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Acting Director
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CNRO-2004-00006

February 23, 2004

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

SUBJECT: Request for Alternatives ANO1-R&R-005 and ANO1-R&R-006 - Proposed Alternatives to ASME Weld Repair and Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles

Arkansas Nuclear One, Unit 1
Docket No. 50-313
License No. DPR-51

REFERENCES:

1. Entergy Operations, Inc. letter CNRO-2003-00022 to the NRC dated June 6, 2003
2. Entergy Operations, Inc. letter CNRO-2002-00052 to the NRC dated October 26, 2002
3. Entergy Operations, Inc. letter CNRO-2002-00054 to the NRC dated November 26, 2002

Dear Sir or Madam:

In Reference #1, Entergy Operations, Inc., (Entergy) proposed alternatives ANO1-R&R-005 and ANO1-R&R-006 for use at Arkansas Nuclear One, Unit 1 (ANO-1). Specifically, these requests proposed alternatives to the requirements of ASME Sections III and XI as applied to reactor pressure vessel (RPV) head penetration nozzles.

In a telephone conversation held on December 18, 2003 representatives of the NRC staff and Entergy discussed these requests. The staff asked that Entergy update the requests to reflect the current status of the various analyses and evaluations referenced in the requests. The staff also requested that Entergy provide the basis for not performing water jet conditioning on repaired RPV head penetration nozzles.

To address the staff's comments, Entergy has revised Requests ANO1-R&R-005 and ANO1-R&R-006, which are contained in Enclosures 1 and 2, respectively. These revised requests supercede the originals in their entirety. Changes are denoted by revision bars in the page margins.

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As stated in Reference #1, ANO1-R&R-005 and ANO1-R&R-006 are equivalent to Requests ANO1-R&R-003 and ANO1-R&R-004, which were submitted to the NRC via Reference #2. ANO1-R&R-005 and ANO1-R&R-006 expand the application of the previous requests to encompass refueling outage 1R18, which is scheduled for the second quarter of 2004.

Request No. ANO1-R&R-005, Rev. 0 (Enclosure 1) proposes an alternate repair method to the temper bead methods of ASME Sections III and XI. The proposed alternative uses 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 post-weld heat treatment.

Request No. ANO1-R&R-006, Rev. 0 (Enclosure 2) proposes an alternative to the requirement to evaluate actual flaw characteristics as defined in ASME Section III NB-5330(b) and ASME Section XI IWA-3300(b), IWB-3142.4, and IWB-3420. In lieu of fully characterizing the remaining cracks, Entergy proposes to utilize worst-case assumptions to conservatively estimate the crack extent and orientation. ANO Calculations 86-E-0074-156, -160, -161, and -164 were previously submitted to the NRC staff to support ANO1-R&R-004 via Reference #2. These calculations are also applicable to ANO1-R&R-006.

Entergy requests that the NRC staff authorize use of ANO1-R&R-005 and ANO1-R&R-006 by March 15, 2004 to support preparations for refueling outage 1R18, which is scheduled to begin during the second quarter of 2004.

Should you have any questions regarding this letter, please contact Guy Davant at (601) 368-5756.

This letter contains no new commitments.

Very truly yours,

FGB/GHD/ghd
Enclosures: 1. Request for Alternative ANO1-R&R-005, Rev. 0
2. Request for Alternative ANO1-R&R-006, Rev. 0

cc: Mr. W. A. Eaton (ECH)
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ENCLOSURE 1

CNRO-2004-00006

REQUEST FOR ALTERNATIVE
ANO1-R&R-005, Rev. 0

ENTERGY OPERATIONS, INC.
ARKANSAS NUCLEAR ONE, UNIT 1
3rd 10-YEAR INTERVAL
REQUEST No. ANO1-R&R-005, Rev. 0

REFERENCE CODE:

The original code of construction for Arkansas Nuclear One, Unit 1 (ANO-1) is ASME Section III 1965 Edition with Addenda through Summer, 1967. The components (including supports) may meet the requirements set forth in subsequent editions and addenda of the ASME Code incorporated by reference in 10 CFR 50.55a(b) subject to the limitations and modifications listed therein and subject to NRC approval. The codes of record for the repairs described within this request are the 1989 Edition of ASME Section III and 1992 Edition of ASME Section XI codes. ANO-1 is in its third (3rd) 10-Year Inservice Inspection interval.

I. System/Component(s)

a) Name of component:

Reactor Pressure Vessel (RPV) head nozzles (There are 69 nozzles welded to the RPV head.)

b) Function:

These welds serve as the pressure boundary weld for the RPV head nozzle and RPV head.

c) ASME Code Class:

The RPV head and RPV head nozzles are ASME Class 1.

d) Category:

Examination Category B-E, Pressure Retaining Partial Penetration Welds in Vessels; Item No. B4.12

II. Code Requirement

The 1992 Edition of ASME Section XI, paragraph IWA-4170(b) states:

"Repairs and installation of replacement items shall be performed in accordance with the Owner's Design Specification and the original Construction Code of the component or system. Later editions and addenda of the construction code or of Section III, either in their entirety or portions thereof, and Code Cases may be used. If repair welding cannot be performed in accordance with these requirements, the applicable alternative requirements of IWA-4200 and IWA-4400 or IWA-4500 may be used."

Because of the risk of damage to the RPV head material properties or dimensions, it is not feasible to apply the post welding heat treatment requirements of paragraph NB-4622 of the 1989 ASME Section III Code to the RPV head. The alternative temper bead methods (IWA-4500 and NB-4622.9, NB4622.10 or NB-4622.11) offered by ASME Section III and

ASME Section XI require elevated temperature preheat and post weld soaks that will result in added radiation dose to repair personnel.

III. Proposed Alternatives

Entergy will examine RPV head nozzles in accordance with NRC Order EA-03-009, *Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors*. The use of any of the alternatives permitted by the applicable ASME Codes for repairs will result in increased radiation dose with no compensating increase in quality or safety. The post-weld heat treatment (PWHT) parameters required by NB-4622 would be difficult to achieve on a RPV head in containment and would pose significant risk of distortion to the geometry of the RPV head and RPV head nozzles. In addition, the existing J-groove welds would be exposed to PWHT for which they were not qualified. This request applies to any nozzle requiring repair by the methods described herein.

Entergy has determined that compliance with the specified requirements would result in unusual difficulty or hardship without a compensating increase in the level of quality. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), Entergy requests authorization to use an ambient temperature temper bead method of repair as an alternative to the requirements of the 1989 Edition of ASME Section III, NB-4622 as defined in Attachment 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique.". This alternative uses 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 repairs will be conducted in accordance with the 1992 Edition of ASME XI (as applicable), the 1989 Edition of Section III (as applicable), and alternative requirements discussed below. A list of the most applicable articles, subarticles, paragraphs, and subparagraphs of ASME Section III and Section XI is given below. Where the Code requirements will not be met, the alternative or reference to the alternative is given in italic print.

<u>NB-4331</u> establishes the requirement that all welding procedure qualification tests be in accordance with the requirements of ASME Section IX as supplemented or modified by the requirements of NB-4331.

The welding procedure has been qualified in accordance with the requirements of paragraphs 2.0 and 2.1 of Attachment 1. These two paragraphs are modeled on ASME Code Case N-638 and include the additional requirements of ASME Section III Paragraph NB-4335.2. No alternative to the requirements of NB-4331 is needed or proposed.

<u>NB-4622.1</u> establishes the requirement for PWHT of welds including repair welds. *In lieu of the requirements of this subparagraph, Entergy proposes to utilize a temper bead weld procedure obviating the need for post weld stress relief.*

<u>NB-4622.2</u> establishes requirements for time-at-temperature recording of the PWHT and their availability for review by the Inspector. This requirement of this subparagraph will not apply because the proposed alternative does not involve PWHT.

<u>NB-4622.3</u> discusses the definition of nominal thickness as it pertains to time-at-temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.4 establishes the holding times-at-temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.5 establishes PWHT requirements when different P-number materials are joined. This subparagraph is not applicable because the proposed alternative involves no PWHT.

NB-4622.6 establishes PWHT requirements for non-pressure-retaining parts. The subparagraph is not applicable in this case because the potential repairs in question will be to pressure retaining parts. Furthermore, the proposed alternative involves no PWHT.

NB-4622.7 established exemptions from mandatory PWHT requirements. NB-4622.7(a) through NB-4622.7(f) are not applicable in this case because they pertain to conditions that do not exist for the proposed repairs. NB-4622.7(g) discusses exemptions to weld repairs to dissimilar metal welds if the requirements of NB-4622.11 are met. *As described below, the ambient temperature temper bead repair is being proposed as an alternative to the requirements of NB-4622.11.*

NB-4622.8 establishes exemptions from PWHT for nozzle-to-component welds and branch connection-to-run piping welds. NB-4622.8(a) establishes criteria for exemption of PWHT for partial penetration welds. This is not applicable to the proposed repairs because the criteria involve buttering layers at least 1/4 inch thick, which will not exist for the welds in question. NB-4622.8(b) also does not apply because it discusses full penetration welds and the welds in question are partial penetration welds.

NB-4622.9 establishes requirements for temper bead repairs to P-No. 1 and P-No. 3 materials and A-Nos. 1, 2, 10, or 11 filler metals. The subparagraph does not apply in this case because the proposed repairs will involve F-No. 43 filler metals using GTAW instead of Shielded Metal Arc Welding (SMAW).

NB-4622.10 establishes requirements for repair welding to cladding after PWHT. The subparagraph does not apply in this case because the proposed repair alternative does not involve repairs to cladding.

NB-4622.11 discusses temper bead weld repair to dissimilar metal welds or buttering. *The ambient temperature temper bead repair is being proposed as an alternative to the requirements of subparagraph NB-4622.11. As described below, elements of NB-4622.11 are incorporated into the proposed alternative.*

- NB-4622.11(a) requires surface examination prior to repair in accordance with NB-5000. The proposed alternative will include surface examination prior to repair consistent with NB-5000.

- NB-4622.11(b) contains requirements for the maximum extent of repair including a requirement that the depth of excavation for defect removal not exceed 3/8 inch in the base metal. The proposed alternative includes the same limitations on the maximum extent of repair.

- NB-4622.11(c) discusses the repair welding procedure and requires procedure and welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy this requirement. In addition, NB-4622.11(c) requires that the Welding Procedure Specification (WPS) include the following requirements:

- <u>NB-4622.11(c)(1)</u> requires the area to be welded be suitably prepared for welding in accordance with the written procedure to be used for the repair. The proposed alternative will satisfy this requirement.

- <u>NB-4622.11(c)(2)</u> requires the use of the SMAW process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. *The proposed alternative utilizes GTAW with weld filler metals meeting F-No. 43 classifications.*

- <u>NB-4622.11(c)(3)</u> discusses requirements for covered electrodes pertaining to hermetically sealed containers or storage in heated ovens. These requirements do not apply because the proposed alternative uses weld filler metals that do not require storage in heated ovens since weld GTAW bare filler metals will not pick up moisture from the atmosphere.

- <u>NB-4622.11(c)(4)</u> discusses requirements for storage of covered electrodes during repair welding. These requirements do not apply because the proposed alternative utilizes bare weld filler metals, which do not require any special storage conditions to prevent the pick up of moisture from the atmosphere.

- <u>NB-4622.11(c)(5)</u> requires preheat to a minimum temperature of 350°F prior to repair welding, a maximum interpass temperature of 450°F and that thermocouples and recording instruments shall be used to monitor the metal temperature during welding. *The proposed ambient temperature temper bead alternative does not require an elevated temperature preheat and interpass will be limited to 350°F. Because of the massive structure involved in the assembly, the absence of preheat and the complex configuration, thermocouples will not be used to monitor metal temperature.*

- <u>NB-4622.11(c)(6)</u> establishes requirements for shielded metal arc electrode diameters for the first, second, and subsequent layers of the repair weld and requires removal of the weld bead crown before deposition of the second layer. Because the proposed alternative uses the machine GTAW process, the requirement to remove the weld crown of the first layer is unnecessary and the proposed alternative does not include the requirement.

- <u>NB-4622.11(c)(7)</u> requires the preheated area to be heated to 450°F to 660°F for four (4) hours after a minimum of 3/16 inch of weld metal has been deposited. *The proposed alternative does not require this heat treatment because the use of the extremely low hydrogen GTAW temper bead procedure does not require the hydrogen bake-out.*

- <u>NB-4622.11(c)(8)</u> requires welding subsequent to the hydrogen bake out of NB-4622.11(c)(7) be done with a minimum preheat of 100°F and maximum interpass temperature of 350°F. *The proposed alternative limits the interpass temperature to a maximum of 350°F and requires the area to be welded be at least 50°F prior to welding.* These limitations have been demonstrated to be adequate for the production of sound welds.

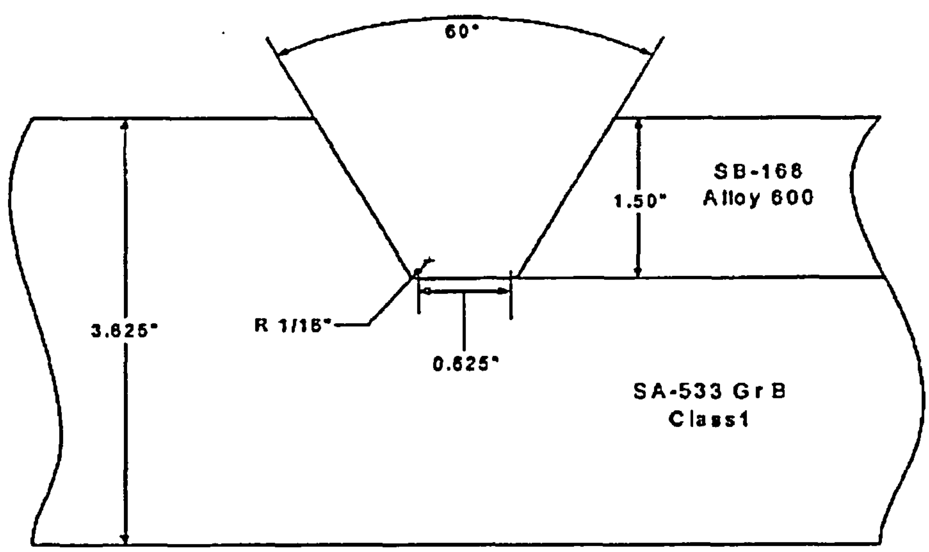
- <u>NB-4622.11(d)(1)</u> requires a liquid penetrant examination after the hydrogen bake out described in NB-4622.11(c)(7). The proposed alternative does not require the hydrogen bake-out because it is unnecessary for the very low hydrogen GTAW temper bead welding process.

- NB-4622.11(d)(2) requires liquid penetrant and radiographic examinations of the repair welds after a minimum time of 48 hours at ambient temperature. Ultrasonic inspection is required if practical. The proposed alternative includes the requirement to inspect after a minimum of 48 hours at ambient temperature. *Because the proposed repair welds are of a configuration that cannot be radiographed, final inspection will be by liquid penetrant and ultrasonic inspection.*

- NB-4622.11(d)(3) requires that all nondestructive examination be in accordance with NB-5000. *The proposed alternative will comply with NB-5000 except that the progressive liquid penetrant inspection required by NB-5245 will not be done. In lieu of the progressive liquid penetrant examination, the proposed alternative will use liquid penetrant and ultrasonic examination of the final weld.*

- NB-4622.11(e) establishes the requirements for documentation of the weld repairs in accordance with NB-4130. The weld repair will be documented in accordance with NB-4130.

- NB-4622.11(f) establishes requirements for the procedure qualification test plate relative to the P-No. and Group Number and the postweld heat treatment of the materials to be welded. The proposed alternative meets and exceeds those requirements in that the root width and included angle of the cavity are stipulated to be no greater than the minimum specified for the repair. In addition, the location of the V-notch for the Charpy test is more stringently controlled in the proposed alternative than in NB-4622.11(f). A 60 degree included angle was used with a 5/8-inch wide root in the Framatome-ANP Procedure Qualification Record (PQR) test assembly as shown in the sketch below taken from PQR 7183. The Charpy specimen locations were controlled by tilting them in such a way that the root of the notch was in the heat affected zone (HAZ).



Weld sample used for PQR 7183

- NB-4622.11(g) establishes requirements for welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs, which is particularly pertinent to the SMAW manual welding process. The proposed alternative involves a machine GTAW process and requires welding operators be qualified in accordance with ASME Section IX. The use of a machine process eliminates concern about obstructions, which might interfere with the welder's abilities since these obstructions will have to be eliminated to accommodate the welding machine.

NB-4453.4 of Section III requires examination of the repair weld in accordance with the requirements for the original weld. The welds being made per the proposed alternatives will be partial penetration welds as described by NB-4244(d) and will meet the weld design requirements of NB-3352.4(d). For these partial penetration welds, paragraph NB-5245 requires a progressive surface examination [liquid penetrant test (PT) or magnetic particle test (MT)] at the lesser of ½ the maximum weld thickness or ½ inch as well as a surface examination on the finished weld.

For the proposed alternative, the repair weld will be examined by a liquid penetrant and ultrasonic examination no sooner than 48 hours after the weld has cooled to ambient temperature in lieu of the progressive surface exams required by NB-5245.

IV. Basis for Proposed Alternative

Experience gained from performing repairs to RPV head nozzles at ANO-1 and throughout the industry indicates that remote automated repair methods are needed to reduce radiation dose to repair personnel. Additionally, achieving and maintaining the required preheat and post weld soak temperatures is time consuming and radiation dose intensive. Therefore, a remote semi-automated repair method utilizing a qualified machine GTAW ambient temperature temper bead process is planned for each nozzle that requires repair. Using a remote tool from above the RPV head, each of the subject nozzles will first receive a roll expansion into the RPV head base material. The roll expansion ensures that the nozzle will not move during the repair operations. Second, an automated machining tool from underneath the RPV head will remove the lower portion of the nozzle to a depth above the existing J-groove partial penetration weld. This operation will sever the existing J-groove partial penetration weld from the subject RPV head nozzles and machine a bevel onto the end of the nozzles in preparation for the repair weld (see Figure 1). Third, a weld tool, utilizing the GTAW-machine process, will be used to install a new pressure boundary weld between the shortened nozzle and the inside bore of the RPV head base material (see Figure 2).

This approach for repairing RPV head nozzles will significantly reduce radiation dose to repair personnel while still maintaining acceptable levels of quality and safety. The total radiation dose (assuming two nozzles for estimation purposes) for the proposed remote repair method is projected to be about 10 REM. Entergy estimates the dose accumulated to provide access, install heating pads and perform the preheat and post weld heat treatment required by the construction code would total an additional 15 REM. In contrast, using manual repair methods would result in a total radiation dose of approximately 60 REM.

The automated repair method described above leaves a strip of low alloy steel exposed to the primary coolant. The effect of corrosion on the exposed area [reduction in RPV head thickness and primary coolant ferric (Fe) release] was evaluated by Framatome-ANP. This calculation shows that the general corrosion of the low alloy steel base material is insignificant for the remaining life of the RPV head (0.0032 inch/year). (The remaining life of the RPV head will be one operating cycle since Entergy plans to replace the ANO-1 RPV head during 1R19.) The estimate is based on extensive industry data and Framatome-ANP experience. The calculation estimates that the iron (Fe) release from a total of 69 repaired RPV head nozzles presents a 16.9% increase in the annual release of Fe into the reactor coolant system (RCS). Framatome has determined that this extremely low material loss and Fe release provide an acceptable level of safety.

An analysis of the new pressure boundary welds, using a 3-dimensional model of a RPV head nozzle located at the most severe hillside orientation was performed. The software program ANSYS (general purpose finite element program that is used industry wide) was utilized for this analysis. Per Framatome-ANP internal procedures, the ANSYS computer code is independently verified as executing properly by the solution of verification problems using ANSYS and then comparing the results to independently determined values.

The analytical model included the RPV head, RPV head nozzle, repair weld, and remnant portions of the original Alloy 600 welds. The model was analyzed for thermal transient conditions as contained in the Reactor Coolant Functional Specifications. The resulting maximum thermal gradients were applied to the model along with the coincident internal pressure values. The ANSYS program then calculated the stresses throughout the model (including the repair welds). The stresses were post-processed by ANSYS routines to categorize stresses into categories that are consistent with the criteria of the ASME Code.

The calculated stress values were compared to the ASME Code, Section III, NB-3000 criteria for:

- Design Conditions
- Normal, Operating, and Upset Conditions
- Emergency Conditions
- Faulted Conditions
- Testing Conditions

A very conservative stress concentration factor (SCF) of 4.0 was assumed for the new pressure boundary weld, as required by ASME NB-3352.4(d)(5).

The detailed stress analysis for design conditions calculated maximum Primary General Membrane Stress Intensities (P_m), which were shown to be less than the maximum allowed by ASME Code.

The maximum cumulative fatigue usage factor was calculated for the point at the intersection of the bottom of the repair weld and the penetration bore and the crevice between the RPV head nozzle outside surface and the RPV head bore. Allowable years of future plant operation were based on the maximum allowed ASME Code usage factor criterion of 1.0. The calculation anticipated that the limiting location for this value is the point at the intersection of the bottom of the repair weld and the penetration bore. At the bottom of the crevice between the RPV head nozzle outside surface and the RPV head bore, the calculated fatigue usage factor for 40 years of future operation is not expected to be limiting to the fatigue life of the repair.

Justification for Proposed Alternatives:

NB-4331

As described below under NB-4622, the characteristics of the weld proposed for this repair have been well defined by research and qualification for this and similar applications.

NB-4622

The proposed alternative requires the use of an automatic or machine GTAW temper bead technique without the specified preheat or post weld heat treatment of the Construction Code. The proposed alternative will include the requirements of paragraphs 1.0 through 5.0 of Attachment 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." The alternative will be used to make welds joining P-No. 3, RPV head material to P-No. 43 RPV head nozzle material using F-No. 43 filler material.

Results of procedure qualification work undertaken to date indicate that the process produces sound and tough welds. For instance, typical tensile test results have been ductile breaks in the weld metal.

As shown below, the Framatome-ANP PQR 7164 using P-No. 3, Group No. 3 base material exhibited improved Charpy V-notch properties in the HAZ from both an absorbed energy and lateral expansion perspective as compared to the unaffected base material. PQR 7183, using P-No. 3 Group No. 3 base material and P-43 base material exhibited slightly degraded impact properties in the weld HAZ. An evaluation to address the affect of the degraded impact properties was performed as described below (under Properties of PQR 7183).

Properties of PQR 7164

	Absorbed energy (ft-lbs @ 50°F)	Lateral expansion (mils @ 50°F)	Shear fracture (% @ 50°F)	Absorbed energy (ft-lbs @ 80°F)	Lateral expansion (mils @ 80°F)	Shear fracture (% @ 80°F)
Unaffected Base Material	69, 55, 77	50, 39, 51	30, 25, 30	78, 83, 89	55, 55, 63	35, 35, 55
HAZ	109, 98, 141	59, 50, 56	40, 40, 65	189, 165, 127	75, 69, 60	100, 90, 80

The absorbed energy, lateral expansion, and percent shear were significantly greater for the HAZ than the unaffected base material at both test temperatures.

Properties of PQR 7183

	Absorbed energy (ft-lbs @ 30°F)	Lateral expansion (mils @ 30°F)	Shear fracture (% @ 30°F)	Absorbed energy (ft-lbs @ 35°F)	Lateral expansion (mils @ 35°F)	Shear fracture (% @ 35°F)
Unaffected Base Material	59, 54, 61	53, 51, 47	20, 30, 20	-	-	-
HAZ	-	-	-	95, 84, 95	49, 52, 50	45, 35, 55

The results of this second PQR require that the Reference Temperature (RT_{NDT}) of the base material be adjusted in accordance with the rules of NB-4335.2. This adjustment temperature increases the RT_{NDT} of the RPV head by 5°F. Entergy has evaluated the impact of the 5°F RT_{NDT} adjustment temperature on the RPV head against the fracture toughness requirements of 10 CFR 50 Appendix G and existing Technical Specification pressure-temperature limits for the RPV head and the RCS. However, this minor degradation has no effect on the safe operation of the RPV head or Technical Specification pressure-temperature limits.

Framatome-ANP has previously qualified the GTAW temper bead process in support of ASME approval of Code Case N-606-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique for Boiling Water Reactor (BWR) CRD Housing/Stub Tube Repairs." The qualifications were performed at room temperature with cooling water to limit the maximum interpass temperature to a maximum of 100°F. The qualifications were performed on the same P-3 Group-3 base material as proposed for the RPV head nozzle repairs, using the same filler material, i.e. Alloy 52 AWS Class ERNiCrFe-7, with similar low heat input controls as will be used in the repairs. Also, the qualifications did not include a post weld heat soak.

The Welding Procedure Qualifications supporting the applicable WPS to be used for the repair weld are for P-No. 3 Group No. 3 base material welded with F-No. 43 filler metal and P-No. 3 to P-No. 43 base material welded with F-No. 43 filler metal. The use of this WPS, for welding P-No.43 to P-No.3 Group No. 3 with F-No. 43 filler metal, i.e., dissimilar metal welding, is justified based on the following:

- PQR 55-PQ7164, as discussed above, supporting the ambient temperature temper bead WPS for welding, was a groove weld performed using F-No. 43 filler wire on P-No. 3 Group No. 3 base material. The PQR 55-PQ7164 groove (cavity) in the P-No. 3 Group No. 3 base material coupon was 2¾ inches deep with a ¾-inch wide root and 30 degree side bevels (60 degree included angle). All the effects of welding to the P-3 base material with F-No. 43 filler metal have been verified by full thickness transverse tensile tests, full thickness transverse side bends, and impact testing.

- The PQR 55-PQ7183 is similar except that one side of the weld was P-43 material and the groove was 1½ inches deep.

The NB-4622 temper bead procedure requires a 350°F preheat and a post weld soak at 450° - 660°F for 4 hours for P-No. 3 materials. Typically, these kinds of restrictions are used to mitigate the effects of the solution of atomic hydrogen in ferritic materials prone to hydrogen embrittlement cracking. The susceptibility of ferritic steels is directly related to their ability to transform to martensite with appropriate heat treatment. The P-No. 3 material of the RPV head is able to produce martensite from the heating and cooling cycles associated with welding. However, the proposed alternative temper bead procedure utilizes a welding process that is inherently free of hydrogen. The GTAW process relies on bare welding filler metals with no flux to trap moisture. An inert gas blanket positively shields the weld and surrounding material from the atmosphere and moisture it may contain. To further reduce the likelihood of any hydrogen evolution or absorption, the alternative procedure requires particular care to ensure the weld region is free of all sources of hydrogen. The GTAW process will be shielded with welding grade argon which typically produces porosity free welds. The gas would typically have no more than 1 ppm of hydrogen (H_2) and no more than 1 ppm of water vapor (H_2O). A typical argon flow rate would be about 15 to 50 cfh and would be adjusted to assure adequate shielding of the weld without creating a venturi affect that might draw oxygen or water vapor from the ambient atmosphere into the weld.

Entergy has concluded that quality temper bead welds can be performed with 50°F minimum preheat and no post heat treatment based on ASME committee approval of Code Case N-638 and Framatome-ANP prior welding procedure qualification test data using machine GTAW ambient temperature temper bead welding. The proposed alternative (Attachment 1) provides a technique for repair welding 1/8-inch of the ferritic base metal of the RPV head.

NB-4622.11(c)(5)

The closure head preheat temperature will be essentially the same as the reactor building ambient temperature; therefore, closure head preheat temperature monitoring in the weld region using thermocouples is unnecessary and would result in additional personnel dose associated with thermocouple placement and removal. Consequently, preheat temperature verification by use of a contact pyrometer on accessible areas of the closure head is sufficient.

In lieu of using thermocouples for interpass temperature measurements, calculations were performed to show that the maximum interpass temperature will never be exceeded based on a maximum allowable low welding heat input, weld bead placement, travel speed, and conservative preheat temperature assumptions. The calculation supports the conclusion that, when using the maximum heat input through the third layer of the weld, the interpass temperature returns to near ambient temperature. Heat input beyond the third layer will not have a metallurgical effect on the low alloy steel HAZ.

The calculation is based on a typical inter-bead time interval of five minutes; specifically: 1) the time required to explore the previous weld deposit with the two remote cameras housed in the weld head, 2) time to shift the starting location of the next weld bead circumferentially away from the end of the previous weld-bead, and 3) time to shift the starting location of the next bead axially to insure a 50% weld bead overlap required to properly execute the temper bead technique.

A welding mockup on the full size Midland RPV head, which is similar to the ANO-1 RPV head, was used to demonstrate the welding technique described herein. During the mockup, thermocouples were placed to monitor the temperature of the closure head during welding. Thermocouples were placed on the outside surface of the closure head within a 5-inch band surrounding the RPV head nozzle. Three other thermocouples were placed on the closure head inside surface. One of the three thermocouples was placed 1½ inches from the RPV head nozzle penetration, on the lower hillside. The other inside surface thermocouples were placed at the edge of the 5-inch band surrounding the RPV head nozzle, one on the lower hillside, the second on the upper hillside. During the mockup, all thermocouples fluctuated less than 15°F throughout the welding cycle. Based on past experience, it is believed that the temperature fluctuation was due more to the resistance heating temperature variations than the low heat input from the welding process. For the Midland RPV head mockup application, 300°F minimum preheat temperature was used. Therefore, for ambient temperature conditions used for this repair, maintenance of the 350°F maximum interpass temperature will not be a concern.

NB-4622.11(d)(2)/ NB-4622.11(d)(3)/NB-4453.4

UT will be performed in lieu of radiographic testing (RT) due to the repair weld configuration. Meaningful RT cannot be performed as can be seen in the applicable attached figures. The weld configuration and geometry of the penetration in the head provide an obstruction for the x-ray path and interpretation would be very difficult. UT will be substituted for the RT and qualified to evaluate defects in the repair weld and at the base metal interface. This examination method is considered adequate and superior to RT for this geometry. The new structural weld is sized like a coaxial cylinder partial penetration weld. ASME Code Section III construction rules require progressive PT of partial penetration welds. The Section III original requirements for progressive PT were in lieu of volumetric examination. Volumetric examination is not practical for the conventional partial penetration weld configurations. In this case the weld is suitable, except for the taper transition, for UT and a final surface PT will be performed.

The effectiveness of the UT techniques to characterize the weld defects has been qualified by demonstration on a mockup of the repair temper bead weld involving the same materials used for repair. Notches were machined into the mockup at depths of 0.10 inch, 0.15 inch, and 0.25 inch in order to quantify the ability to characterize the depth of penetration into the nozzle. The depth characterization is performed using tip diffraction UT techniques that have the ability to measure the depth of a reflector relative to the nozzle bore. Each of the notches in the mockup could be measured using the 45-degree transducer. During the examination longitudinal wave angle beams of 45 degrees and 70 degrees are used. These beams are directed along the nozzle axis looking up and down. The downward looking beams are effective at detecting defects near the root of the weld because of the impedance change at the triple point (intersection of weld material, penetration tube, and vessel head). The 45-degree transducer is effective at depth characterization by measuring the time interval to the tip of the reflector relative to the transducer contact surface. The 70-degree longitudinal wave provides additional qualitative data to support information obtained with the 45-degree transducer. Together, these transducers provide good characterization of possible defects. These techniques are routinely used for examination of austenitic welds in the nuclear industry for flaw detection and sizing.

In addition to the 45 and 70-degree beam angles described above, the weld is also examined in the circumferential direction using 45-degree longitudinal waves in both the clockwise and counterclockwise directions to look for transverse fabrication flaws. A 0-degree transducer is also used to look radially outward to examine the weld and adjacent material for laminar type flaws and evidence of under bead cracking.

The UT transducers and delivery tooling are capable of scanning from cylindrical surfaces with inside diameters near 2.75 inches. The UT equipment is not capable of scanning from the face of the taper. Approximately 70% of the weld surface will be scanned by UT. Approximately 83% of the RPV head ferritic steel HAZ will be covered by the UT. The transducers to be used are shown in Table 1. The UT coverage volumes are shown in Figures 5 through 10 for the various scans. Additionally, the final modification configuration and surrounding ferritic steel area affected by the welding is either inaccessible or extremely difficult to access, to obtain the necessary scans.

UT of the repair weld and HAZ are limited by the repair configuration. As can be observed from Figure 2, the RPV head nozzle weld repair configuration limits access to the ferritic steel base material above the weld as well as scanning from the taper at the bottom of the weld. See also Figures 5 through 10 and Table 1.

The PT examination extent is consistent with the Construction Code requirements. PT examination of the entire ferritic steel bore will be performed after removal by boring of the lower end of the existing RPV head nozzle prior to welding. As can be observed from Figures 2, 3, and 4, the configuration of the new RPV head nozzle repair configuration limits access to the ferritic steel base material. The ferritic steel base material area above the new weld is inaccessible due to the RPV head nozzle. The ferritic steel base material below the new weld and within ½ inch of the bottom weld toe will be PT examined subsequent to welding.

The welding head has video capability for torch positioning and monitoring during welding. The operator observes the welding operation as well as observing each bead deposited prior to welding the next bead. The video clarity and resolution is such that the welding operator can observe a ½ mil diameter color contrast wire.

Based on the above information, it may be concluded that using the proposed alternative ambient temperature temper bead weld technique (Attachment 1) is an acceptable alternative to Code requirements and will produce sound, permanent repair welds and an acceptable level of quality and safety.

This proposed alternative, submitted as ANO1-R&R-003, was previously approved by the NRC staff for use during the previous refueling outage 1R17 at ANO-1.[1]

V. Duration of the Proposed Alternative

Entergy plans to replace the ANO-1 RPV head during Refueling Outage 1R19, which is scheduled to begin during the fall of 2005. Therefore, any repairs made in accordance with this request will be limited to one operating cycle.

In previously approved request ANO1-R&R-003, Entergy informed the NRC of the need to employ abrasive water jet mitigation to any nozzle repairs.[2] For the upcoming 1R18 refueling outage, Entergy has re-evaluated the need to employ any type of water jet conditioning and has determined such activities are not required. Entergy has performed an evaluation to determine the time for a postulated crack to grow 75% through-wall in the Alloy 600 nozzle material above the repair weld without employing water jet conditioning. The evaluation considers RPV head nozzles in the as-repaired condition and encompasses initiation and crack growth due to primary water stress corrosion cracking (PWSCC). This evaluation found that nozzle axial stresses are considerably lower than nozzle hoop stresses. Because of this, the likelihood of axial cracking is greater than the likelihood of circumferential cracking; therefore, only axial crack conditions were analyzed.

Entergy has estimated 4 years for a crack to grow 75% through-wall. This estimate is based on the following assumptions:

1. After PT and UT examination of the repaired ID surface, an undetected axial crack 0.157 inch long and 0.0679 inch deep is assumed present.

[1] See NRC letter to Entergy dated November 25, 2003 (TAC No. MB6559).
[2] See Entergy letter CNRO-2002-00052 to the NRC dated October 28, 2002.

2. The crack growth rate under operating conditions was determined using the MRP-55 recommended curve modified for a crack growth amplitude (α) that represents B&W material data.

3. The minimum wall thickness of the CRDM nozzle repair is 0.6175.

4. Water jet conditioning is not applied.

Since Entergy plans to replace the ANO-1 RPV head during 1R19, which is prior to the end of service life (4 years), water jet conditioning is not necessary.

Given these expected results, the proposed inspection schedules given above, and the planned replacement date for the ANO-1 RPV head, Entergy believes the proposed alternatives to the ASME code requirements are justified.

The proposed alternatives are applicable to the repairs and examinations after repair to any ANO-1 RPV head nozzles. This request is applicable to the repair of RPV head nozzles with leaks or other unacceptable conditions that may be identified prior to replacing the RPV head.

VI. Implementation Schedule

This request will be implemented during upcoming refueling outage 1R18, which is scheduled to begin during the second quarter of 2004. As mentioned above, Entergy plans to replace the ANO-1 RPV head during Refueling Outage 1R19, which is scheduled to begin during the fall of 2005.

TABLE 1

ANO-1 PENETRATION Replacement Weld UT Search Unit Transducer Characteristics				
Angle/Mode	**Freq.**	**Size**	**Focal Depth**	**Beam Direction**
0° L-wave	2.25 MHz	0.15" x 0.30"	0.45"	N/A
45° L-wave	2.25 MHz	0.30" x 0.20"	0.45"	Axial
70° L-wave	2.25 MHz	0.72" x 0.21"	0.69"	Axial
45° L-wave (effective)	2.25 MHz	0.30" x 0.20"	0.45"	Circ.

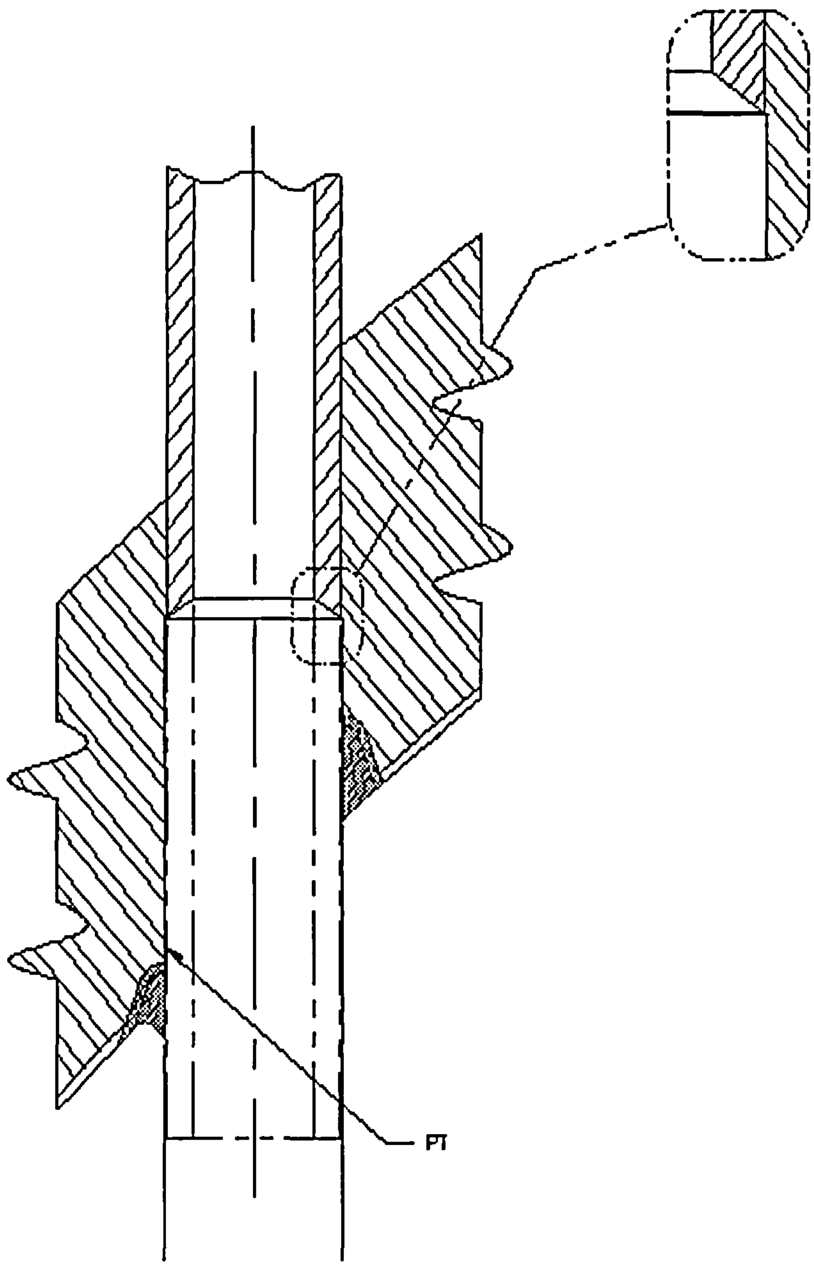


Figure 1
New ANO-1 RPV Head Nozzle

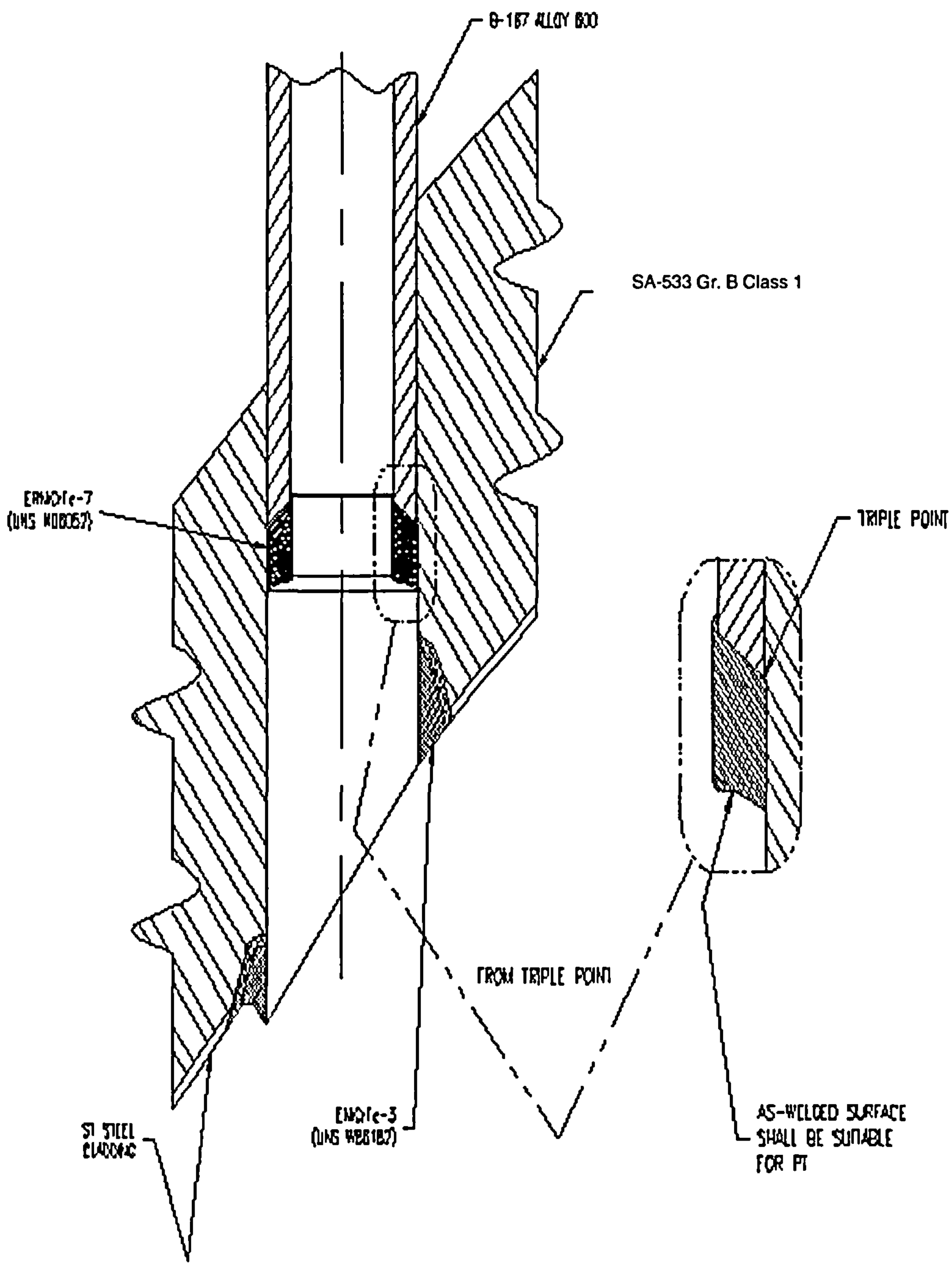


Figure 2
New ANO-1 RPV Head Nozzle Pressure Boundary Weld

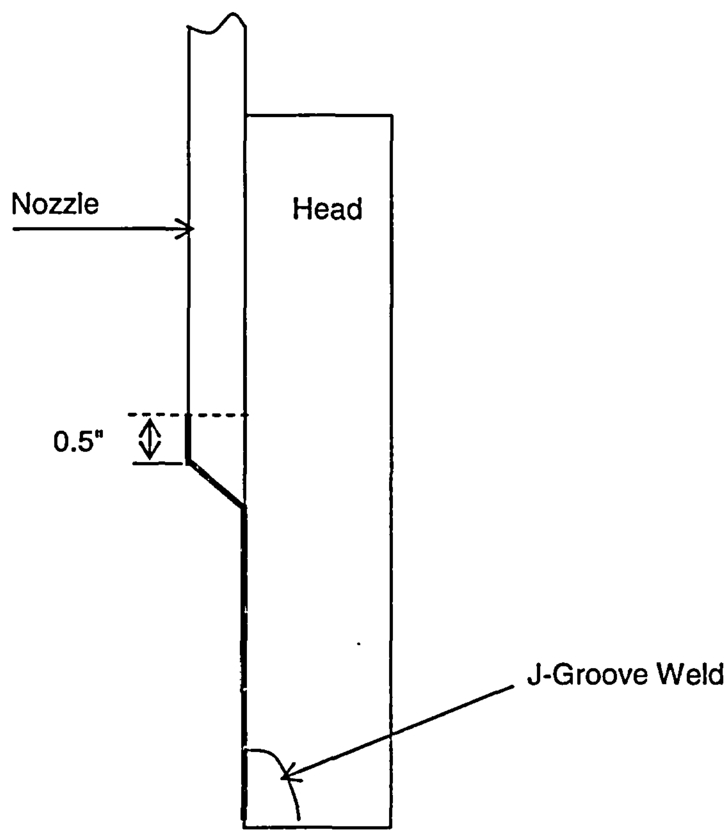


Figure 3
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
PT Coverage Prior to Welding

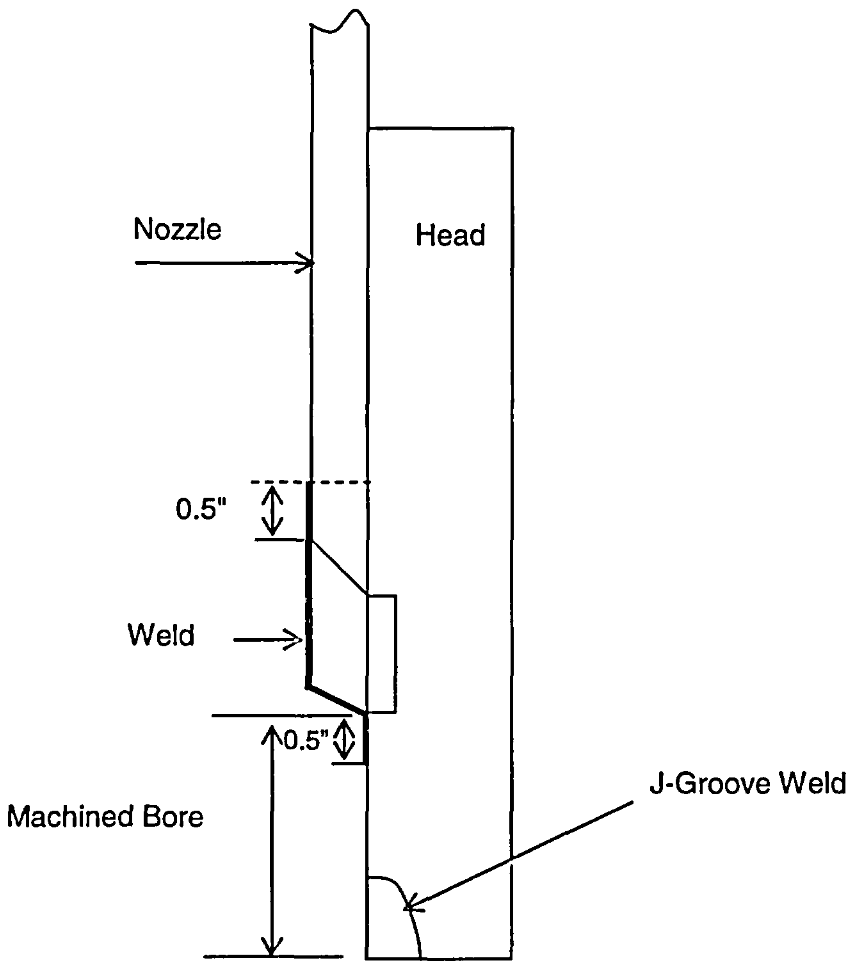


Figure 4
ANO-1 RPV head Nozzle Temper Bead Weld Repair
PT Coverage after Welding

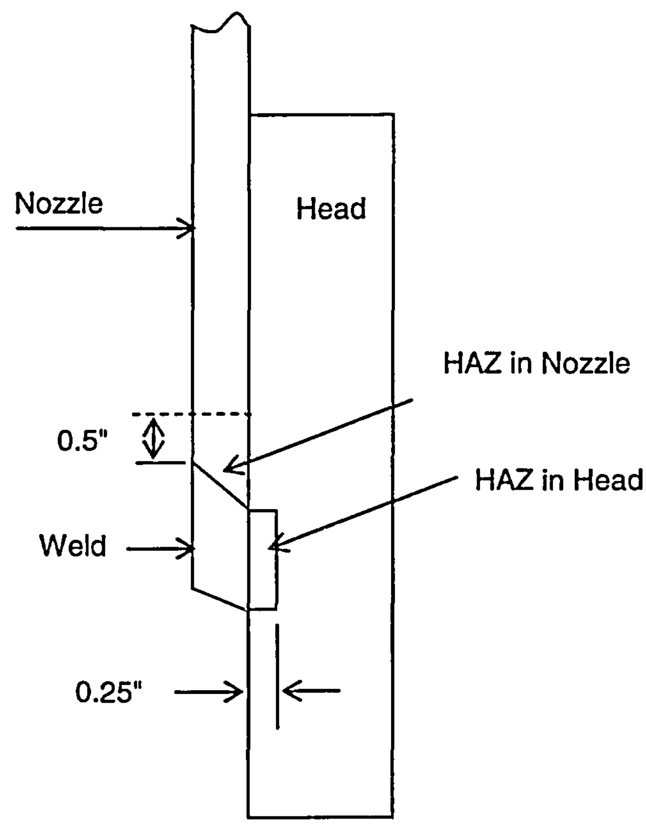


Figure 5
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
Areas to be Examined

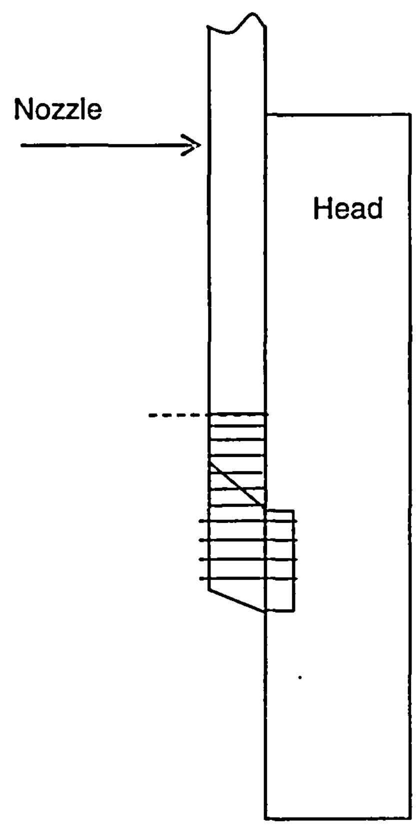


Figure 6
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
UT 0 degree and 45L Beam Coverage
Looking Clockwise and Counter-Clockwise

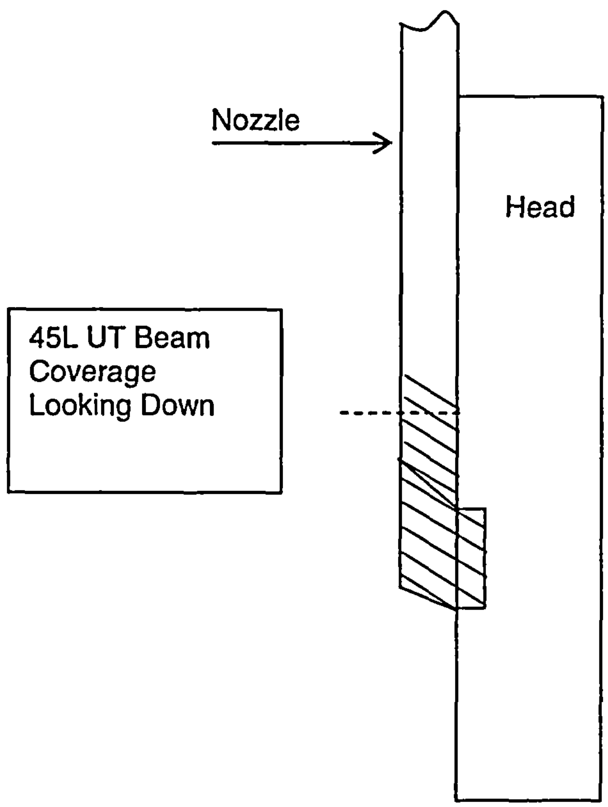


Figure 7
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
45L UT Beam Coverage Looking Down

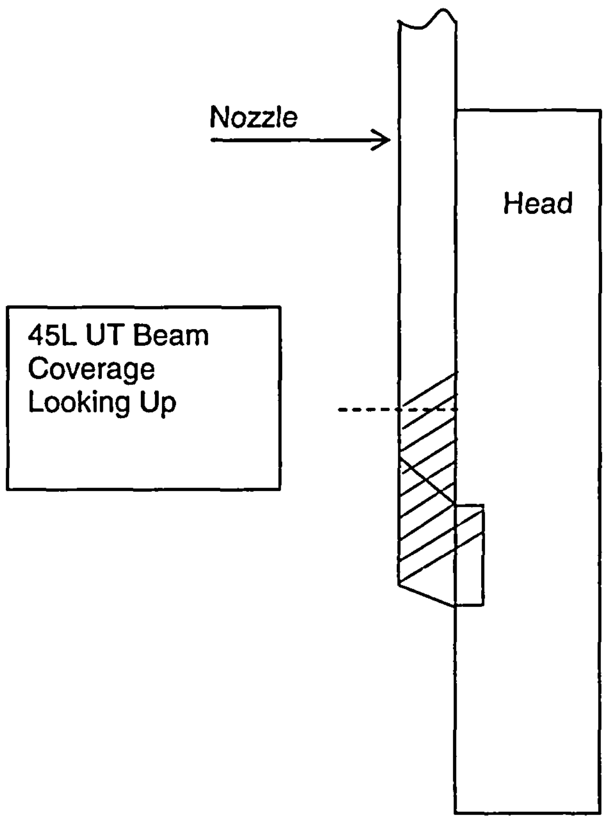


Figure 8
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
45L UT Beam Coverage Looking Up

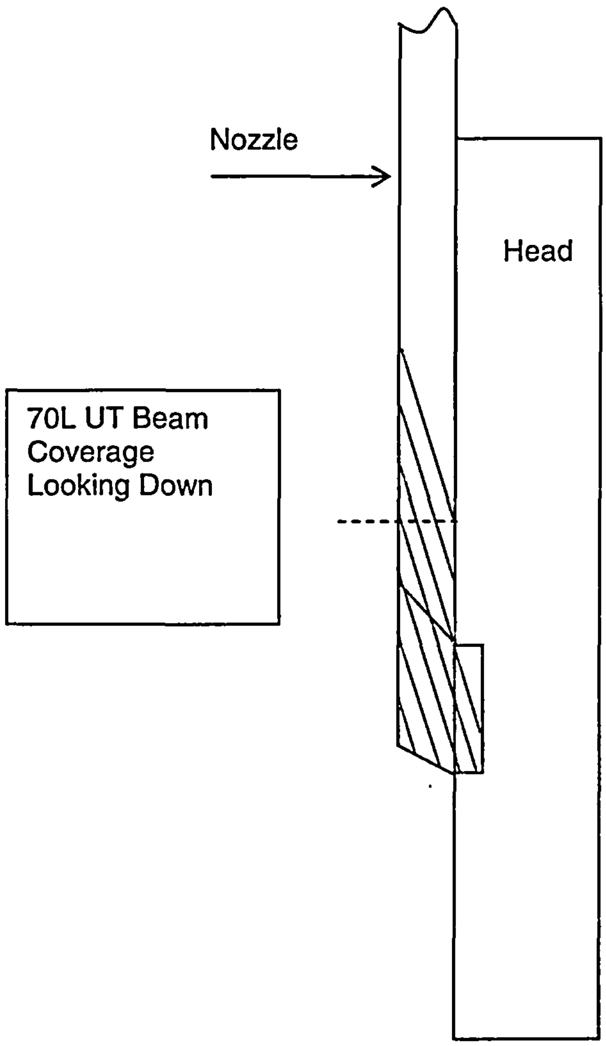


Figure 9
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
70L UT Beam Coverage Looking Down

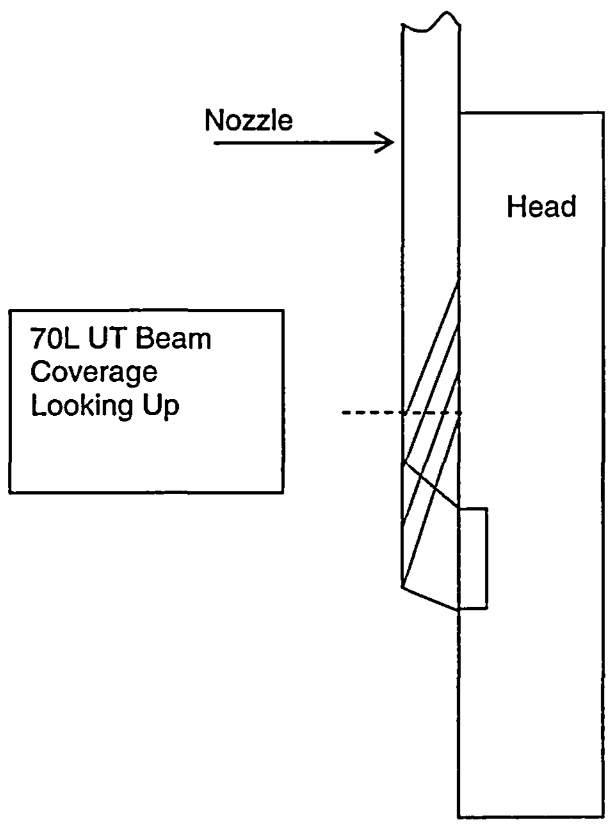


Figure 10
ANO-1 RPV Head Nozzle Temper Bead Weld Repair
70L UT Beam Coverage Looking Up

REQUEST NO. ANO1-R&R-005

ATTACHMENT 1

DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

DISSIMILAR METAL WELDING USING AMBIENT TEMPERATURE MACHINE GTAW TEMPER BEAD TECHNIQUE

Entergy plans to perform RPV head nozzle repairs by welding the RPV head (P-No. 3 base material) and nozzle (P-No. 43 base material) with filler material F-No. 43, in accordance with the following:

1.0 General Requirements:

(a) The maximum area of an individual weld based on the finished surface will be less than 100 square inches, and the depth of the weld will not be greater than one-half of the ferritic base metal thickness.

(b) Repair/replacement activities on a dissimilar-metal weld are limited to those along the fusion line of a nonferritic weld to ferritic base material on which 1/8 inch or less of nonferritic weld deposit exists above the original fusion line.

(c) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed provided the depth of repair in the base material does not exceed 3/8 inch.

(d) Prior to welding, the area to be welded and a band around the area of at least 1½ times the component thickness (or 5 inches, whichever is less) will be at least 50°F.

(e) Welding materials will meet the Owner's Requirements and the Construction Code and Cases specified in the repair/replacement plan. Welding materials will be controlled so that they are identified as acceptable until consumed.

(f) Peening will not be used, however, the weldment final surface will be abrasive water jet conditioned.

2.0 Welding Qualifications:

The welding procedures and the welding operators shall be qualified in accordance with Section IX and the requirements of paragraphs 2.1 and 2.2.

2.1 Procedure Qualification

(a) The ferritic steel base material for the welding procedure qualification is P-No. 3 Group No. 3 which is the same P-No. and Group No. as the low alloy steel closure head base material to be welded. The base material shall be postweld heat treated to at least the time and temperature that was applied to the materials being welded. The filler metal is F-No. 43.

(b) The root width and included angle of the cavity in the test assembly will be no greater than the minimum specified for the repair.

(c) The maximum interpass temperature for the first three layers of the test assembly will be 150°F.

(d) The ferritic steel P-No. 3 Group No. 3 base material test assembly cavity depth will be at least one-half the depth of the weld to be installed during the repair/replacement activity, and at least 1 inch. The test assembly thickness will be at least twice the test assembly cavity depth. The test assembly will be large enough to permit removal of the required test specimens. The test assembly dimensions surrounding the cavity will be at least the test assembly thickness, and at least 6 inches. The qualification test plate will be prepared in accordance with Figure A-1.

(e) Ferritic base material for the procedure qualification test will meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material, at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in subparagraph (f) below, but shall be in the base metal.

(f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) will be performed at the same temperature as the base metal test of subparagraph (e) above. Number, location, and orientation of test specimens will be as follows:

1. The specimens will be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The test coupons for HAZ impact specimens will be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimens will be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen will be inclined to allow the root of the notch to be aligned parallel to the fusion line.

2. If the test material is in the form of a plate or a forging, the axis of the weld will be oriented parallel to the principal direction of rolling or forging.

3. The Charpy V-notch test will be performed in accordance with SA-370. Specimens will be in accordance with SA-370, Figure 11, Type A. The test will consist of a set of three full-sized 10-mm x 10-mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens will be reported in the Procedure Qualification Record.

(g) The average values of the three HAZ impact tests will be equal to or greater than the average values of the three unaffected base metal tests.

(h) If the average Charpy V-notch lateral expansion for the HAZ of 2.1(g) above is less than that for the unaffected base material, and the qualification test meets the other criteria of acceptance, the Charpy V-notch test results may be recorded on the Welding Procedure Qualification Record. Data shall then be obtained as specified in 2.1(i) below to provide an additive temperature for any base material for which the welding procedure is being qualified, and shall be included. Alternatively, the welding procedure qualification may be re-welded and retested.

(i) The data for use in 2.1 (h) above shall be developed by performing additional Charpy V-notch tests on either the welding procedure qualification HAZ or the unaffected base material, or both, at temperatures which provide lateral expansion values equal to or greater than 35 mils. The average lateral expansion data for the HAZ and the unaffected base material shall be plotted on a lateral expansion-temperature chart. The temperatures at which these two sets of data exhibit a common lateral expansion value equal to or greater than 35 mils shall be determined. The determined temperature for the unaffected base material shall be subtracted from the similarly determined temperature for the HAZ. This difference shall be used in 2.1 (h) above as the adjustment temperature. The adjustment temperature shall be added to the highest nil ductility temperature (RT_{NDT}) temperature for all of the base material to be welded by this procedure in production. If the temperature difference is zero or is a negative number, no adjustment is required for the base material to be welded in production.

2.2 Performance Qualification

Welding operators will be qualified in accordance with ASME Section IX.

3.0 Welding Procedure Requirements

The welding procedure shall include the following requirements:

(a) The weld metal will be deposited by machine GTAW process.

(b) Dissimilar metal welds shall be made using F-No. 43 weld metal (QW-432) for P-No. 43 to P-No. 3 weld joints.

(c) The ferritic steel area to be welded will be buttered with a deposit of at least three layers to achieve at least 1/8 inch overlay thickness as shown in Figure A-2, steps 1 through 3, with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. Particular care will be taken in placement of the weld layers at the weld toe area of the ferritic material to ensure that the ferritic HAZ is tempered. Subsequent layers will be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

(d) The maximum interpass temperature for field applications will be 350°F regardless of the interpass temperature during qualification. The new weld is inaccessible for mounting thermocouples near the weld. Therefore, thermocouples will not be used to monitor interpass temperature. Preheat temperature will be monitored using contact pyrometers, on accessible areas of the closure head external surface(s).

4.0 Examination

(a) Prior to welding, a surface examination will be performed on the area to be welded.

(b) The final weld surface and adjacent HAZ shall be examined using surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours.

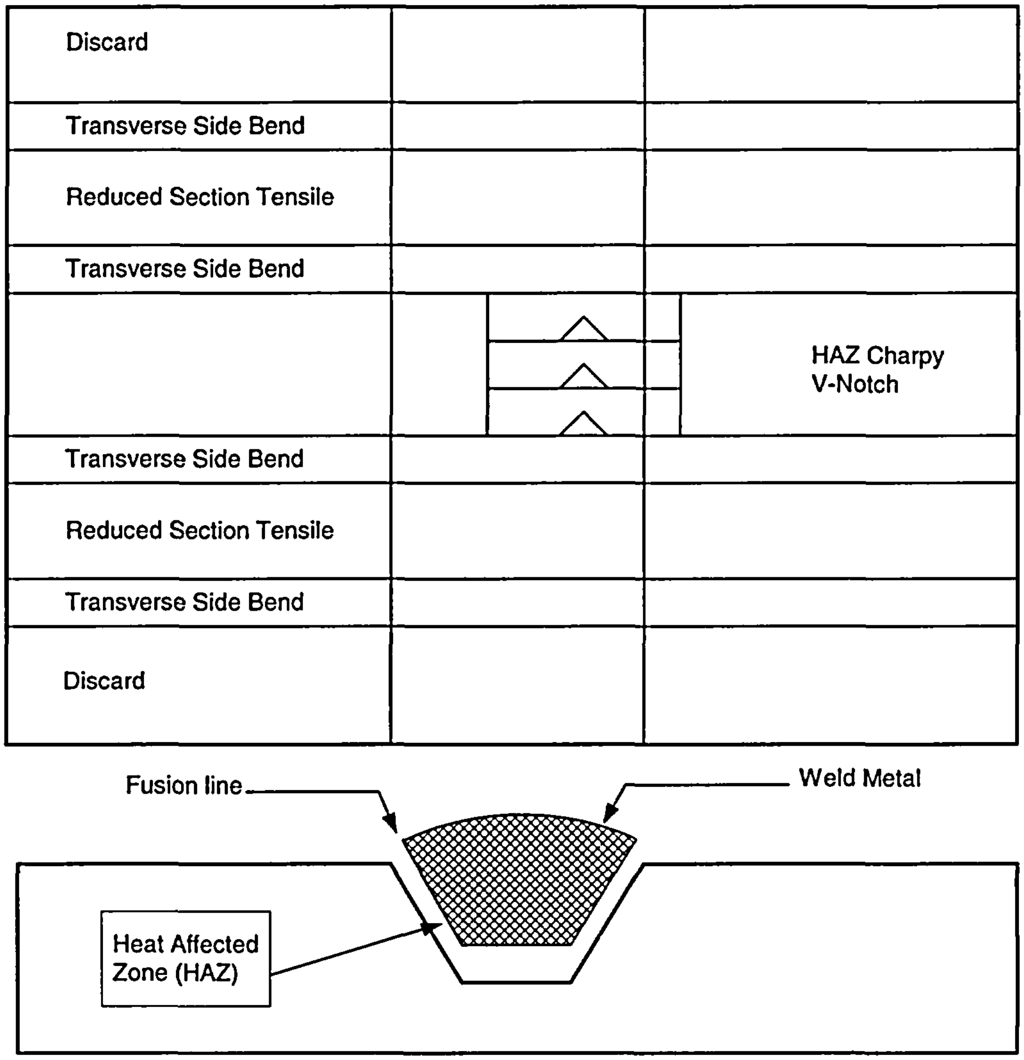
(c) The purpose for the examination of the band is to assure all flaws associated with the weld repair area have been removed or addressed. However, the band around the area defined in paragraph 1.0(d) cannot be examined due to the physical configuration of the partial penetration weld. The final examination of the new weld repair and immediate surrounding area within the band will be sufficient to verify that defects have not been induced in the low alloy RPV head material due to the welding process. Liquid penetrant (PT) coverage is shown in Figures 3 and 4 of ANO1-R&R-005. Ultrasonic testing (UT) will be performed scanning from the ID surface of the weld, excluding the transition taper portion at the bottom of the weld and adjacent portion of the RPV head nozzle bore. The UT is qualified to detect flaws in the repair weld and base metal interface in the repair region, to the maximum practical extent. The examination extent is consistent with the Construction Code requirements.

(d) NDE personnel will be qualified in accordance with IWA-2300 or NB-5500.

(e) Surface examination acceptance criteria will be in accordance with NB-5350. Ultrasonic examination acceptance criteria will be in accordance with NB-5330.

5.0 Documentation

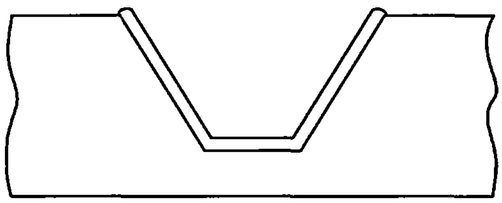
Repairs will be documented on Form NIS-2. Alternatively, repairs may be documented on Form NIS-2A as described in Code Case N-532 if prior approval is obtained from the NRC.



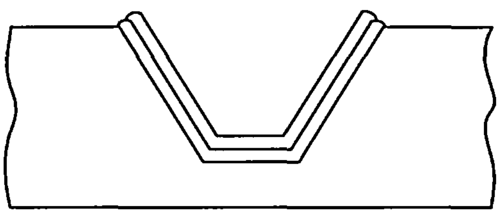
GENERAL NOTE: Base Metal Charpy impact specimens are not shown.

QUALIFICATION TEST PLATE

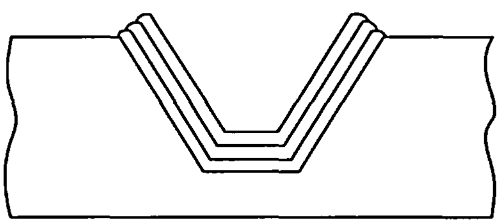
FIGURE A-1



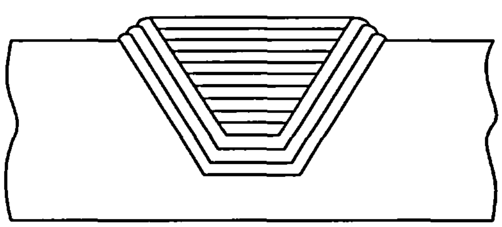
Step 1: Deposit layer one with first layer weld parameters used in qualification.



Step 2: Deposit layer two with second layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the second layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.



Step 3: Deposit layer three with third layer weld parameters used in qualification. NOTE: *Particular care shall be taken in application of* the third layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.



Step 4: Subsequent layers to be deposited as qualified, with heat input less than or equal to that qualified in the test assembly. NOTE: *Particular care shall be taken in application of* the fill layers to preserve the temper of the weld metal and HAZ.

GENERAL NOTE: For dissimilar-metal welding, only the ferritic base metal is required to be welded using Steps 1 through 3 of the temper bead welding technique.

AUTOMATIC OR MACHINE GTAW TEMPER BEAD WELDING

FIGURE A-2

ENCLOSURE 2

CNRO-2004-00006

REQUEST FOR ALTERNATIVE
ANO1-R&R-006, Rev. 0

ENTERGY OPERATIONS, INC.
ARKANSAS NUCLEAR ONE, UNIT 1
3rd 10-YEAR INTERVAL
REQUEST No. ANO1-R&R-006, Rev. 0

REFERENCE CODE:

The original code of construction for Arkansas Nuclear One, Unit 1 (ANO-1) is ASME Section III, 1965 Edition with Addenda through Summer, 1967. The components (including supports) may meet the requirements set forth in subsequent editions and addenda of the ASME Code incorporated by reference in 10 CFR 50.55a(b) subject to the limitations and modifications listed therein and subject to NRC approval. The codes of record for the repairs described within this request are the 1989 Edition of ASME Section III and 1992 Edition of ASME Section XI codes. ANO-1 is in its third (3rd) 10-Year Inservice Inspection interval.

I. System/Component(s)

a) Name of component:

Reactor Pressure Vessel (RPV) head nozzles (There are 69 nozzles welded to the RPV head.)

b) Function:

These welds serve as the pressure boundary weld for the RPV head nozzle and RPV head.

c) ASME Code Class:

The RPV head and RPV head nozzles are ASME Class 1.

d) Category:

Examination Category B-E, Pressure Retaining Partial Penetration Welds in Vessels; Item No. B4.12

II. Code Requirements

IWA-4310 requires in part that "Defects shall be removed or reduced in size in accordance with this Paragraph." Furthermore, IWA-4310 allows that "...the defect removal and any remaining portion of the flaw may be evaluated and the component accepted in accordance with the appropriate flaw evaluation rules of Section XI." The ASME Section XI, IWA-3300 rules require characterization of flaws detected by inservice examination.

Paragraph IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300. However, none of the nondestructive evaluation techniques that can be performed on the remnant of the J-groove weld that will be left on the RPV head can be used to characterize flaws in accordance with any of the paragraphs or subparagraphs of IWA-3300. In lieu of those requirements, a conservative worst case flaw shall be assumed to exist and appropriate fatigue analyses will be performed to establish the minimum remaining service life of the RPV head.

Subsubparagraph IWB-3142.4 allows for analytical evaluation to demonstrate that a component is acceptable for continued service. It also requires that components found acceptable for continued service by analytical evaluation be subject to successive examination during the next three inspection periods. Analytical evaluation of the worst case flaw referred to above will be performed to demonstrate the acceptability of continued operation. However, because of the impracticality of performing any subsequent inspection that would be able to characterize any remaining flaw, successive examination will not be performed. In addition, Entergy plans to replace the ANO-1 RPV head during refueling outage 1R19, which is scheduled to begin during the fall of 2005. 1R19 will occur before the end of the next inspection period obviating the need for successive inspections of the J-weld remnant.

Section III Subsection NB-5330(b) requires that "Indications characterized as cracks, lack of fusion, or incomplete penetrations are unacceptable regardless of length." Entergy is requesting relief from the requirements of NB-5330(b). The new pressure boundary weld that will connect the remaining portion of the RPV head nozzles to the low alloy RPV head contains a material "triple point." The triple point is at the root of the weld where the Alloy 600 nozzle will be welded with Alloy 690 (52) filler material to the SA-533 Grade B, Class 1 Mn-Mo low alloy steel plate (See Figures 1 and 2). Experience has shown that during solidification of the Alloy 52 weld filler material, a lack of fusion (otherwise known as a welding solidification anomaly) area may occur at the root of the partial penetration welds.

III. Proposed Alternatives

Entergy has determined that compliance with the specified requirements would result in unusual difficulty or hardship without a compensating increase in the level of quality. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), Entergy proposes the following alternatives to IWB-3420/IWA-3300, IWB-3142.4, and NB-5330(b).

The planned repair for the subject RPV head nozzles does not include removal of any cracks discovered in the remaining J-groove partial penetration welds. Therefore, per the requirements of IWA-4310, the cracks must be evaluated using the appropriate flaw evaluation rules of Section XI. No additional inspections are planned to characterize the cracks. Thus, the actual dimensions of the flaw will not be fully determined as required by IWA-3300. In lieu of fully characterizing the existing cracks, Entergy will use worst-case assumptions to conservatively estimate the crack extent and orientation. The postulated crack extent and orientation will be evaluated using the rules of IWB-3600. This evaluation will also justify leaving the remnant weld in place without performing successive examinations in accordance with IWB-3142.4.

If a weld triple point anomaly occurs in any of the repair welds as discussed above, it must also be evaluated in accordance with the appropriate flaw evaluation rules of Section XI. Calculations will be completed to justify this welding solidification anomaly.

IV. Basis for Relief

Inspections of the RPV head will be performed in accordance with NRC Order EA-03-009, *Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors.* These inspections may identify conditions that indicate a need to repair flaws discovered in the RPV head penetrations. The use of any of the alternatives permitted by the applicable ASME Codes for repairs will result in increased radiation dose with no compensating increase in quality or safety. The post-weld heat treatment (PWHT) parameters required by NB-4622 would be difficult to achieve on a RPV head in containment and would pose significant risk of distortion to the geometry of the RPV head and vessel head penetrations. In addition the existing J-groove welds would be exposed to PWHT for which they were not qualified. This request applies to repair of any or all of the noted penetrations and to others that may be identified by subsequent inspections during the outage.

Industry experience gained from earlier repairs of RPV head nozzles indicates that removal and repair of the defective portions of the original J-groove partial penetration welds were time consuming and radiation dose intensive. The prior repairs indicated that more automated repair methods were needed to reduce radiation dose to repair personnel. For the present ANO-1 repairs, a remote semi-automated repair method will be used for each of the subject nozzles. Using a remote tool from above the RPV head, each of the nozzles subject to this repair will first receive a roll expansion into the RPV head base material to insure that the nozzle will not move during subsequent repair operations. Second, a semi-automated machining tool from underneath the RPV head will remove the lower portion of the nozzle to a depth above the existing J-groove partial penetration weld. This operation will sever the existing J-groove partial penetration weld from the subject RPV head nozzles. Third, a semi-automated weld tool, utilizing the machine GTAW process, will then be used to install a new Alloy 690 pressure boundary weld between the shortened nozzle and the inside bore of the RPV head base material (see Figures 1 and 2). It was intended, as a part of the new repair methodology and to reduce radiation dose to repair personnel that the original J-groove partial penetration welds would be left in place. These welds will no longer function as pressure boundary RPV head nozzle to RPV head welds. However, the possible existence of cracks in these welds mandates that the flaw growth potential be evaluated.

The requirements of IWA-4310 allow two options for determining the disposition of discovered cracks. The subject cracks are either removed as part of the repair process or left as-is and evaluated per the rules of IWB-3600. The repair design specifies the inside corner of the J-groove weld be progressively chamfered from the center to outermost penetrations to maintain an acceptable flaw size. Section III paragraph NB-3352.4(d)(3) requires that the corners of the end of each nozzle to be rounded to a radius of ½ t_n or ¾ inch which ever is smaller. A 1/8-inch minimum chamfer considered equivalent to the radius specified in NB-3352.4(d)(3) will be incorporated on the bottom corner of the repaired RPV head nozzle penetrations in lieu of the radius. The radius is specified to reduce the stress concentration that might occur at a sharp corner; however, since the original partial penetration weld that remains in this area is analyzed assuming through weld cracks exist therein the presence or absence of a radius or chamfer at this location is not significant with respect to stress concentration. The primary purpose of the chamfer is to assure that any remaining cracks are no larger than those assumed for the analysis.

The assumptions of IWB-3600 are that the cracks are fully characterized to be able to compare the calculated crack parameters to the acceptable parameters addressed in IWB-3500. In the alternative being proposed, the acceptance of the postulated crack is calculated based on the two inputs of expected crack orientation and the geometry of the weld. Typically, an expected crack orientation is evaluated based on prevalent stresses at the location of interest. In these welds, operating stresses are obtained using finite element analysis of the RPV head. Since hoop stresses will be the dominant stress as determined by calculations, it is expected that radial type cracks (with respect to the penetration) will occur. Using worst case (maximum) assumptions with the geometry of the as-left weld, the postulated crack will be assumed to begin at the intersection of the RPV head inner diameter surface and the RPV head nozzle bore and propagate slightly into the RPV head low alloy steel. The depth and orientation are worst-case assumptions for cracks that may occur in the remaining J-groove partial penetration weld configuration.

The original nozzle-to-RPV head weld configuration is extremely difficult to UT due to the compound curvature and fillet radius as can be seen in Figures 1 and 2. These conditions preclude ultrasonic coupling and control of the sound beam in order to perform flaw sizing with reasonable confidence in the measured flaw dimension. Therefore it is impractical, and presently, the technology does not exist, to characterize flaw geometries that may exist therein. Not only is the configuration not conducive to UT but the dissimilar metal interface between the Ni-Cr-Fe weld and the low alloy steel RPV head increases the UT difficulty. Furthermore, due to limited accessibility from the RPV head outer surface and the proximity of adjacent nozzle penetrations, it is impractical to scan from this surface on the RPV head base material to detect flaws in the vicinity of the original weld. Entergy proposes to accept these flaws by analysis of the worst case that might exist in the J-groove. Since the worst case condition is to be analyzed as described below, no future examinations of these flaws is planned.

As previously discussed, after the boring and removal of the nozzle end, the remaining weld will be chamfered to assure the remaining weld metal is thinner than the maximum allowable flaw size. Since it has been determined that through-wall cracking in the J-groove weld will most likely accompany a leaking RPV head nozzle, it must be assumed that the "as-left" condition of the remaining J-groove weld includes degraded or cracked weld material.

A fracture mechanics evaluation was performed to determine if degraded J-groove weld material could be left in the vessel, with no examination to size any flaws that might remain following the repair.[1] Since the hoop stresses in the J-groove weld are generally about two times the axial stress at the same location, the preferential direction for cracking is axial, or radial relative to the nozzle. A radial crack in the Alloy 182 weld metal was postulated to propagate by primary water stress corrosion cracking (PWSCC) through the weld and butter, to the interface with the low alloy steel RPV head. Such a crack is expected to blunt and arrest at the butter-to-head interface. In the worst case, on the uphill side of the nozzle, where the hoop stresses are highest and the area of the J-groove weld is the largest, a radial crack depth extending from the corner of the weld to the low alloy steel RPV head would be very deep, up to approximately 1 3/8 inches at the outermost row of nozzles after chamfering.

[1] See ANO Calculation 86-E-0074-156 submitted to the NRC via Entergy letter CNRO-2002-00054 dated November 26, 2002.

Ductile crack growth through the Alloy 182 material would tend to relieve the residual stresses in the weld as the crack grew to its final size and blunted. Although residual stresses in the RPV head material are low, a small crack was conservatively assumed to initiate in the low alloy steel material and grow by fatigue. It was postulated that a small crack in the RPV head could result from a large stress corrosion crack in the weld to form a radial corner flaw that would propagate into the low alloy steel RPV head by fatigue crack growth under cyclic loading conditions associated with heatup and cooldown. Residual stresses were not included in the flaw evaluations since analysis demonstrated that these stresses are compressive at the postulated crack tip in the low alloy steel base metal. Any residual stresses that remained in the area of the weld following the boring operation would be relieved by such a deep crack, and therefore need not be considered.

Flaw evaluations were performed for a postulated radial corner crack on the uphill side of the RPV head penetration, where stresses are the highest and the radial distance from the inside corner to the low alloy steel base metal (crack depth) is the greatest.[2] Hoop stresses were used since they are perpendicular to the plane of the crack. Fatigue crack growth will be calculated for a sufficient number of operating cycles to support operation until the RPV head is replaced in 2005. The analysis was required to demonstrate compliance with the fracture toughness requirements of the ASME Code using an upper shelf value of 200 ksi/in for ferritic materials.

The described analysis determined the acceptability of leaving the postulated cracks in the attachment weld (J-groove) and buttering. The calculations showed the remaining flaws within the base material are acceptable for a number of heat-up/cool-down cycles that will exceed the number of heat-up/cooldown cycles expected to occur prior to replacement of the RPV head. The only driving mechanism for fatigue crack growth of the base material is heat-up/cool-down cycles. The fracture mechanics evaluation assumed a radial (with respect to the penetration centerline) crack exists with a length equal to the partial penetration weld preparation depth plus an additional distance into the RPV head low alloy steel where the residual stresses become compressive. Based on industry experience and operating stress levels, there is no reason for service related cracks to exist in the ferritic material.

Based on these evaluations, a postulated 1.375-inch radial crack in the Alloy 182 J-groove weld and butter would be acceptable for 25 years of operation.[3]

An additional evaluation was performed to determine the potential for debris from a cracking J-groove partial penetration weld.[4] As noted above, radial cracks were postulated to occur in the weld due to the dominance of the hoop stress at this location. The possibility of occurrence of transverse cracks that could intersect the radial cracks was considered remote since there are no forces that would drive a transverse crack. The radial cracks would relieve the potential transverse crack driving forces. Hence, it is unlikely that a series of transverse cracks could intersect a series of radial cracks resulting in any fragments becoming dislodged.

[2] Ibid.
[3] Ibid.
[4] See ANO Calculation E-86-0074-164 submitted to the NRC via Entergy letter CNRO-2002-00054 dated November 26, 2002.

The cited evaluations provide an acceptable level of safety and quality in insuring that the RPV head remains capable of performing its design function for a sufficient number of heat-up/cool-down cycles to support one (1) operating cycle, with flaws existing in the original J-groove weld.

For the reasons described above, areas containing flaws accepted by analytical evaluation were not be reexamined as required by IWB-3142.4. Additionally, Entergy plans to replace the ANO-1 RPV head during 1R19, which is scheduled to begin in the fall of 2005.

In the case of the RPV head nozzle inside diameter (ID) temper bead repair, the term "anomaly" is applied to the unusual solidification patterns that result along the low alloy steel / Alloy 600/Filler Metal 52 interface of the repair weld. The anomalies originate along the low alloy steel (RPV head) to Alloy 600 (original nozzle) interface where melting occurs and generally extend back towards the center of the weld bead. These anomalies are typical for welds that involve a "lap joint" type interface, such as typical partial penetration weld geometries, in the weld joint design. Cross sections of nickel alloy welds made utilizing similar joint designs with Alloy 600 base materials and Alloy 82 filler metals have exhibited these phenomena consistently.

This phenomenon is compounded by the different solidification rates for the base materials and weld metal used in performing the repair. Other suspected factors in the anomaly occurrence are the size of the interface gap, gap cleanliness and position of the welding arc relative to the edge of the interface. The molten weld puddle simply freezes back to each side of the interface and follows the interface into the weld as solidification of the weld puddle take place. Weld root anomalies have been observed on several mockups with configurations simulating the repair weld. UT methods have been developed based on the characteristics of this anomaly so that verification to the prescribed acceptance criteria can be performed. The defect is treated like a crack, which is worst case. Two types of flaws are common in this area. The first is localized melting away of the feathered end of the beveled nozzle weld prep leaving occasional small voids. The second type flaw is caused due to an inherent problem during solidification of high Ni-Cr alloys in the presence of a notch such as a partial penetration weld. This type of flaw is in fact often called a "solidification anomaly" to differentiate it from what it is not – a crack.

IWA-4170 mandates that the repair design meets the original construction code or the adopted ASME Section III Code. As noted, the 1989 ASME Section III code has been adopted for qualification of the described repairs. Subsection NB-5330(b) stipulates that no lack of fusion area be present in the weld. A fracture mechanics analysis was performed to demonstrate compliance with Section XI of the ASME Code, for operating with the postulated weld anomaly described above.[5] The anomaly was modeled as a 0.1 inch semi-circular "crack-like" defect, 360 degrees around the circumference at the "triple point" location. Full-size mockups using coupons from the Midland RPV head were metallographically evaluated. Both flaw types were occasionally found as expected and were less than the analyzed maximum allowed of 0.100 inch.

Based on the fact that this anomaly is predictable as discussed herein, the anomaly can be detected by UT within the prescribed acceptance criteria and evaluated for fatigue and flaw growth using applicable ASME Sections III and XI methods. Therefore, the intent of the ASME Codes will be met. The ASME Section III analysis conservatively assumes a reduction

[5] See ANO Calculations 86-E-0074-160 and 86-E-0074-161 submitted to the NRC via Entergy letter CNRO-2002-00054 dated November 26, 2002.

in weld area (along the new weld-to-ferritic steel penetration fusion line) due to the anomaly and the ASME Section XI analysis assumes the anomaly is a crack-like defect.

Postulated flaws could be oriented within the anomaly such that there are two possible flaw propagation paths, as discussed below.

Path 1:

Flaw propagation path 1 traverses the RPV head tube wall thickness from the outside diameter (OD) of the tube to the ID of the tube. This is the shortest path through the component wall, passing through the new Alloy 690 weld material. However, Alloy 600 tube material properties or equivalent are used to ensure that another potential path through the heat affected zone (HAZ) between the new repair weld and the Alloy 600 tube material is bounded.

For completeness, two types of flaws are postulated at the outside surface of the tube. 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 anomaly. This flaw is subjected to axial stresses in the tube. 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 tube.

Path 2:

Flaw propagation path 2 runs down the outside surface of the repair weld between the weld and RPV head. A semi-circular cylindrically oriented flaw is postulated to lie along this interface, subjected to radial stresses with respect to the tube. This flaw may propagate through either the new Alloy 690 weld material or the low alloy steel RPV head material.

The result of the analysis demonstrated that a 0.10-inch weld anomaly is acceptable for 25 years, which is beyond 2005 when the ANO-1 RPV head is scheduled to be replaced. Residual stresses and stresses due to operation were considered. Significant fracture toughness margins were expected for both of the flaw propagation paths considered in the analysis. The minimum calculated fracture toughness margins were required to be greater than the required margin of 10 per ASME Section XI IWB-3612. Based on similar analysis, fatigue crack growth was expected to be minimal. The maximum final flaw size was small considering both flaw propagation paths. A limit load analysis was also performed considering the ductile Alloy 600/Alloy 690 materials along flaw propagation path 1. The analysis was required to show limit load margins for normal/upset conditions and emergency/faulted conditions greater than the required margins of 3.0 and 1.5 for normal/upset conditions and emergency/faulted conditions, respectively, per ASME Section XI, IWB-3642.

Acceptance of the repair will be based on this evaluation in accordance with ASME Section XI and will demonstrate that for the intended service life of the repair, the fatigue crack growth is acceptable and the crack-like indications remain stable. These two findings will satisfy the Section XI criteria but do not include considerations of stress corrosion cracking such as PWSCC. However, since the crack-like indications in the weld triple point anomaly are not exposed to the primary coolant and the air environment is benign for the materials at the triple point, the time-dependent crack growth from PWSCC is not applicable.

As required by ASME Section XI, the results of the analysis will determine the maximum design life which is expected to be greater than the one (1) operating cycle that will occur before the RPV head is replaced in the fall of 2005.

For the reasons described above, areas of J-welds containing flaws accepted by analytical evaluation will not be reexamined as required by IWB-3142.4. Although solidification anomalies may occur in the new repair weld, volumetric examination of these welds during a subsequent refueling outage is not required since Entergy plans to replace the ANO-1 RPV head during 1R19. (1R19 is scheduled to begin during the fall of 2005.)

Justification for Proposed Alternative:

Removal of the cracks in the existing J-groove partial penetration welds would incur excessive radiation dose for repair personnel. With the installation of the new pressure boundary welds previously described, the original function of the J-groove partial penetration welds is no longer required. It is well understood that the cause of the cracks in the subject J-groove welds is PWSCC. As shown by industry experience, the low alloy steel of the RPV head impedes crack growth by PWSCC. Entergy believes the alternative will provide an acceptable level of quality and safety when compared to the code requirements in IWB-3500 to characterize the cracks left in service. Using flaw tolerance techniques and an assumed worst-case crack size, the analysis demonstrated that unacceptable flaw growth into the RPV head does not occur within the next operating cycle.[6] Thus, the RPV head can be accepted per the requirements of IWA-4310.

Based on extensive industry experience and Framatome-ANP direct experience, there are no known cases where flaws initiating in an Alloy 82/182 weld have propagated into the ferritic base material. The surface examinations performed associated with flaw removal during recent repairs at Oconee 1 and 3 on RPV head penetrations, Catawba 2 steam generator channel head drain connection penetration, ANO-1 hot leg level tap penetrations and the VC Summer Hot Leg pipe to primary outlet nozzle repair (reference MRP-44: Part I: Alloy 82/182 Pipe Butt Welds, EPRI, 2001. TP-1001491) all support the assumption that the flaws would blunt at the interface of the Ni-Cr-Fe weld to ferritic base material. Additionally, the Small Diameter Alloy 600/690 Nozzle Repair Replacement Program (CE NPSD-1198-P) provides data that shows PWSCC does not occur in ferritic pressure vessel steel. Based on industry experience and operation stress levels, there is no reason for service related cracks to propagate into the ferritic material from the Alloy 82/182 weld.

Elimination of the weld triple point anomaly would require use of an entirely different process than that proposed for use on ANO-1. The only qualified method currently available would involve extensive manual welding that would result in radiation doses estimated to be in excess of 30 REM per nozzle as compared to the 5 REM estimated for each nozzle repaired by the proposed process.

Compliance with the specified Code requirements would result in excessive radiation exposure: a hardship or unusual difficulty without a compensating increase in the level of quality and safety.

[6] See ANO Calculation 86-E-0074-156 submitted to the NRC via Entergy letter CNRO-2002-00054 dated November 26, 2002.

This proposed alternative, submitted as ANO1-R&R-004, was previously approved by the NRC staff for use during the previous refueling outage 1R17 at ANO-1.[7]

V. Duration of the Proposed Alternative

Entergy plans to replace the ANO-1 RPV head during Refueling Outage 1R19, which is scheduled to begin during the fall of 2005. Therefore, this request will be limited to one operating cycle.

In previously approved request ANO1-R&R-003, Entergy informed the NRC of the need to employ abrasive water jet mitigation to any nozzle repairs.[8] For the upcoming 1R18 refueling outage, Entergy has re-evaluated the need to employ any type of water jet conditioning and has determined such activities are not required. Entergy has performed an evaluation to determine the time for a postulated crack to grow 75% through-wall in the Alloy 600 nozzle material above the repair weld without employing water jet conditioning. The evaluation considers RPV head nozzles in the as-repaired condition and encompasses initiation and crack growth due to primary water stress corrosion cracking (PWSCC). This evaluation found that nozzle axial stresses are considerably lower than nozzle hoop stresses. Because of this, the likelihood of axial cracking is greater than the likelihood of circumferential cracking; therefore, only axial crack conditions were analyzed.

Entergy has estimated 4 years for a crack to grow 75% through-wall. This estimate is based on the following assumptions:

1. After PT and UT examination of the repaired ID surface, an undetected axial crack 0.157 inch long and 0.0679 inch deep is assumed present.

2. The crack growth rate under operating conditions was determined using the MRP-55 recommended curve modified for a crack growth amplitude (α) that represents B&W material data.

3. The minimum wall thickness of the CRDM nozzle repair is 0.6175.

4. Water jet conditioning is not applied.

Since Entergy plans to replace the ANO-1 RPV head during 1R19, which is prior to the end of service life (4 years), water jet conditioning is not necessary.

Given these expected results, the proposed inspection schedules given above, and the planned replacement date for the ANO-1 RPV head, Entergy believes the proposed alternatives to the ASME Code requirements are justified. The proposed alternatives are applicable to the repairs and examinations after repair to any ANO-1 RPV head nozzle.

VI. Implementation Schedule

This request will be implemented during upcoming refueling outage 1R18, which is scheduled to begin during the second quarter of 2004. Entergy plans to replace the ANO-1 RPV head during Refueling Outage 1R19, which is scheduled to begin during the fall of 2005.

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[7] See NRC letter to Entergy dated November 25, 2003 (TAC No. MB6559).
[8] See Entergy letter CNRO-2002-00052 to the NRC dated October 28, 2002.

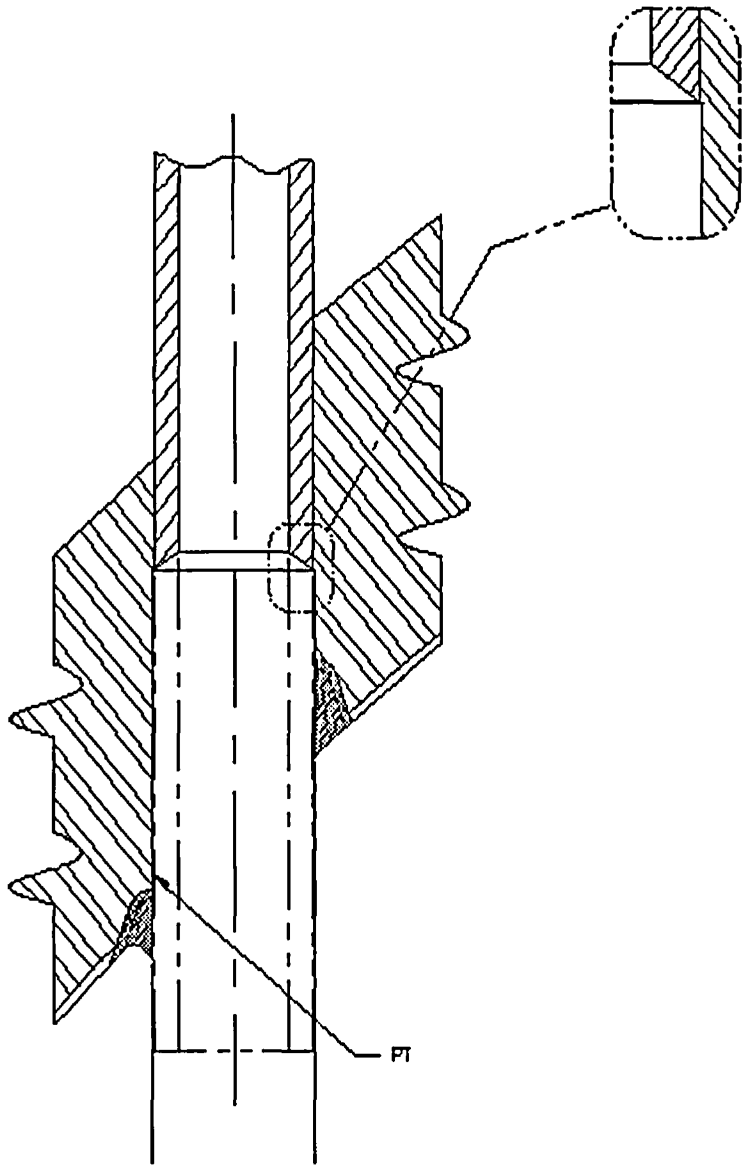

FIGURE 1
New ANO-1 RPV Head Nozzle

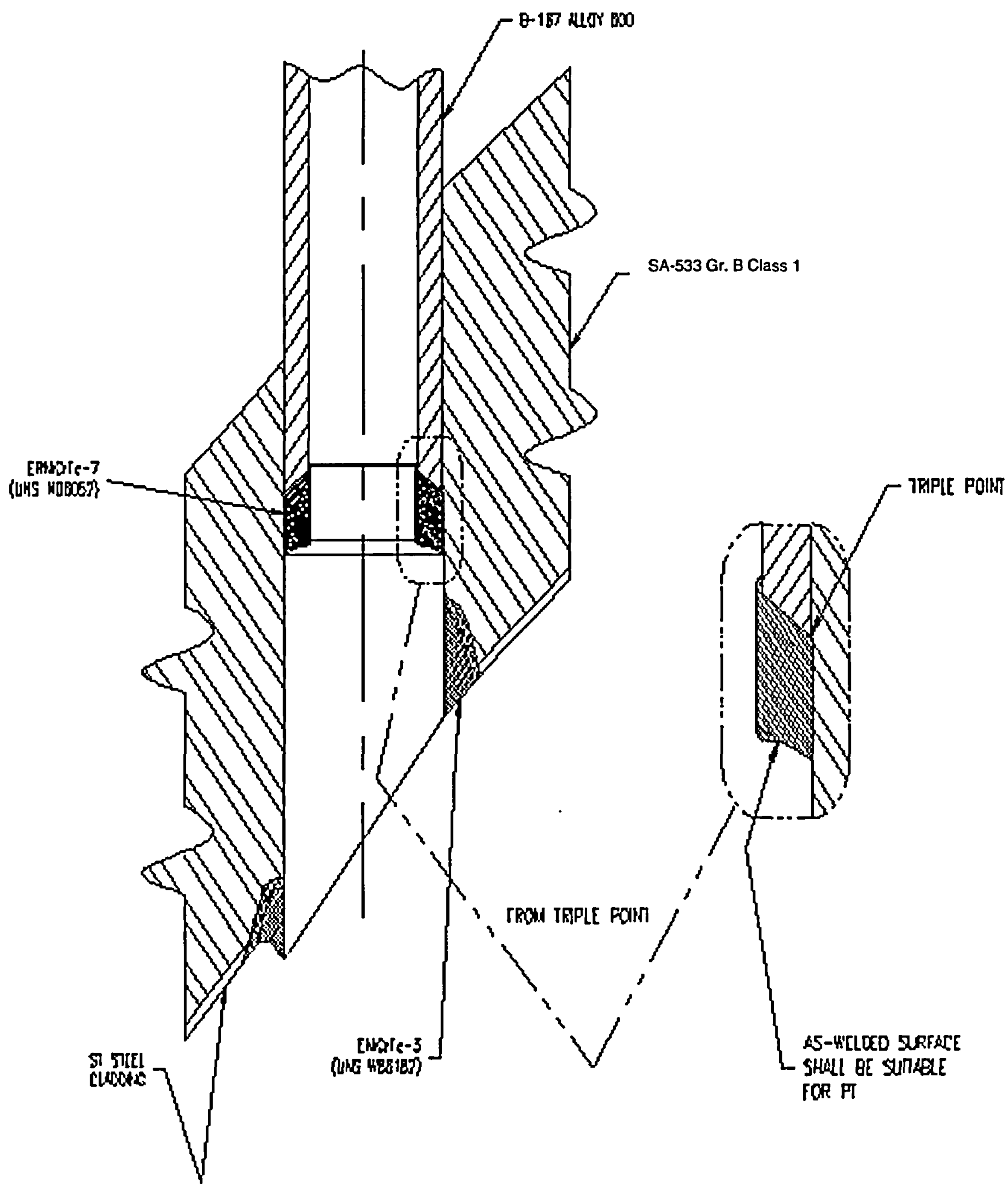

FIGURE 2
ANO-1 New RPV Head Pressure Boundary Welds