprietary information has executed the enclosed affidavit, which identifies that the enclosed proprietary information has been handled and classified as proprietary, is customarily held in confidence, and has been withheld from public disclosure. The proprietary information was provided to EGC by Areva as referenced by the affidavit. The proprietary information has been faithfully reproduced in the attached information such that the affidavit remains applicable. Arvea hereby requests that the attached proprietary information be withheld, in its entirety, from public disclosure in accordance with the provisions of 10 CFR 2.390 and 10 CFR 9.17. The affidavit supporting the proprietary nature of the information is contained in Attachment 6.

There are no regulatory commitments contained within this letter.

Should you have any questions concerning this letter, please contact Ms. Jessica Krejcie at (630) 657-2816.

Respectfully,

David M. Gullott
Manager – Licensing
Exelon Generation Company, LLC

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Attachment 1: 10 CFR 50.55a Request Number I3R-16 for Braidwood Station Units 1 and 2 and I3R-28 for Byron Station Units 1 and 2
Attachment 2: Areva Calculation, "IDTB RVCH Repair Weld Anomaly Fracture Mechanics Stress Analysis (32-9237284-000)", BYR15-032 / BRW-15-0050-M, Revision 0 (PROPRIETARY), See Note 1
Attachment 3: Areva Calculation, "Byron/Braidwood RVCH Nozzle IDTB Repair Weld Anomaly, 32-9244389-000, Revision 0" (NON-PROPRIETARY), See Note 1
Attachment 4: Areva calculation, "IDTB RVCH Repair Fracture Mechanics Stress Analysis (As-Left J-Groove Weld) (32-9236713-000)," BYR15-034 / BRW-15-0052-M, Revision 0 (PROPRIETARY), See Note 2
Attachment 5: Areva Calculation, "Byron and Braidwood RVCH Nozzle As-Left J-Groove Analysis 32-9244434-000 Revision 0" (NON-PROPRIETARY), See Note 2
Attachment 6: Areva Affidavit

Notes:

1. Areva Calculation 32-9244389-000 (Attachment 3) is the Non-Proprietary 'equivalent' version of EGC approved Areva Calculation 32-9237284-000 (Attachment 2), though titles are dissimilar. EGC chose titles to facilitate internal document electronic searches.
2. Areva Calculation 32-9244434-000 (Attachment 5) is the Non-Proprietary 'equivalent' version of EGC approved Areva Calculation 32-9236713-000 (Attachment 4), though titles are dissimilar. EGC chose titles to facilitate internal document electronic searches.

Attachments 2 and 4 contain Proprietary Information. Withhold from public disclosure under 10 CFR 2.390. When separated from Attachments 2 and 4, this document is decontrolled.

ATTACHMENT 1

10 CFR 50.55a Relief Request Number
Braidwood Station I3R-16 and Byron Station I3R-28
Request for Relief
Alternative Requirements for the Repair of Reactor Vessel Head Penetrations in Accordance with 10 CFR 50.55a(z)(1)

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Request for Relief
Alternative Requirements for the Repair of Reactor Vessel Head Penetrations In Accordance with 10 CFR 50.55a(z)(1)

1.0 ASME CODE COMPONENTS AFFECTED:

Component Numbers:	Braidwood and Byron Station, Units 1 and 2, Reactor Vessels 1RC01R (Unit 1) and 2RC01R (Unit 2)
Description:	Alternative Requirements for the Repair of Reactor Vessel Head Penetrations (VHPs) with Nozzles Having Pressure-Retaining Partial-Penetration J-groove Welds
Code Class:	Class 1
Examination Category:	ASME Code Case N-729-1
Code Item:	B4.20
Identification:	Byron Units 1 and 2, VHP Numbers 1 through 78, (P-1 through P-78) - Except VHPs with Previous Repairs Previous repairs: Unit 2, P-6 and P-68 and Unit 1, P-31, P-43, P-64 and P-76 Braidwood Units 1 and 2, VHP Numbers 1 through 78, (P-1 through P-78) - Except VHPs with Previous Repairs Previous repairs: Unit 1, P-69
Reference Drawing:	Closure Head Assembly: Byron / Braidwood (185282E)
Size:	4 Inch Nominal Outside Diameter
Material	Inconel SB-167

2.0 APPLICABLE CODE EDITION AND ADDENDA:

Interval Inservice Inspection (ISI) and Repair/Replacement Programs: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, 2001 Edition through the 2003 Addenda (Reference 1). Examinations of the VHPs are performed in accordance with 10CFR50.55a(g)(6)(ii)(D), which specifies the use of Code Case N-729-1, with conditions.

Code of Construction [Reactor Pressure Vessel (RPV)]: ASME Section III, 1971 Edition through Summer 1973 Addenda.

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3.0 APPLICABLE CODE REQUIREMENT:

The applicable requirements of the following Construction Codes for the removal or mitigation of defects from which relief is requested are as follows:

ASME Code, Section XI, 2001 Edition, including Addenda through 2003

- 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, 2001 Edition, including Addenda through 2003

- NB-5245, Butt-Welded Nozzles or Branch Connections, specifies progressive surface examination of partial penetration welds.

- NB-5331(b) states:

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

Code Case N-638-4, *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 post weld heat treatment.

- Paragraph 1(g) states:

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

The applicable requirements of the following Construction Codes for the removal or mitigation of defects from which relief is not specifically requested are as follows:

ASME Code, Section XI, 2001 Edition, including Addenda through 2003

- IWA-3300 specifies requirements for characterization of flaws detected by inservice examination.

- 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.

- 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.....

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- IWA-4224.1, Identical material Procured to a Later Edition or Addenda of the Construction Code, Section III or Material Specification.

  (a) Materials, including welding materials may meet the requirements of later dates...
  (b) Differences in the specified material tensile stress...

- IWA-4400 provides welding, brazing, metal removal, and installation requirements related to repair/replacement activities.

- 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.

- 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). Filler metal requirements shall be reconciled, as required, in accordance with IWA-4224.

- IWA-4412 states:

  Defect removal shall be accomplished in accordance with the requirements of IWA-4420.

- IWA-4420(a) states:

  Defect removal by mechanical processing shall be in accordance with IWA-4462.

- IWA-4462(b) states:

  Where welding is to be performed, the cavity shall be ground smooth and clean with beveled sides and edges rounded to provide suitable accessibility for welding.

- 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 III, 1971 Edition, including Addenda through 1973

- Table NB-4622.1-1 requires:

  Post Weld Heat Treatment (PWHT) for P3 materials.

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 VHPs.

Code Case N-749, *Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in the Upper Shelf Temperature Range, Section XI, Division 1*

4.0 REASON FOR REQUEST:

To ensure timely repair and minimize impact on NRC resource's on an emergent basis, a preemptive submittal of this relief request is being made as a contingency effort to support the required repair for potential indication(s) discovered in upcoming outages. If an indication requiring repair was detected during an ISI Program ultrasonic (UT) examination of the VHPs, the affected VHP(s) will be modified under this request.

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 RVCH Code of Construction, Exelon proposes to perform the modification of the VHP(s) 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 gas tungsten arc welding (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 2001 Edition, including Addenda through 2003, of ASME Section XI, Code Case N-638-4, Code Case N-729-1, and the alternatives discussed in 5.0.

Basic steps for the modification are:

1) Removal of a lower portion of the existing thermal sleeve assembly at the applicable VHP(s) to provide access for IDTB welding.
2) Roll expansion above the region to be modified to stabilize the nozzle and prevent any movement when the nozzle is separated from the nozzle to RVCH J-groove weld.
3) Machining to remove the lower nozzle (and CETC nozzle guide at CETC nozzle locations) to an elevation above the J-groove weld eliminating the portions of the nozzle which may contain the unacceptable indication(s). This machining operation also establishes the weld prep area (Refer to Fig. A-1 and A-10).
4) Liquid penetrant (PT) examination of the machined area (Refer to Fig. A-3 and A- 12).
5) Welding the remaining portion of the nozzle, and replacement CETC nozzle extension at the applicable VHP(s), to the RVCH using primary water stress corrosion cracking (PWSCC) resistant Alloy 52/Alloy 52M/Alloy 52MSS, hereinafter all referred to as Alloy 52, weld material (Refer to Figures A-2 and A-11).
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 region (Refer to Fig. A-3 and A-12).
8) Rotary peening on the portion of the remaining nozzle most susceptible to PWSCC to impart compressive residual stress on the nozzle surface.

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9) PT examination of the peened area.

10) Welding of a new lower thermal sleeve assembly at the applicable VHP(s) and / or installation of a CETC nozzle guide at the CETC nozzle locations.

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

Exelon has determined that modification of the VHP(s) 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).

5.0 PROPOSED ALTERNATIVE AND BASIS FOR USE:

5.1 IDTB Modification Acceptance Examination

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 surface (PT) 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 CRDM and RVLIS nozzle repair/modification, the welds are suitable for UT examination. However, the welds are only accessible from the top side, and therefore limited UT coverage of the volume within the lower taper transition is available as discussed herein (Refer to Figures A-4 thru A-8). For a CETC nozzle repair/modification, the weld is suitable for UT examination and the weld is accessible from both the top and bottom sides (Refer to Figures A-13 thru A-17).

UT volumetric examination of the repaired/modified configuration will be performed as specified in ASME Code Case N-638-4, 4(a)(2)and 4(a)(4). The acceptance criteria of NB-5330, in ASME Section III, 2001 Edition, including Addenda through 2003, apply to all flaws identified within the repaired/modified volume. Regulatory Guide 1.147, Rev. 17, has conditionally approved Code Case N-638-4 with the condition that UT volumetric examinations are performed with personnel and procedures qualified for the repaired volume and qualified by demonstration using representative samples which contain construction type flaws (see 7.1).

The UT transducers and delivery tooling are capable of scanning from cylindrical surfaces with inside diameters of approximately 2.75 in. The scanning is performed using 0° L-wave transducers, 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. Additionally, the low alloy steel extending to ¼ in. beneath the weld into the low alloy steel base material (see Figures A-

3 and A-12) will be examined using the 0° L-wave transducers searching for evidence of under bead cracking and lack of fusion in the heat affected zone.

The UT equipment is not capable of scanning from the face of the weld taper at CRDM and RVLIS nozzle locations. The 45°L and 70°L axial UT examination scans looking down (see Figures A-5 and A-7) will interrogate the taper transition volume on the CRDM and RVLIS nozzle welds. Approximately 70% of the CRDM and RVLIS nozzle weld surface is expected to be scanned by UT. Approximately 83% of the RVCH ferritic steel heat affected zone is expected to be covered by UT. The actual CRDM and RVLIS nozzle 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 for the CRDM and RVLIS nozzle modified configuration. There is no portion of the CRDM or RVLIS nozzle weld volume that does not receive at least single direction UT coverage. The UT coverage of the modified CETC nozzle configuration will exceed the coverage of the CRDM and RVLIS nozzle modified configuration since it receives essentially 100% coverage. The UT examination coverage volumes are shown in Figures A-4 through A-8 for CRDM and RVLIS nozzle scans and A-13 through A-17 for CETC nozzle scans.

In addition to the UT examinations, a final surface PT examination will be performed on the entire weld as shown in Figure A-3 for the CRDM and RVLIS nozzle welds and Figure A-12 for the CETC nozzle welds. PT examination will also be repeated on the remediated surfaces. Further, the volume in question will be examined to the extent practical using the 70°L and 45°L (see Figures A-5, A-7, A-14, and A-16) 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. 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 the welding, to the extent practical.

The combination of performing PT and UT examinations depicted in Figures A-3 and A-12 during the IDTB repair provides assurance of structural integrity. Thus, EGC requests relief from the progressive surface examination requirements specified in NB-5245.

5.2 Triple Point Anomaly

ASME Section III, 2001 Edition, including Addenda through 2003, NB-5331(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. 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 52 weld intersect. The location of the triple point for the CRDM and RVLIS nozzle is shown in Figure A-2 and the upper and lower triple points for the CETC nozzle are shown in Figure A-11.

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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 in. 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 [10] 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 in. 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 below.

Path 1: Flaw propagation is across the nozzle wall thickness from the outside surface to the inside surface of the nozzle.

This is also the shortest path through the new Alloy 52 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 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 new IDTB 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 when subjected to high cyclic stresses in the nozzle penetration repair.

Path 2: Flaw propagation extends down the outside surface of the repair weld between the weld and the RVCH.

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 52 weld material or the ferritic low alloy steel RVCH base material.

The results of the analyses demonstrate that the 0.10 in. weld anomaly is acceptable for a 40-year design life of the nozzle modification considering the applicable transients and cycles. Sufficient design margins are demonstrated for all flaw propagation paths considered in the analysis. Flaw acceptance is based on criteria for limit load (IWB-3644). Fatigue crack growth is conducted along each flaw propagation paths for the CRDM, RVLIS and CETC nozzles. For the postulated axial and circumferential flaws in the Alloy 52 repair weld, the acceptance criteria of IWB-3642 which permits the use of the analytical procedures described in ASME Section XI, Appendix C. For the CRDM, RVLIS and CETC nozzle welds, net section collapse analysis is performed for the postulated circumferential flaw. Cross-sectional bending at the postulated flaw locations is insignificant due to the nozzle being encased in the vessel head. The limit load failure is driven by applied membrane stresses and evaluated. The allowable bending stress is shown to be more than the applied bending stress. Also, the minimum limit load margins

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for postulated axial and cylindrical flaws are less than the required safety factor of 2.7, as specified in IWB-3644. 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.

These evaluations are prepared in accordance with ASME Section XI and demonstrate for the intended service life of the modification that 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 postulated crack-like defects at the top of the CRDM nozzle weld(s), RVLIS nozzle weld(s) and CETC nozzle weld(s) 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 crack growth rates from PWSCC are not applicable.

EGC request relief from the acceptance criteria specified in NB-5331(b) to permit anomalies, as described herein, at the triple point region to remain in service.

5.3 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. 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.

The J-groove flaws have been evaluated using worst-case postulated flaw sizes. Fatigue crack growth for cyclic loading conditions using operational stresses from pressure and thermal loads and crack growth rates from Article A-4300 of Section XI for ferritic material in a primary water environment will be calculated. The results of this evaluation show that, based on a combination of linear elastic fracture mechanics (LEFM) analysis and elastic-plastic fracture mechanics (EPFM) analysis [11] of a postulated remaining flaw in the original Alloy 82/Alloy 182 J- groove weld and buttering for the modified RVCH nozzle is acceptable for the remaining life of the Unit plus a 20 year life extension following an IDTB weld repair.

LEFM and EPFM analyses [11] were used to demonstrate the remaining service life plus life extension for the remaining worst-case "as-left" flaw in the J-groove weld. 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 VHP penetration is the worst case position for the postulated flaw,

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- calculated the final flaw size by fatigue crack growth, and
- identified the controlling service conditions for evaluation by EPFM analysis.

Crack stress intensity factors for initial "as-left" flaws are first determined using 3-dimensional finite element analysis and applying both residual and operating stresses for each of the applicable transients. Crack size is incremented based on the fatigue crack growth rate equations given in A-4300 of ASME Section XI, as modified by 10CFR50.55a. For the VHP nozzle welds the maximum flaw growth into the RVCH low alloy steel is calculated on the uphill side and on the downhill side and the remaining service life determined. The crack stress intensity factor, including pressure, thermal and residual stress effects, for the final maximum flaw size using the acceptance criteria of IWB-3612 indicated insufficient available fracture toughness to provide the specified margins under all conditions, thus, the appropriate failure mechanism (ductile tearing) was determined below.

Based on a determination that ductile tearing is the failure mechanism for the final flaw under the conditions being evaluated, EPFM analysis is utilized to evaluate the final flaw sizes for all propagation paths. EPFM analysis is performed using a J-integral/tearing modulus (J-T) diagram to evaluate flaw stability under ductile tearing. Additionally, the crack driving force (applied J-integral) is checked against the J-R curve at a crack extension of 0.10 in. (J0.1). The safety factors that are applied to the primary and secondary stresses in the EPFM analysis are tabulated below:

Operating Condition	Evaluation Method	Safety Factors*	
		Primary	Secondary
Normal/Upset	J/T based flaw stability	2.14	1.0
Normal/Upset	J0.1 limited flaw extension	1.5	1.0
Emergency/Faulted	J/T based flaw stability	1.2	1.0
Emergency/Faulted	J0.1 limited flaw extension	1.25	1.0

* EPFM safety factors from Code Case N-749 as modified by the NRC (see attachment in ML14330A510).

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. The conclusion is that there are no known service conditions that could drive radial cracks and transverse cracks to intersect to produce a loose part.

Flaws are postulated to exist in the remaining portion of the J-groove weld and shown in the evaluation to be acceptable for 33 years of remaining operation (based on a 60 year plant licensed life).

Successive examinations required by IWB-3132.3 will not be performed because analytical evaluation of the worst-case postulated flaw is performed to demonstrate

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acceptability. A reasonable assurance of the RVCH structural integrity is maintained without the successive examinations.

EGC requests relief from flaw characterization specified in IWB-3420 and subsequent examination requirements specified in IWB-2420(b) and IWB-2420(c).

5.4 Rotary Peening

Rotary peening is performed on the final layer to provide further assurance of the modified configuration being resistant to PWSCC [12]. However, peening on the final layer of a temper bead weld is prohibited by ASME Code Case N-638-4, 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 [15]. This is not considered applicable to the rotary peening process, which is highly controlled, uniform, and only influences a shallow surface layer (approximately 20 mils at the base metal i.e., bounding depth). 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.

ASME Code Section III, 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 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.

However, the additional benefits of rotary peening regarding increased PWSCC resistance will not influence the inspection frequency for the modified nozzles as depicted in Code Case N-729-1.

EGC requests relief from Code Case N-638-4,1(g).

5.5 Preservice Inspection (PSI) and Inservice Inspection (ISI) of VHPs Repaired as shown in Figures A-9 and A-18

Parts Examined	Examination Requirement / Figure	PSI / ISI Examination Method	Acceptance Standard	Extent / Frequency
CRDM / RVLIS	Fig. A-9	Surface	N-729-1, -3130	All nozzles, each refueling outage
CETC	Fig. A-18	Volumetric	N-729-1, -3130	All nozzles, each refueling outage

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Code Case (CC) N-729-1 provides requirements for the inspection of VHPs with nozzles having partial penetration welds. CC N-729-1 Table 1, Item B4.20, permits either volumetric or surface examination. Item B4.20 examination requirements are specified in Figure 2 of CC N-729-1. Since either volumetric or surface examination is acceptable, surface examination will be used for PSI/ISI for repaired CRDM and RVLIS nozzles as shown in Figure A-9 due to limited tooling access and volumetric examination will be used for PSI/ISI for repaired CETC nozzles as shown in Figure A-18 (see 7.2).

The repair/modification proposed by this relief request removes much of the examination area depicted in figure 2 of CC N-729-1 at several locations. Thus, Figure A-9 of this relief request is used to establish the examination area of a repaired CRDM or RVLIS nozzle for the preservice inspection following repair and for future inservice inspections. Similarly, Figure A-18 of this relief request is used to establish the examination area of a repaired CETC nozzle for the preservice inspection following repair and for future inservice inspections. The established examination areas are equivalent to that required by Figure 2 in CC N-729-1; as it examines the nozzle weld and the same area above the CRDM nozzle weld, RVLIS nozzle weld, CETC nozzle weld and the CETC nozzle base material below the weld as would be required by Figure 2 in the Code Case.

Therefore, preservice inspection following repair and future inservice inspections will comply with Code Case N-729-1 as modified by 10 CFR 50.55a(g)(6)(ii)(D) and as depicted in Figures A-9 and A-18.

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 [13] was performed for the potential corrosion concerns at the RVCH low alloy steel wetted surface. 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. The general corrosion rate is conservatively estimated to be 0.0036 in./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 performed.

5.7 Conclusions

Implementation of an IDTB repair to the VHP(s) will produce an effective repair that will restore and maintain the pressure boundary integrity of the VHPs. Similar modifications have been performed successfully and have been in service for several years without any known degradation (e.g., Shearon Harris, Palisades). This 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(z)(1).

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6.0 DURATION OF PROPOSED ALTERNATIVES

The analyses of the modified configurations described herein and others for the modified configuration that will be implemented under 10 CFR 50.59 support the remaining life of the original 40 year plant design life plus License renewal life (20 years) of a new 60 year plant design life [14]. The analysis results are based upon expected repair parameters which may vary during implementation. The design lifetime is sensitive to the vertical length of the Alloy 52 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 schedules, and asset management plans. All repaired RVCH penetration nozzles will be examined in accordance with ASME Code Case N-729-1 as conditioned by 10CFR50.55a(g)(6)(ii)(D). The periodic examinations will provide reasonable assurance of the structural integrity of RVCH nozzles prior to exceeding the design life of the repair.

The 33 EFPY life is based on the as-left J-Groove flaw evaluation. A combination of linear elastic and elastic-plastic fracture mechanics, show the postulated flaws to be acceptable for a 33 year plant life utilizing the appropriate safety factors and the lower bound J-R curve from Reg. Guide 1.161 [11]. The results of the weld anomaly flaw evaluation demonstrated that a 0.10" weld anomaly is acceptable for 40 years of plant life (after a repair) [10]. The estimated minimum time for a PWSCC flaw to propagate through 75% of the original wall thickness is over 100 EFPY utilizing rotary peening surface remediation. The overall acceptable life of the repair design is based on the most limiting life predicted amongst the weld anomaly analysis [10], the as-left J-groove analysis [11] and the PWSCC evaluation [12] of the original Alloy 600 nozzle, which is 33 EFPY.

The provisions of this relief request are applicable for the remainder of the Third Inservice Inspection Interval for Byron Station Units 1 and 2, currently scheduled to end on July 15, 2016. The provisions of this relief request are applicable for the remainder of the Third Inservice Inspection Interval for Braidwood Station Units 1 and 2, currently scheduled to end on July 28, 2018 and October 16, 2018, respectively. The modification installed in accordance with the provisions of this relief shall remain in place for the design life of the modification, until another alternative is approved by the NRC, or until the RVCH is replaced.

7.0 ADDITIONAL INFORMATION

7.1 VHP Weld Qualification Mockup UT Acceptance

AREVA, in support of many similar modifications, has performed many qualifications using mockups since VHP modifications at Oconee Nuclear Station in 2001. During these 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.

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UT is required by Code Case N-638-4. NRC Reg. Guide 1.147, Rev. 17 imposes a condition for this code case that requires the examination procedure and examination personnel be qualified by demonstration on representative samples which contain construction type flaws. To satisfy this requirement a mockup containing reflectors to simulate construction type flaws applicable to this weld process has been used. A NiCrFe alloy calibration block is used and contains a series of electrical-discharge machining (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 holes and side drilled holes that are used for calibration.

The examination procedure has also demonstrated the ability to detect a linear weld fabrication triple point anomaly extending 0.10 in. into the weld. The examination procedure was used to collect automated data for the demonstration. An IDTB weld NDE mockup was fabricated to replicate the expected configuration. It contains a series of 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 is normal to the surface to simulate under bead cracking, lack of bond, and lack of fusion.

This is the same mockup used for the procedure qualification for the Davis Besse and Shearon Harris VHP nozzle modifications listed in Section 8.0.

7.2 CETC Nozzle Weld Qualification Mockup UT PSI/ISI

The UT examination of the modified configuration has been qualified by demonstration as required by 10CFR50.55a(g)(6)(ii)(D)(4) on a similar mockup configuration that represents the nozzle modification.

8.0 <u>PRECEDENTS:</u>

1. Davis-Besse Nuclear Power Station - Relief Request RR-A34, April 1, 2010, ADAMS Accession Number ML100960276
2. Shearon Harris Nuclear Power Plant, Unit 1 - Relief Request I3R-09, October 2, 2012, ADAMS Accession Number ML12270A258
3. Shearon Harris Nuclear Power Plant, Unit 1 - Relief Request I3R-11, September 13, 2013, ADAMS Accession Number ML13238A154
4. Shearon Harris Nuclear Power Plant, Unit 1 - Relief Request I3R-13, November 22, 2013, ADAMS Accession Number ML13329A354
5. Shearon Harris Nuclear Power Plant, Unit 1 – Relief Request I3R-15, April 29, 2015, ADAMS Accession Number ML15120A406

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9.0 REFERENCES:

1. ASME Code Case N-638-4 Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, Section XI, Division 1.
2. NRC Regulatory Guide 1.147, Revision 17, Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1
3. 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
4. Materials Reliability Program: An Assessment of the Control Rod Drive Mechanism (CRDM) Alloy 600 Reactor Vessel Head Penetration PWSCC Remedial Techniques (MRP-61), EPRI, Palo Alto, CA: 2003. 1008901.
6. ASME Code Case N-749 Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in the Upper Shelf Temperature Range, Section XI, Division 1
7. Byron Station Unit 1 – Relief Request I3R-19, February 1, 2012, ADAMS Accession Number ML112990783
8. Byron Station Unit 2 – Relief Request I3R-14, May 23, 2007, ADAMS Accession Number ML071290011
9. Byron Station Unit 2 (I3R-20) and Braidwood Station (I3R-09), March 29, 2012, ADAMS Accession Number ML120790647
10. Calculation BYR15-032 / BRW-15-0050-M, "IDTB RVCH Repair Weld Anomaly Fracture Mechanics Stress Analysis (32-9237284-000)"
11. Calculation BYR15-034 / BRW-15-0052-M, "IDTB RVCH Repair Fracture Mechanics Stress Analysis (As-Left J-Groove Weld) (32-9236713-000)"
12. Calculation BYR15-037 / BRW-15-0054-M, "IDTB RVCH Repair PWSCC Evaluation (51-9233902-000)"
13. Calculation BYR15-036 / BRW-15-0053-M, "IDTB RVCH Repair Corrosion Evaluation (51-9234023-000)"
14. Calculation BYR15-038 / BRW-15-0055-M, "IDTB RVCH Repair Life Assessment Evaluation (51-9240805-000)"
15. ASME Boiler and Pressure Vessel Code, Section XI, Interpretation XI-1-13-19, File No. 13-56, Code Case N-606-1, June 21, 2013

10.0 LIST OF FIGURES:

FIGURE A-1: CRDM AND RVLIS NOZZLE MACHINING
FIGURE A-2: CRDM AND RVLIS NOZZLE WELD
FIGURE A-3: CRDM AND RVLIS NOZZLE EXAMINATION
FIGURE A-4: CRDM AND RVLIS NOZZLE UT 0° AND 45° L-WAVE BEAM COVERAGE LOOKING CLOCKWISE AND COUNTER-CLOCKWISE
FIGURE A-5: CRDM AND RVLIS NOZZLE UT 45° L-WAVE BEAM COVERAGE LOOKING DOWN
FIGURE A-6: CRDM AND RVLIS NOZZLE UT 45° L-WAVE BEAM COVERAGE LOOKING UP
FIGURE A-7: CRDM AND RVLIS NOZZLE UT 70° L-WAVE BEAM COVERAGE LOOKING DOWN
FIGURE A-8: CRDM AND RVLIS NOZZLE UT 70° L-WAVE BEAM COVERAGE LOOKING UP
FIGURE A-9: CRDM AND RVLIS NOZZLE PSI AND ISI WELD AND NOZZLE BASE METAL SURFACE EXAMINATION AREA (A-B-C-D)
FIGURE A-10: CETC NOZZLE MACHINING
FIGURE A-11: CETC NOZZLE WELD
FIGURE A-12: CETC NOZZLE EXAMINATION
FIGURE A-13: CETC NOZZLE UT 0° AND 45°L BEAM COVERAGE LOOKING CLOCKWISE AND COUNTER-CLOCKWISE
FIGURE A-14: CETC NOZZLE 45°L UT BEAM COVERAGE LOOKING DOWN
FIGURE A-15: CETC NOZZLE 45°L UT BEAM COVERAGE LOOKING UP
FIGURE A-16: CETC NOZZLE 70°L UT BEAM COVERAGE LOOKING DOWN
FIGURE A-17: CETC NOZZLE 70°L UT BEAM COVERAGE LOOKING UP
FIGURE A-18: CETC NOZZLE PSI AND ISI UT EXAMINATION

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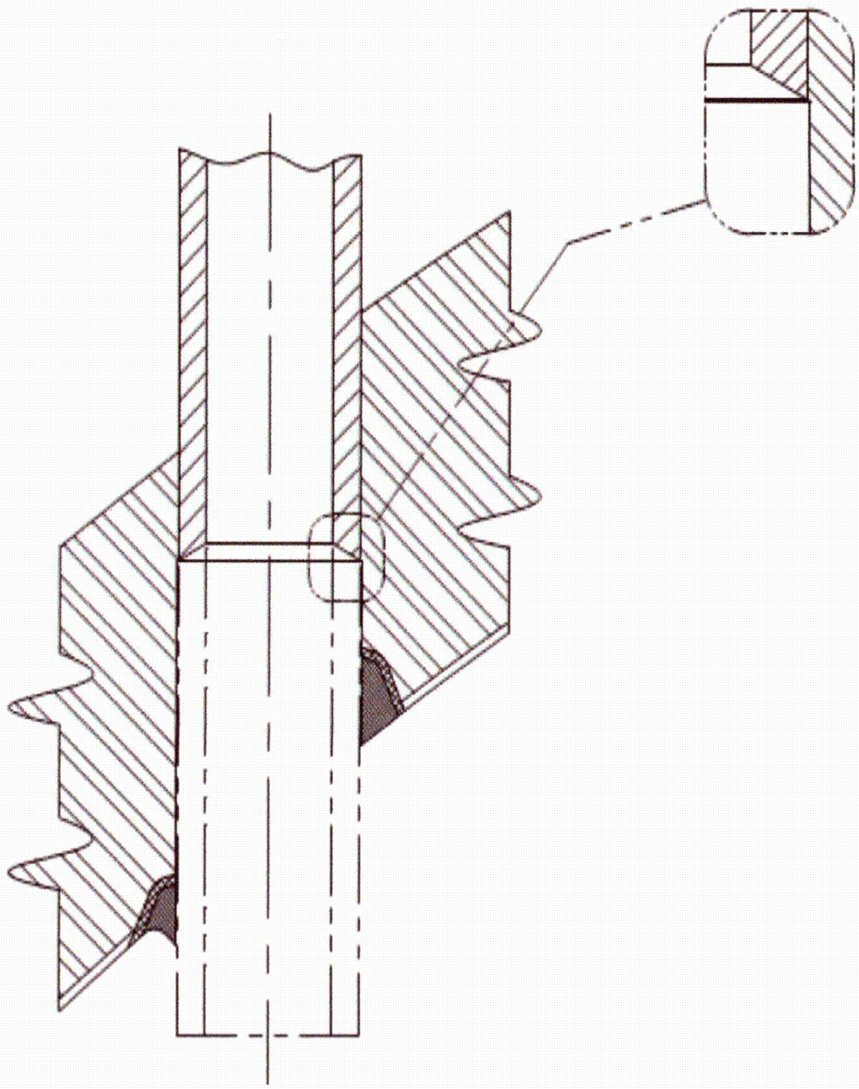

Figure A-1: CRDM and RVLIS Nozzle Machining

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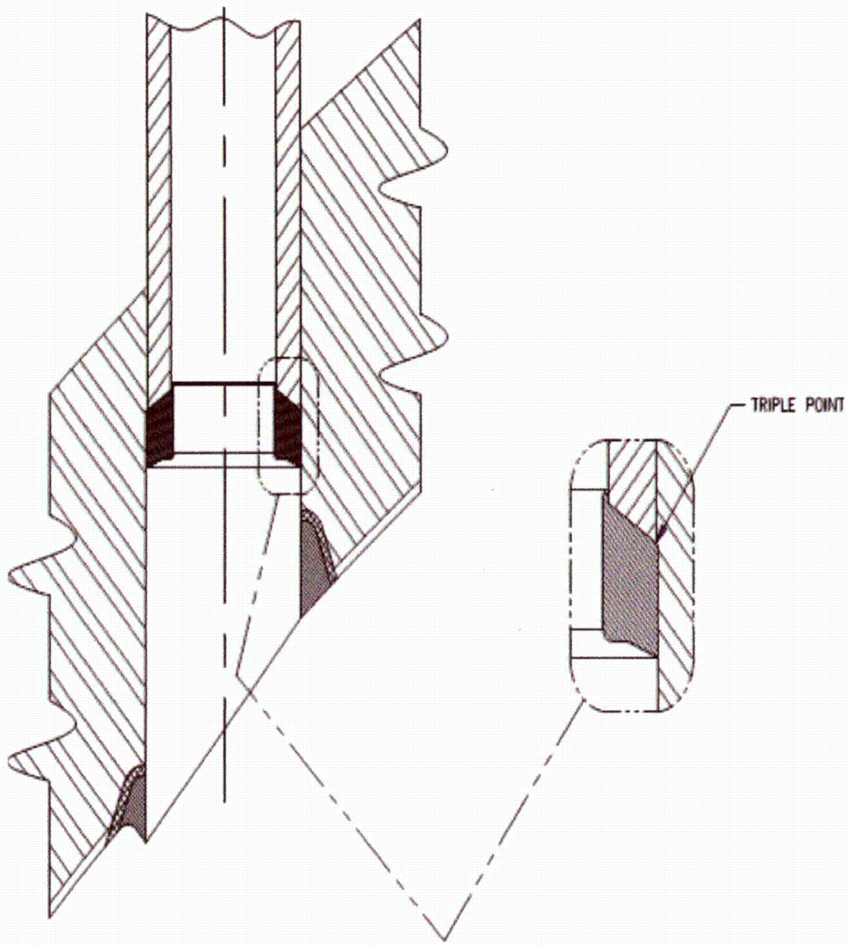

Figure A-2: CRDM and RVLIS Nozzle Weld

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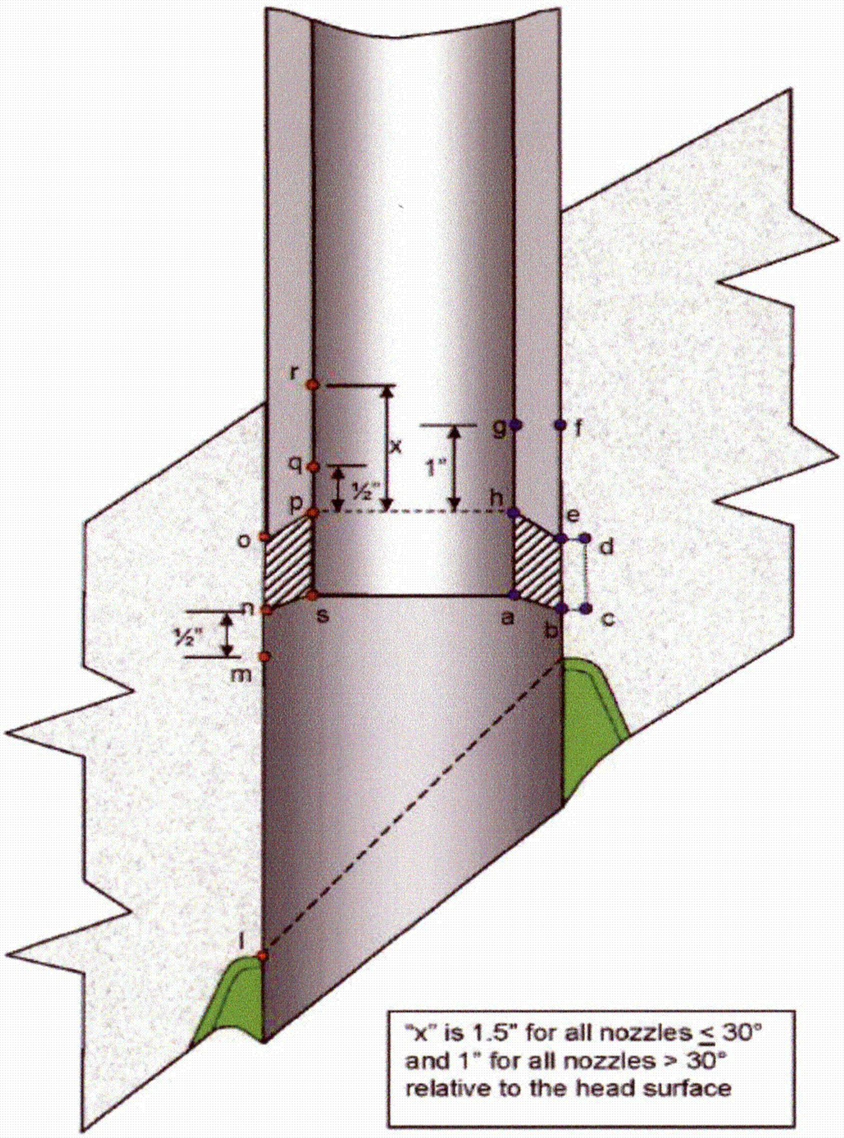

Post – Machining PT	l-m-n-o-p-q
Post – Weld PT	m-n-s-p-q-r
Post – Weld UT (Weld)	a-b-c-d-e-h-a
Post – Weld UT (Nozzle Material)	e-f-g-h-e

Figure A-3: CRDM and RVLIS Nozzle Examination

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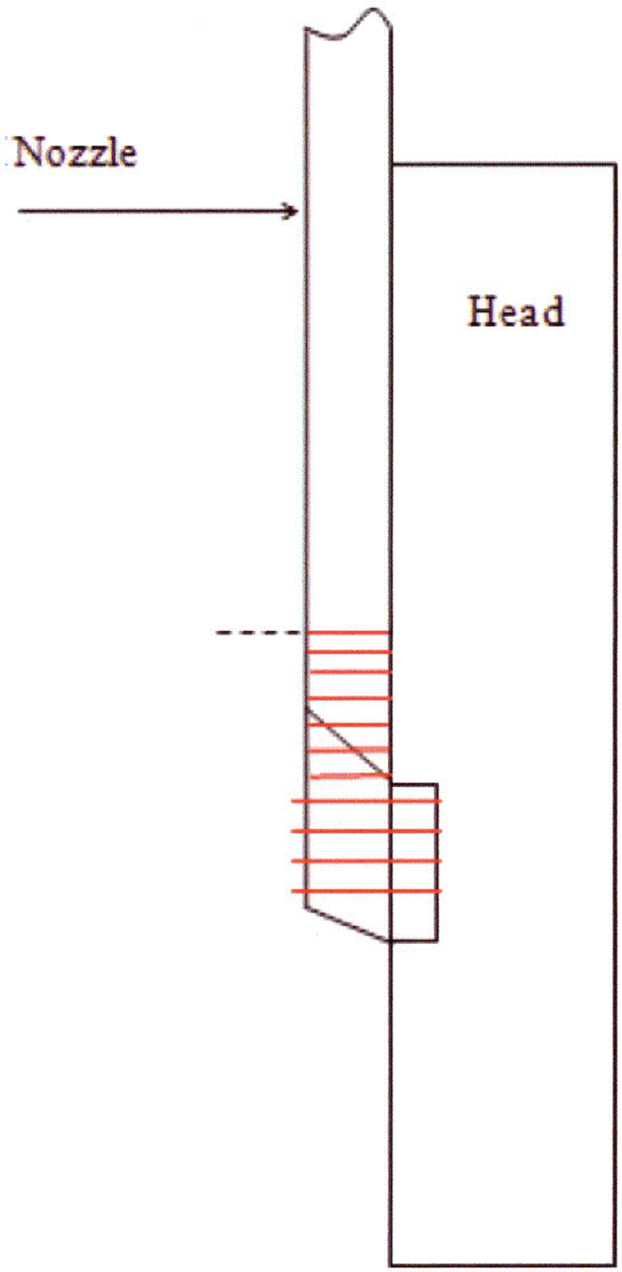

Figure A-4: CRDM and RVLIS Nozzle UT 0° and 45° L-wave Beam Coverage Looking Clockwise and Counter-clockwise

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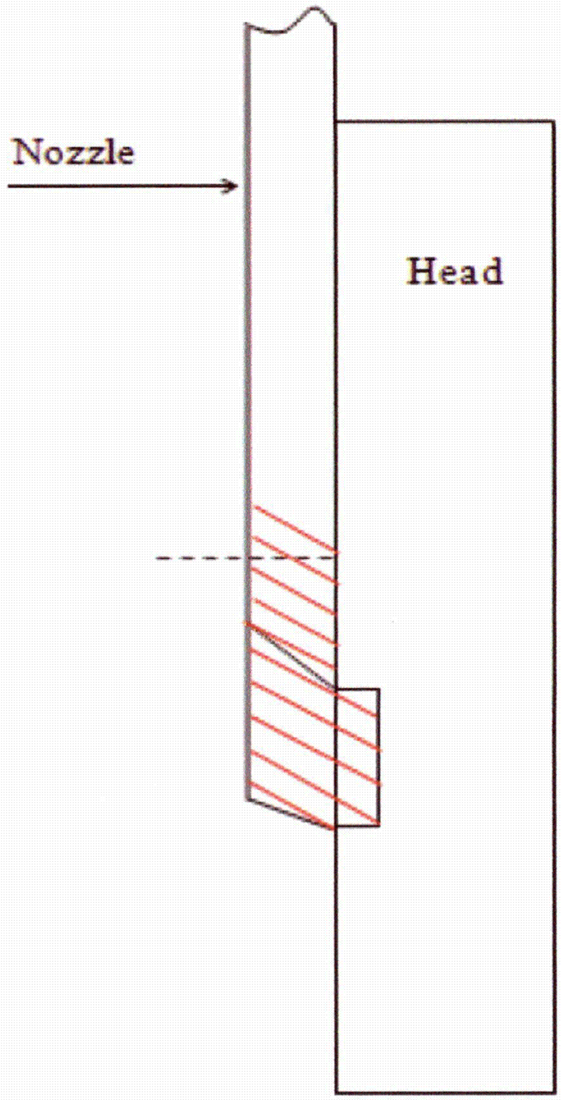

Figure A-5: CRDM and RVLIS Nozzle UT 45° L-wave Beam Coverage Looking Down

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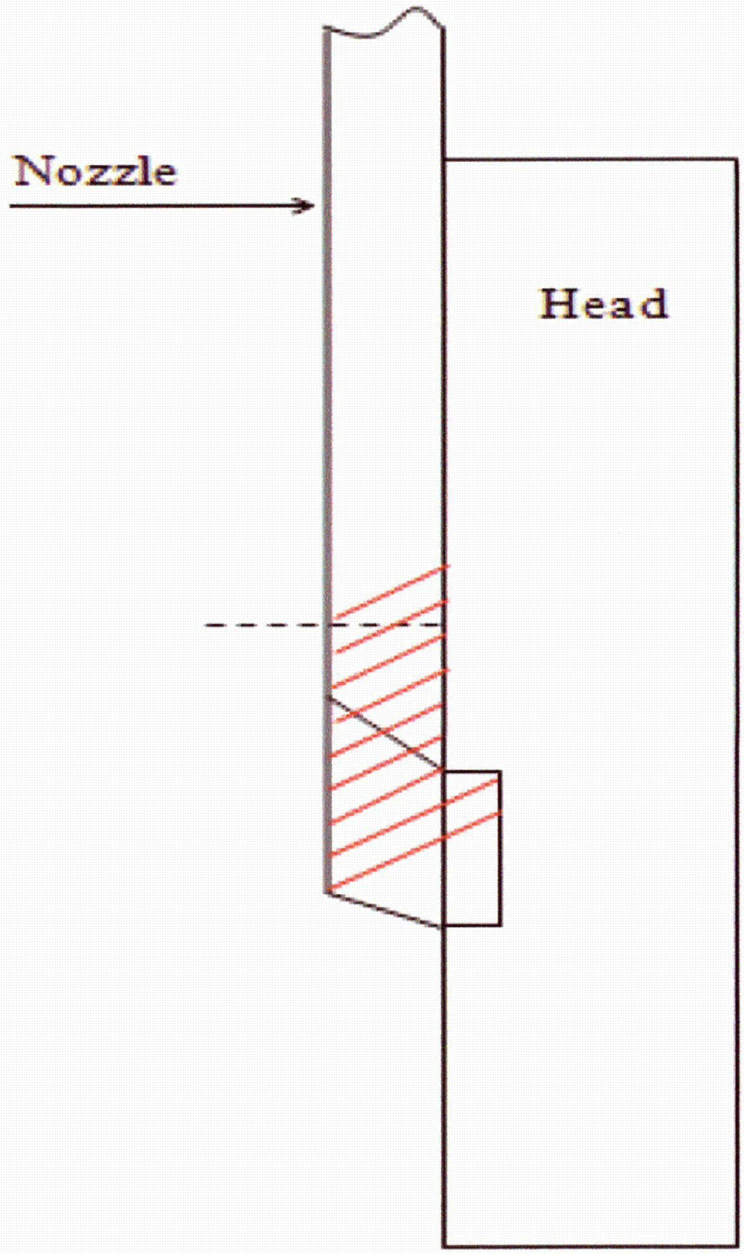

Figure A-6: CRDM and RVLIS Nozzle UT 45° L-wave Beam Coverage Looking Up

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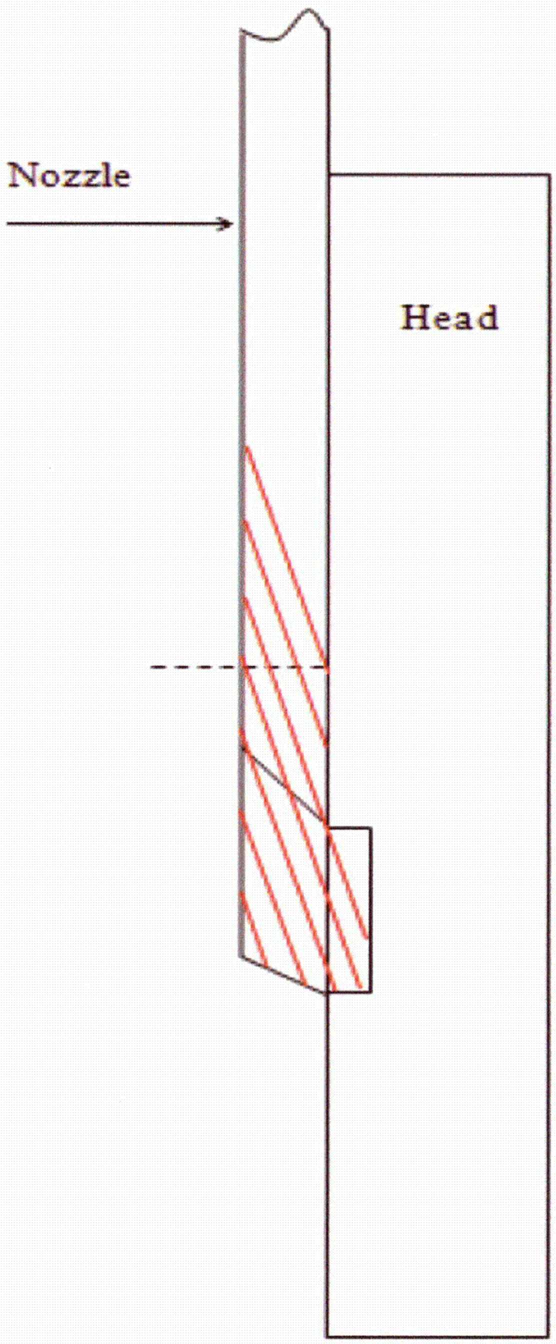

Figure A-7: CRDM and RVLIS Nozzle UT 70° L-wave Beam Coverage Looking Down

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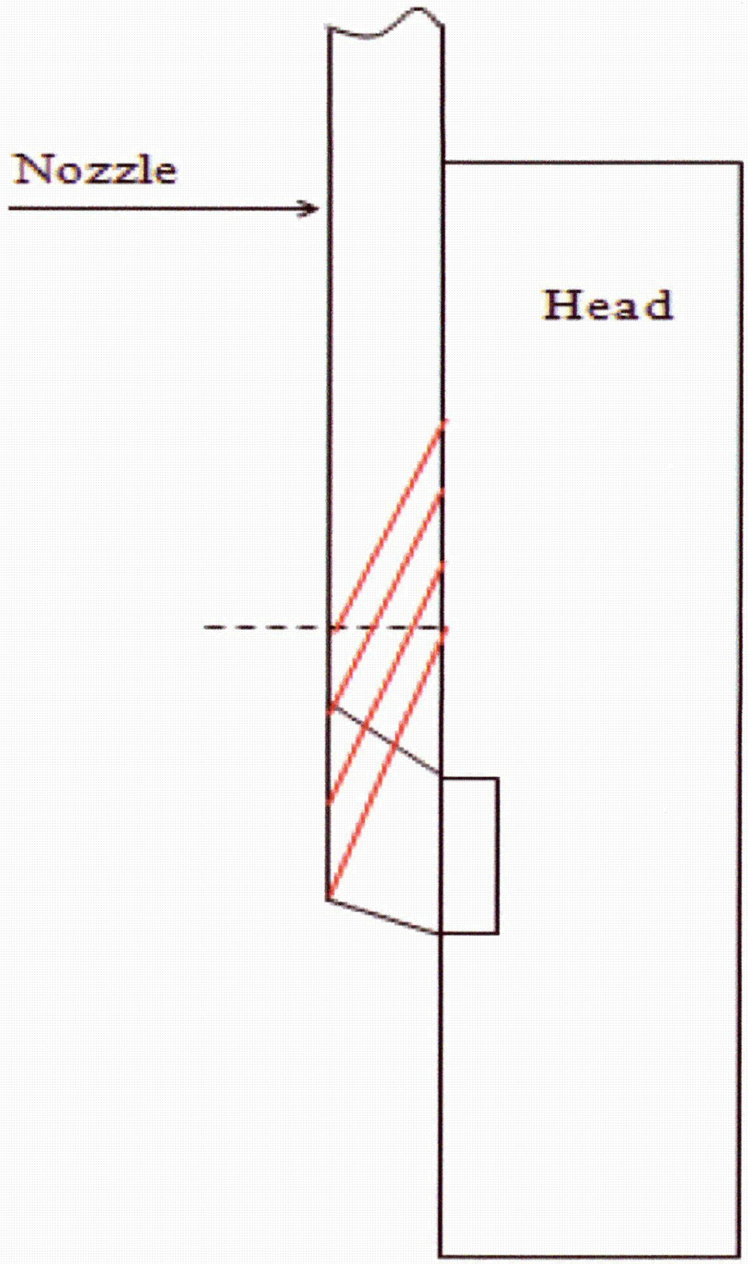

Figure A-8: CRDM and RVLIS Nozzle UT 70° L-wave Beam Coverage Looking Up

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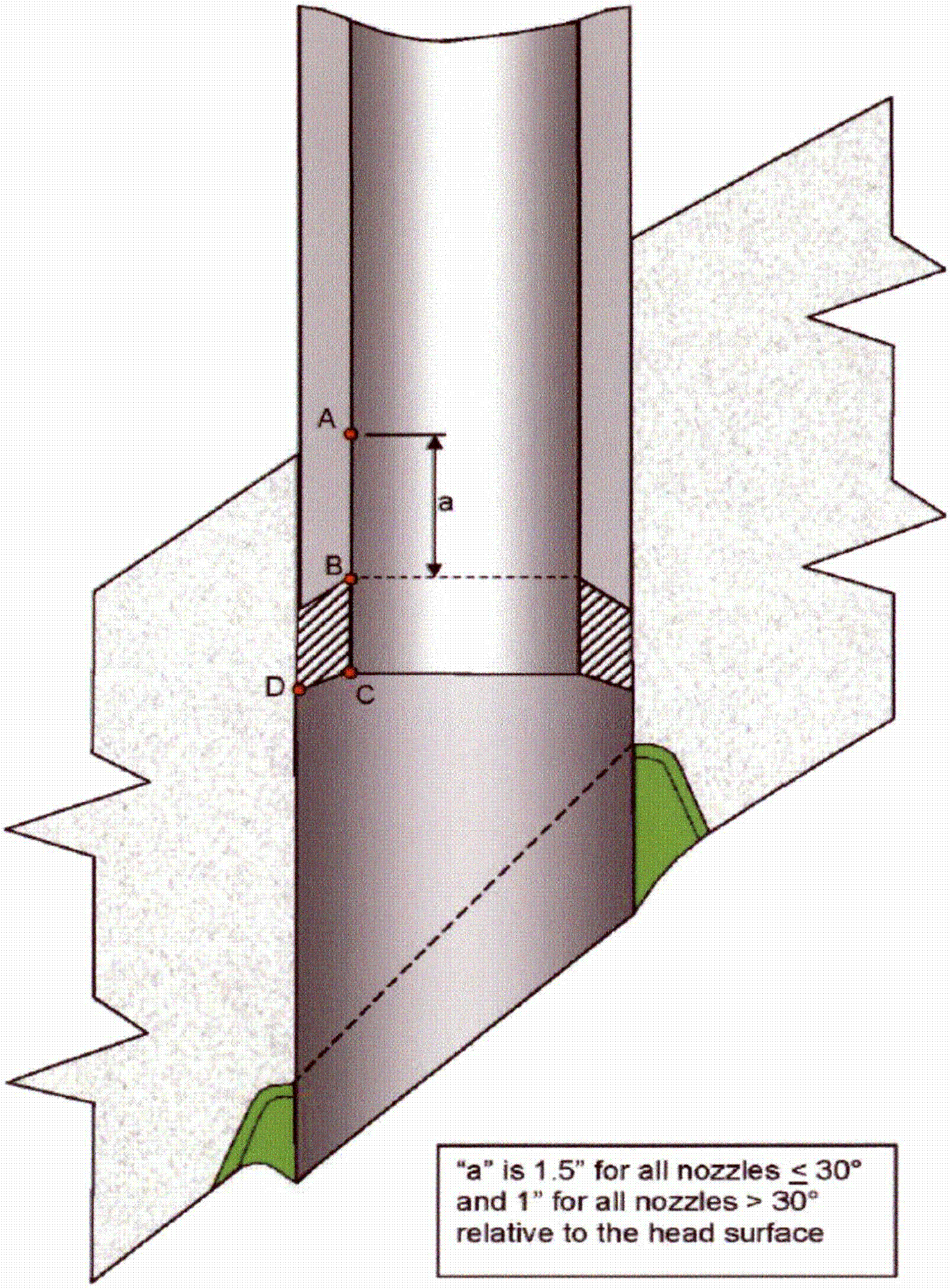

Figure A-9: CRDM and RVLIS Nozzle PSI and ISI Weld and Nozzle Base Metal Surface Examination Area (A-B-C-D)

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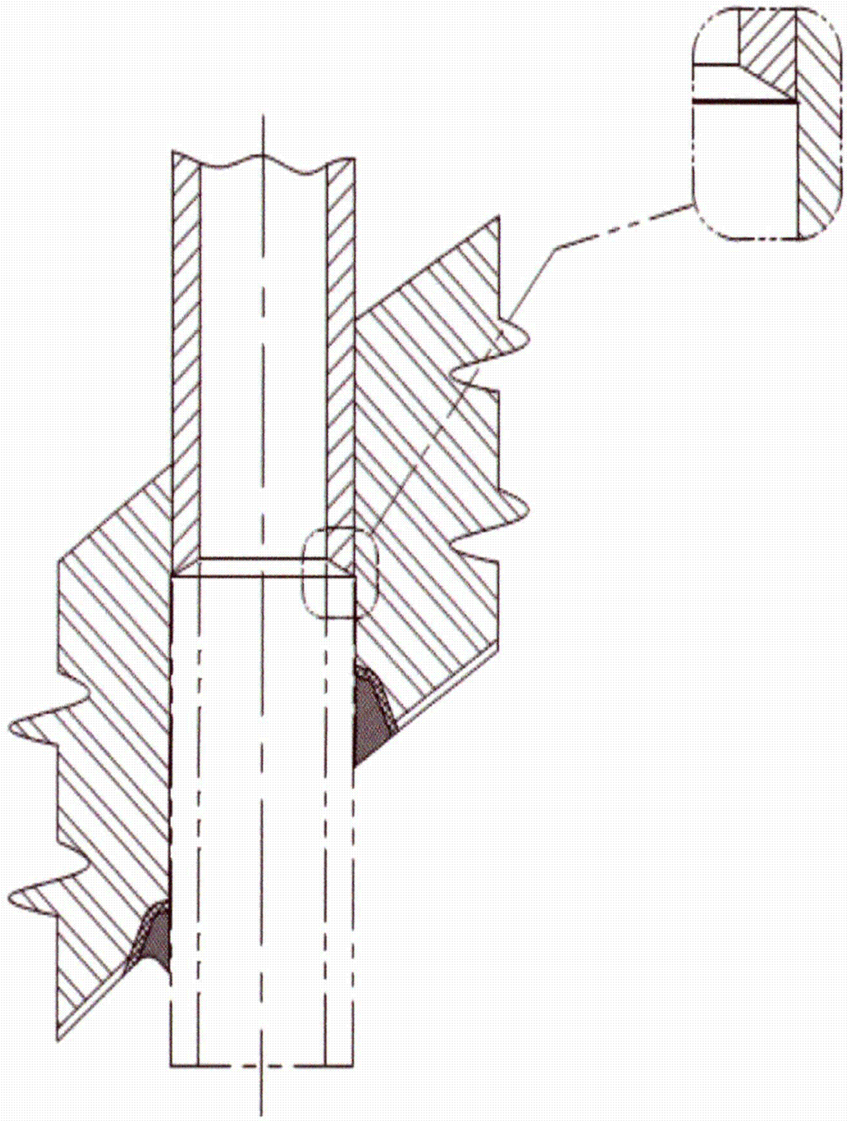

Figure A-10: CETC Nozzle Machining

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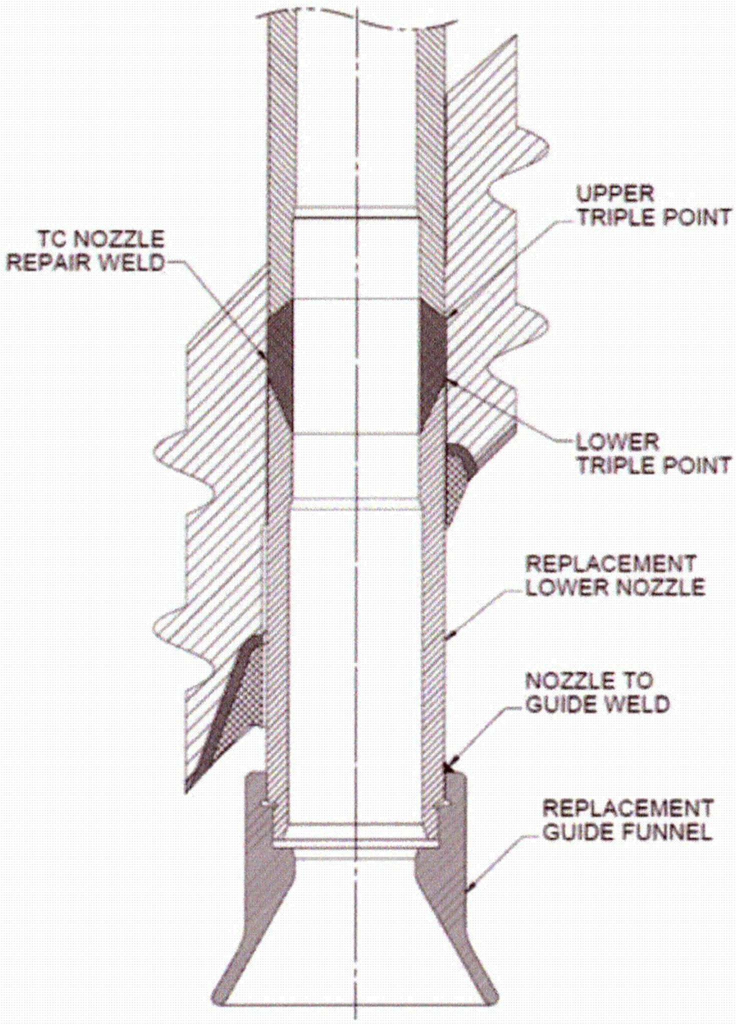

Figure A-11: CETC Nozzle Weld

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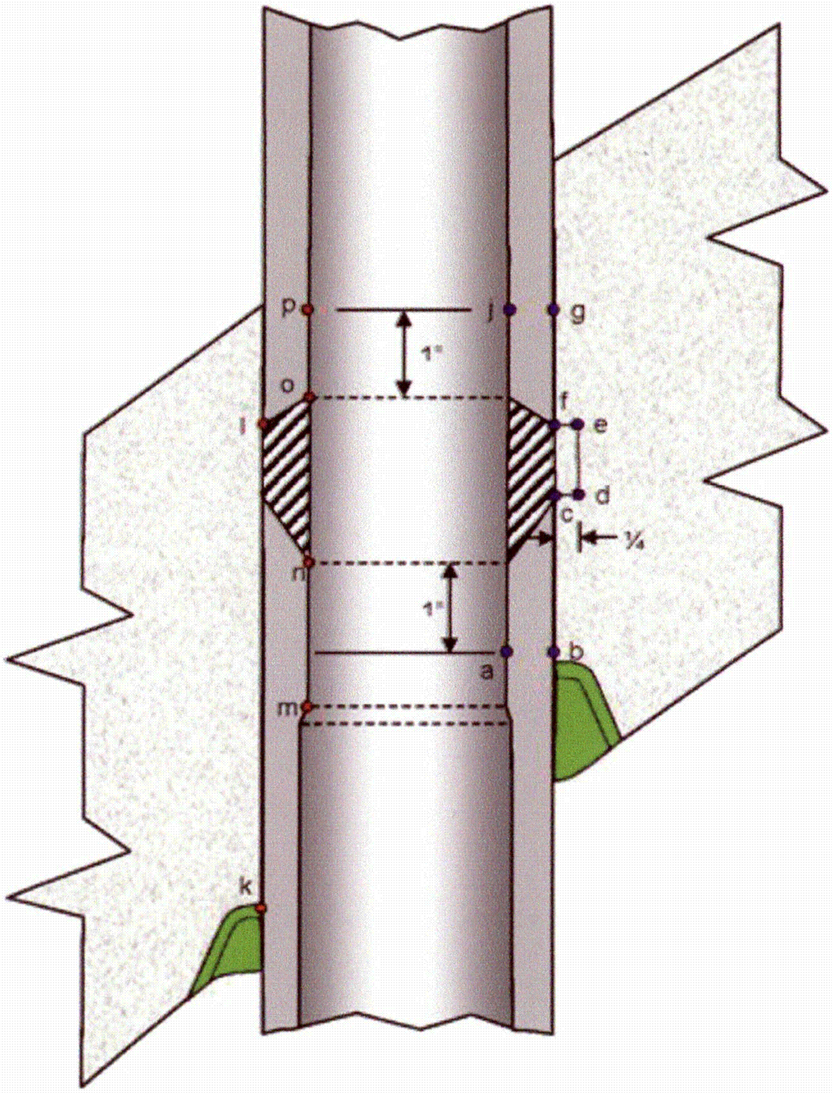

Post – Machining PT	k-l-o-p
Post – Weld PT	m-n-o-p
Post – Weld UT	a-b-c-d-e-f-g-j-a

Figure A-12: CETC Nozzle Examination

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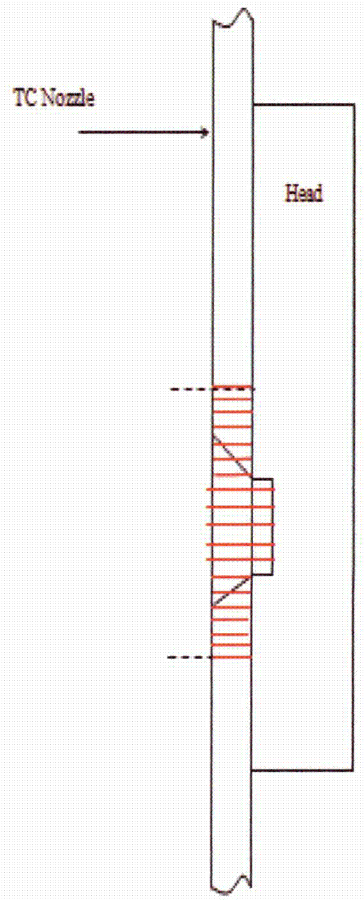

Figure A-13: CETC Nozzle UT 0° and 45°L Beam Coverage Looking Clockwise and Counter-clockwise

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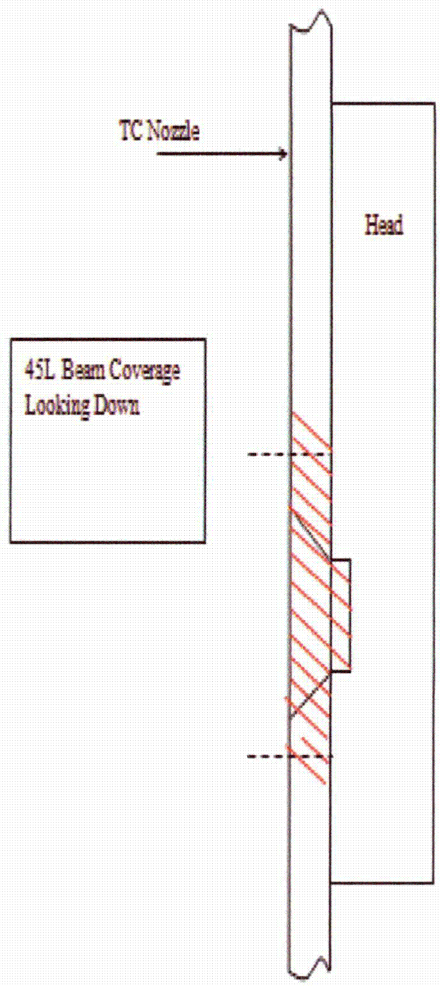

Figure A-14: CETC Nozzle 45°L UT Beam Coverage Looking Down

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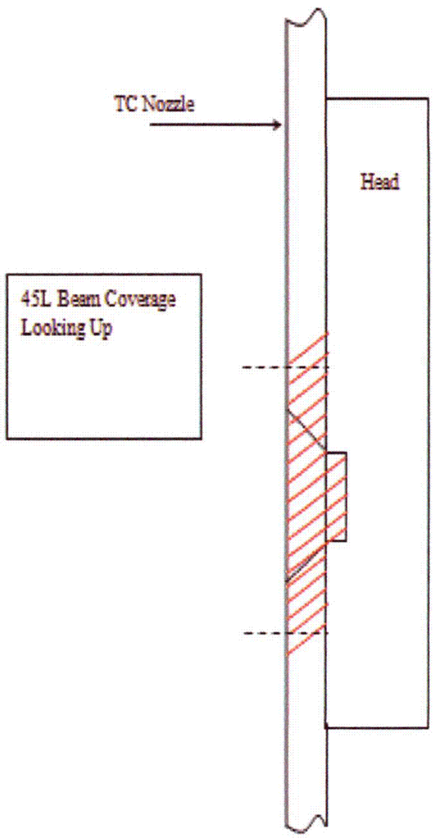

Figure A-15: CETC Nozzle 45°L UT Beam Coverage Looking Up

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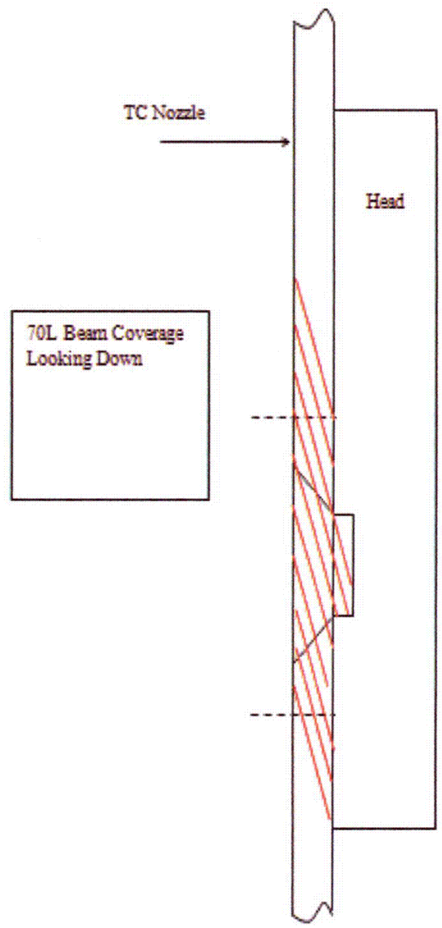

Figure A-16: CETC Nozzle 70°L UT Beam Coverage Looking Down

10 CFR 50.55a RELIEF REQUEST Braidwood Station I3R-16 and Byron Station I3R-28
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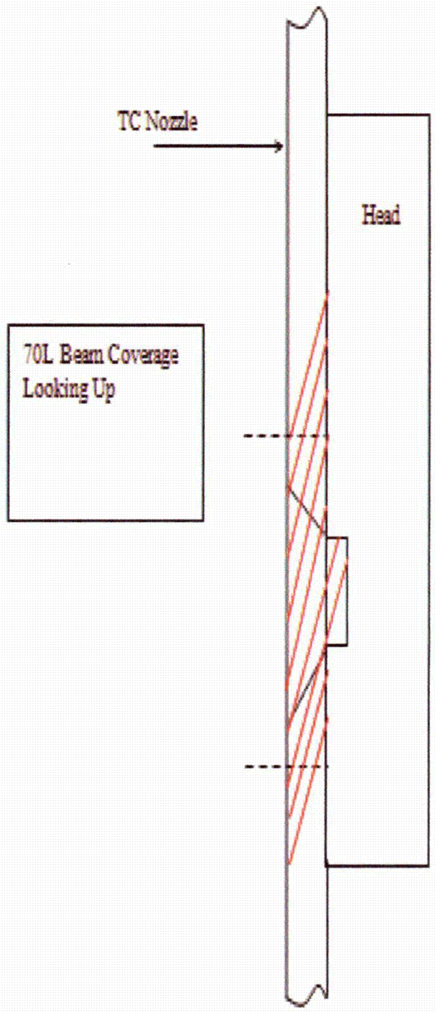

Figure A-17: CETC Nozzle 70°L UT Beam Coverage Looking Up

10 CFR 50.55a RELIEF REQUEST Braidwood Station I3R-16 and Byron Station I3R-28
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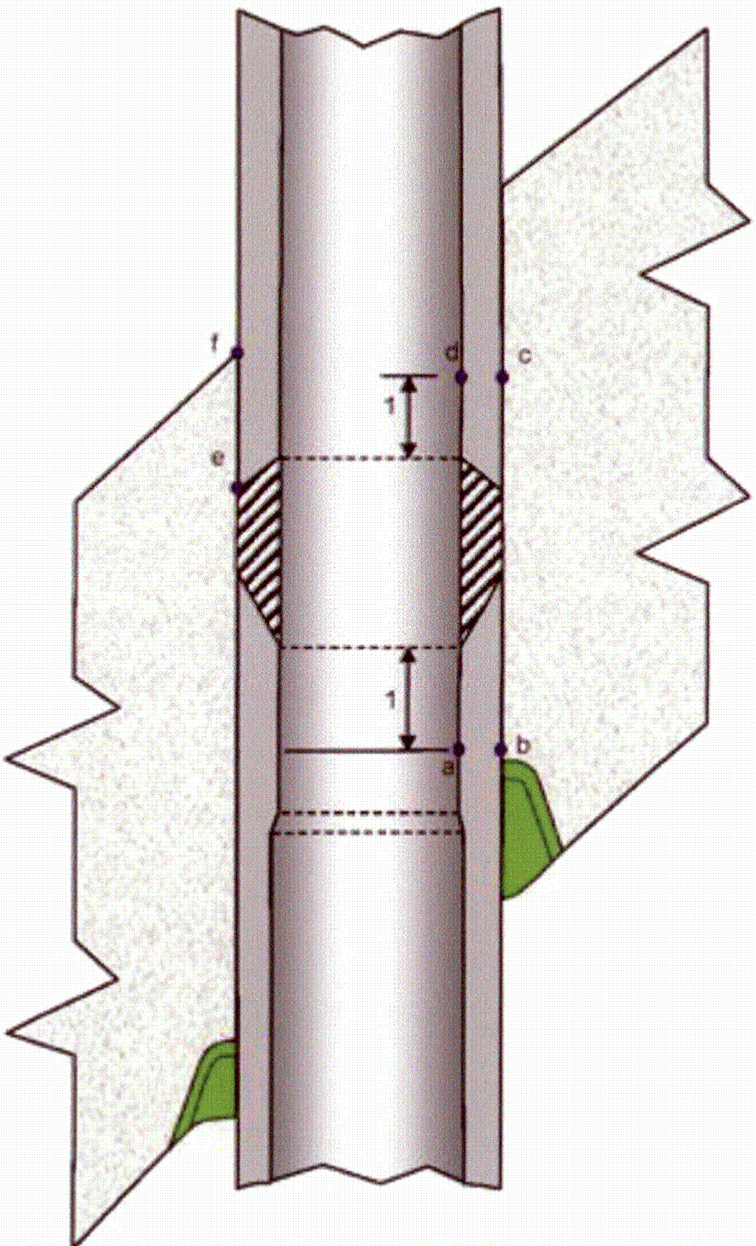

UT	a-b-c-d-a
UT	e-f (leak path)

Figure A-18: CETC Nozzle PSI and ISI UT Examination