



**Duke Energy**

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November 16, 2001

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

Subject: Oconee Nuclear Station Unit 3  
Docket Number 50-287  
Request for Alternates to ASME Section XI per 10 CFR 50.55(a)(3) -  
Relief Requests 01-14, Revision 1, and 01-15, Revision 1

By letter dated October 18, 2001, Duke Energy Corporation (Duke) submitted Relief Request (RR) 01-14, Revision 0 (Attachment A) per 10 CFR 50.55(a)(3)(i), and RR 01-15, Revision 0 (Attachment B) per 10 CFR 50.55(a)(3)(ii) for Oconee Unit 3 (ONS-3). By these requests, Duke sought relief from the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, 1992, should reactor vessel head control rod drive mechanism (CRDM) penetration nozzle leak repair be required in the end of cycle 19 (EOC-19) refueling outage. RR 01-14 proposed performing the weld repair using alternate processes. RR 01-015 proposed alternates to ASME Non-destructive Examination (NDE) and flaw evaluation requirements.

On November 13, 2001, the NRC verbally requested that Duke revise the format and contents of the above requests to emulate a recent submittal by Dominion Generation for their Surry Power Station. In response to this request, Duke herein submits Revision 1 of RR 01-14 and RR 01-15 as Attachments A and B respectively. These revisions replace the prior submittals in their entirety.

On November 10, 2001, ONS-3 was shutdown to begin the EOC-19 refueling outage. On November 11 and 12, a qualified visual inspection of the bare metal reactor vessel head identified four CRDM nozzles with indication of leakage (Nos. 26, 39, 49 and 51) and three other nozzles with suspected leaks (Nos. 2, 10 and 41). As described in Duke's August 28, 2001 response to NRC Bulletin 2001-01<sup>1</sup>, additional NDE will be performed on the leaking and suspect nozzles to identify repairs that will be required to be completed prior to restart. The presently anticipated scope of the CRDM nozzle repairs does not impact the refueling outage schedule or the requested approval of these two requests by November 26, 2001.

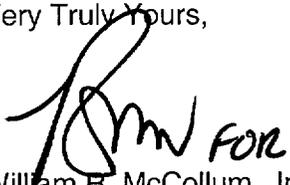
This letter establishes a commitment to provide the NRC with a welding Procedure Qualification Record as described in RR 01-14 (Attachment A) by March 21, 2002. This letter contains no other commitments.

<sup>1</sup> NRC Bulletin 2001-01, Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles, dated August 3, 2001.

A047.

If you have any questions regarding this submittal, please contact Robert Douglas at 864-885-3073.

Very Truly Yours,



William R. McCollum, Jr.  
Site Vice-President,  
Oconee Nuclear Station

Attachments:

- A. Oconee Unit 3 Relief Request 01-14, Revision 1
- B. Oconee Unit 3 Relief Request 01-15, Revision 1

xc w/att:

NRR Project Manager  
Regional Administrator, Region II

xc w/o att:

Senior Resident Inspector  
South Carolina Dept. of Health & Environmental Control

**ATTACHMENT A**

**INSERVICE INSPECTION  
OCONEE UNIT 3  
RELIEF REQUEST 01-14, REVISION 1  
THIRD TEN-YEAR INTERVAL**

**OCONEE UNIT 3  
INSERVICE INSPECTION  
RELIEF REQUEST 01-14, REVISION 1  
THIRD TEN-YEAR INTERVAL**

**REFERENCE CODE:**

The original code of construction for Oconee Unit 3 is ASME Section III 1965 Edition with Addenda through Summer, 1967. The ISI Code of record for Oconee Nuclear Station, Unit 3, third 10-year interval is the 1989 Edition of the ASME Code. 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 Section III and 1992 Section XI codes.

**I System/Component(s) for Which Relief is Requested:**

- a) Name of component:  
Reactor Pressure Vessel (RPV) Closure Head Control Rod Drive Mechanism (CRDM) nozzle penetrations. There are 69 Vessel Head Penetrations (VHP) welded to the RPV Closure head (RVCH).
- b) Function:  
These welds serve as the pressure boundary weld for the CRDM nozzle and Reactor Vessel Head penetration.
- c) ASME Code Class:  
The RPV and CRDM Nozzle Penetrations 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 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 reactor vessel head. The alternative temper bead methods (IWA-4500

and NB-4622.9, NB4622.10 or NB-4622.11) offered by Section III and Section XI require elevated temperature preheat and post weld soaks that will result in added radiation dose to repair personnel.

As an alternative to the requirements of NB-4622, Duke Power Company (Duke) proposes to perform the repair 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 post weld heat treatment. 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.

### **III. Code Requirements for Which Alternatives are Requested**

Oconee Unit 3 has performed inspections that indicate a possible need to repair flaws discovered in the reactor vessel head penetration tube numbers 26, 39, 49 and 51. While the evidence of leaking is not compelling for the other penetrations, there is some indication that three others may also have leaks (tube numbers 2, 10 and 46). 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 PWHT parameters required by NB-4622 would be difficult to achieve on a reactor vessel head in containment and would pose significant risk of distortion to the geometry of the 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.

Therefore, pursuant to 10 CFR 50.55a (a)(3)(i), Duke requests relief 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 an alternative to these requirements, the requirements of, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW temper bead Technique," (Enclosure 1) will be used. A list of the most applicable, articles, subarticles, paragraphs, and subparagraphs of ASME Section III, and Section XI is given below. Where the requirements will not be met, the alternative or reference to the alternative is given in italic print.

NB-2410 requires that all welding material used in the construction and repair of components or material shall conform to the requirements of the welding material specification. This code allows, by reference, the use of alloy 82 weld filler material but does not include the use of alloy 52 weld filler material.

*The proposed repair utilizes alloy 52 filler material, which was introduced and classified in Code Case 2142-1. This code case has not been incorporated by reference into the regulations; therefore, its use requires NRC approval.*

NB-4331 establishes the requirement that all welding procedure qualification tests be in accordance with the requirements of 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 Enclosure 1 with the exception that only P-3 material and F-43 material were*

*contained in the welding procedure qualification test. The results and justification for this testing are summarized below. In addition, a mockup containing P-3, P-43 and F-43 materials equivalent to the materials combined in the head, penetration and repair weld will be tested. The test results from this assembly will be provided to the NRC by March 21, 2002.*

NB-4622.1 establishes the requirement for postweld heat treatment (PWHT) of welds including repair welds. In lieu of the requirements of this subparagraph, Duke proposes to utilize a temper bead weld procedure obviating the need for postweld stress relief.

NB-4622.2 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.

NB-4622.3 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 nonpressure 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. Sub-subparagraphs 4622.7(a) through 4622.7(f) are not applicable in this case because they pertain to conditions that do not exist for the proposed repairs. Sub-subparagraph 4622.7(g) discusses exemptions to weld repairs to dissimilar metal welds if the requirements of subparagraph NB-4622.11 are met.

*The ambient temperature temper bead repair is being proposed as an alternative to the requirements of subparagraph NB-4622.11.*

NB-4622.8 establishes exemptions from PWHT for nozzle to component welds and branch connection to run piping welds. Sub-subparagraph 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. Sub-subparagraph 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 gas tungsten arc welding (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.*

- Sub-subparagraph 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.
- Sub-subparagraph 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.
- Sub-subparagraph 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 except as noted above under paragraph NB-4331. In addition, NB-4622.11(c) requires that the Welding Procedure Specification include the following requirements:
  - NB-4622.11(c)(1) 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.
  - NB-4622.11(c)(2) requires the use of the shielded metal arc welding process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative utilizes gas tungsten arc welding with bare electrodes meeting F-No. 43 classifications.
  - NB-4622.11(c)(3) 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 bare electrodes that do not require storage in heated ovens since bare electrodes will not pick up moisture from the atmosphere.
  - NB-4622.11(c)(4) discusses requirements for storage of covered electrodes during repair welding. These requirements do not apply because the proposed alternative utilizes bare electrodes, which do not require any special storage conditions to prevent the pick up of moisture from the atmosphere.
  - NB-4622.11(c)(5) 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.*

- NB-4622.11(c)(6) 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 GTAW alternative uses bare weld filler metal much smaller than the 3/32, 1/8, and 5/32 inch electrodes required by NB-4622.11(c)(6), the requirement to remove the weld crown of the first layer is unnecessary and the proposed alternative does not include the requirement.
- NB-4622.11(c)(7) requires the preheated area to be heated to 450°F to 660°F for 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.
- NB-4622.11(c)(8) 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.
- NB-4622.11(d)(1) 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 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 complies with those requirements, except that the root width and included angle of the cavity are stipulated to be no greater than the minimum specified for the repair and that both P-No. materials were not qualified in the same PQR. 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).
- 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.

Subparagraph 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 (PT or MT) at the lesser of 1/2 the maximum weld thickness or 1/2-inch as well a surface examination as 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 Relief**

During a refueling outage starting November 10, 2001, visual inspection of the reactor vessel head penetrations revealed small amounts of boron at locations that suggested a degradation of the pressure boundary as described above. This pressure boundary degradation was reported to the NRC in accordance with 10CFR50.72(b)(3)(ii).

Experience gained from previous repairs to this unit and from similar repairs to the Unit 1 and Unit 2 CRDM nozzles 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. So for the current Unit 3 repairs, a remote semi-automated repair method utilizing a qualified ambient temperature temper bead process is planned for each nozzle that requires repairs. Using a remote tool from above the RV head, each of the subject nozzles will first receive a roll expansion into the RV head base material equal to an approximate 1-3% nozzle wall thickness reduction. The roll expansion will insure that the nozzle will not move during the repair operations. Second, an automated machining tool from underneath the RV 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 CRDM

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 Machine Gas Tungsten-Arc Welding (GTAW) process, will be used to install a new pressure boundary weld between the shortened nozzle and the inside bore of the RV head base material (see Figure 2).

This approach for repair of leaking CRDM nozzles will significantly reduce radiation dose to repair personnel while still maintaining acceptable levels of quality and safety. The total radiation dose (assuming four nozzles for estimation purposes) for the proposed remote repair method is projected to be about 25 to 30 REM. Duke 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 11 to 12 REM. In contrast, using manual repair methods previously used for ONS-3 would result in a total radiation dose of approximately 128 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, both reduction in RV head thickness and primary coolant Ferric (Fe) release rates, has been evaluated by Framatome-ANP. This calculation concludes that the general corrosion of the low alloy steel base material is conservatively estimated to be 0.0032 inch/year. This estimate is based on extensive industry data and Framatome ANP experience. This is insignificant compared to the thickness of the RV closure head. It is estimated that the Fe release from a total of 69 repaired CRDM nozzles would equal 1017 gram/year, which is less than 15% of the total Fe release from all other sources. Duke has determined that this extremely low rate of material loss and Fe release rates provide an acceptable level of safety. In addition, the head on this unit will be replaced at the end of the next refueling cycle.

An analysis of the new pressure boundary welds, using a 3-dimensional model of a CRDM 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 includes the RV Head, CRDM nozzle, repair weld and remnant portions of the original Alloy 600 welds. The model is analyzed for thermal transient conditions as contained in the Reactor Coolant Functional Specifications. The resulting maximum thermal gradients are applied to the model along with the coincident internal pressure values. The ANSYS program then calculates the stresses throughout the model (including the repair welds). The stresses are post-processed by ANSYS routines to categorize stresses into categories that are consistent with the criteria of the ASME Code.

The calculated stress values are 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.

The Primary Stress analysis for Design Conditions yields a maximum Primary General Membrane Stress Intensity ( $P_m$ ) = 16.9 ksi as compared to the maximum allowed by the ASME Code = 27.0 ksi. This value is actually for the RV Head but has the minimum margin for Primary Stress criteria of any portion of the model (including repair weld, CRDM nozzle or original welds). The criteria for the Primary Stresses resulting from the remaining service conditions have greater margin than that shown above.

The maximum cumulative fatigue usage factor is calculated as 1.0 for 25 years of future plant operation compared to the maximum allowed ASME Code criterion of 1.0. This value is for the point at the intersection of the bottom of the repair weld and the penetration bore. At the bottom of the crevice between the CRDM nozzle outside surface and the RV closure head bore, the calculated fatigue usage factor for 40 years of future operation = 0.4 (compared to the maximum allowed ASME Code criterion of 1.0).

#### Justification for Using the Proposed Alternatives

##### NB-2410

Industry studies have demonstrated that Alloy 690 weld materials possess a high resistance to primary water corrosion. The use of Alloy 690 has been previously approved for specific applications at Oconee in NRC Safety Evaluation dated September 10, 1999.

The material properties of the existing Alloy 600 (182 weld material) material were compared to the new proposed Alloy 690 (52 weld material). The thermal expansion coefficient of 52 weld material is somewhat higher than the coefficient for 182 weld material (at 600F, the difference is about 4%), however the modulus of elasticity is lower for the 52 weld material than the 182 weld material. Since the thermal stress is a function of the product of modulus of elasticity and thermal expansion coefficient ( $\sigma = E\alpha\Delta T$ ), the effects tend to cancel each other; at 600F for example, the difference in the products is only 2%. Thus, the presence of the two weld materials will have an insignificant effect on the thermal stresses in the total weld.

An evaluation of the weld dilution concluded that the percentage of chromium in the deposited welds, in all cases given above, exceeded 22%. Materials with chromium concentrations above 22% have demonstrated resistance to Primary Water Stress Corrosion Cracking (PWSCC). In summary, the chromium content of all repaired surfaces containing the proposed Alloy 690 material, considering chromium dilution, will exceed that of the original Alloy 600 material, and thus afford superior corrosion resistance.

ASME Code Case 2142-1 establishes the uniform chemical and material properties and the classification of the weld material with respect to its welding characteristics. Code Case 2142-1 establishes the F-No. for the American Welding Society (AWS) specification AWS A5.14 and Unified Numbering System (UNS) designation UNSN06052 conforming to Inconel 52 as F-No. 43 for both procedure and performance qualification purposes. These specifications and F-No. assignments completely describe this material for welding purposes as similar in their welding characteristics to other Code approved nickel based weld metals.

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 similar applications. However, though the intent of paragraph NB-4331 is met by this testing, the qualifications cited do not meet the requirements of paragraph QW-424 of Section IX of the ASME Code. For this reason, in addition to the qualification already performed, Duke proposes to fabricate, a mockup that contains the P-43 material, P-3 material and F-43 weld material. This mockup will be welded and tested in accordance with the ASME Section IX rules for procedure qualification. Testing will produce data similar to that shown below for PQR no. 7164. This data will be submitted to the NRC no later than March 21, 2002.

NB-4622

The proposed alternative will require the use of an automatic or machine gas tungsten arc welding (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 Enclosure 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." The alternative will be used to make welds of P-No. 3, RVH material to P-No. 43 head penetration 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.

**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. It is clear from these results that the GTAW temper bead process has the capability of producing acceptable repair welds.

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 CRDM 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 Welding Procedure Specifications (WPSs) 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. 43 to P-No. 43 base material welded with F-No. 43 filler metal. The use of these WPSs, 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 Welding Procedure Qualification Records (PQRs) for supporting the WPS for welding P-No. 43 to P-No. 43 were groove welds performed using F-No. 43 filler wire on P-No. 43 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 and full thickness transverse side bends.

One of the PQRs for welding the P-No. 43 base material with F-No. 43 filler metal is a full penetration groove weld between two (2) P-No. 43 pipes having outside diameters of 4.45 inches and wall thicknesses of 0.307 inches. All the effects of welding to the P-No. 43 base material with F-No. 43 filler metal have been verified by full thickness transverse tensile tests and full width face and root bends in accordance with ASME IX.

The other PQR for welding the P-No. 43 base material with F-No. 43 filler metal is a full penetration groove weld between two (2) P-No. 43 pipes having 20½ inches outside diameter and wall thicknesses of 2.35 inches. All the effects of welding to the P-No.43 base material with F-No. 43 filler metal have been verified by full thickness transverse tensile tests and full thickness transverse side bends in accordance with ASME IX.

Furthermore, from a practical perspective, due to the size of the groove (cavity) used in PQR 55-PQ7164, and the weld deposition sequencing used, the effects of welding of P-No. 43 to P-No. 43 with F-No.43 filler metal can be considered to have been evaluated (F-No. 43 to F-No. 43) by this PQR and the effects of welding P-No. 43 to P-No. 3 Group No. 3 base material can be considered to have been evaluated by this PQR.

The NB-4622 temper bead procedure requires a 350°F preheat and a postweld soak at 450°-550°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 reactor vessel 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 electrodes 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 (99.9996% pure) which typically produces porosity free welds. The gas would have no more than 1 PPM of hydrogen (H<sub>2</sub>) and no more than 0.5 PPM of water vapor (H<sub>2</sub>O). 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.

Duke 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 ambient temperature temper bead weld technique (Enclosure 1) provides a technique for repairing flaws in the CRDM penetration to vessel head J-groove welds within 1/8-inch of the ferritic base metal that will produce sound and permanent repairs and that the procedure is an alternative to Code requirements that will provide an acceptable level of quality and safety.

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 and using thermocouples is unnecessary and would result in additional personnel dose associated with thermocouple placement and removal. Consequently, preheat temperature verification by use of contact pyrometer on accessible areas of the closure head is sufficient.

In lieu of using thermocouples for interpass temperature measurements, calculations 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 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. The five minute inter-bead interval is based on: 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 RVCH, which is similar to the Oconee Unit 3 RVCH, 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 CRDM nozzle. Three other thermocouples were placed on the closure head inside surface. One of the three thermocouples was placed 1-1/2 inches from the CRDM nozzle penetration, on the lower hillside. The other inside surface thermocouples were placed at the

edge of the 5-inch band surrounding the CRDM 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 RVCH 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 certainly not be a concern.

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

UT will be performed in lieu of RT due to the repair weld configuration. Meaningful RT cannot be performed as can be seen in the applicable figures, attached. 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 of 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", 0.15", and 0.25" in order to quantify the ability to characterize the depth of penetration into the nozzle. The depth characterization is done 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 RVCH 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 CRDM 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. The final modification configuration and surrounding ferritic steel area affected by the welding is either inaccessible or extremely difficult to access.

Liquid penetrant examination of the entire ferritic steel bore will be performed after removal by boring of the lower end of the existing CRDM nozzle prior to welding.

As can be observed from Figures 2, 3 and 4 the configuration of the new CRDM 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 CRDM nozzle. The ferritic steel closure head base material, below the new weld and within ½ inch of the bottom weld toe, will be liquid penetrant 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 (Enclosure 1) is an acceptable alternative to Code requirements and will produce sound, permanent repair welds and an acceptable level of quality and safety, as required by 10 CFR 50.55a(a)(3)(i).

## **V Duration of the Proposed Alternative**

Due to the previous repairs to the Oconee Unit 1 thermocouple nozzles and CRDM nozzle 21, the Unit 2 CRDM nozzles, the Unit 3 CRDM repairs described herein, and Primary Water Stress Corrosion Cracking concerns throughout the nuclear industry, Duke is planning to replace the Oconee Units 1, 2 and 3 RV heads. Orders for the new RV heads have been placed. The RV head for Unit 3 will be replaced at the end-of-cycle 20 refueling outage scheduled to begin in the Spring of 2003.

In the interim, visual inspections of the RV closure head will continue during every planned and forced outage. The inspection schedule is based on the service life of the repairs described herein. A Framatome ANP evaluation has determined the time for a crack to grow 75% through-wall in the Alloy 600 nozzle material above the repair weld. The evaluation considered CRDM nozzles both in the as-repaired condition and following abrasive water jet (AWJ) remediation. The evaluation is for initiation and crack growth due to primary water stress

corrosion cracking (PWSCC). If AWJ mitigation is used, the estimated corrosion time to breach the AWJ compressive residual stress layer and the estimated crack growth time to 75% through-wall would yield 14.6 EFPY estimated service life. The current schedule includes AWJ for the Oconee Unit 3 CRDM repairs.

Flaw growth rates for evaluation were assumed to follow a 4 mm/year rate, which bounds any variation in flaw growth through the Alloy 600 material as a result of the weld repair.

Given these results, the proposed inspection schedules given above and the planned replacement dates for the Oconee Unit 3 RV closure heads, the proposed alternatives to the ASME code requirements are justified.

The proposed alternatives are applicable to the repairs and examinations after repair to any Oconee Unit 3 RV head CRDM nozzles.

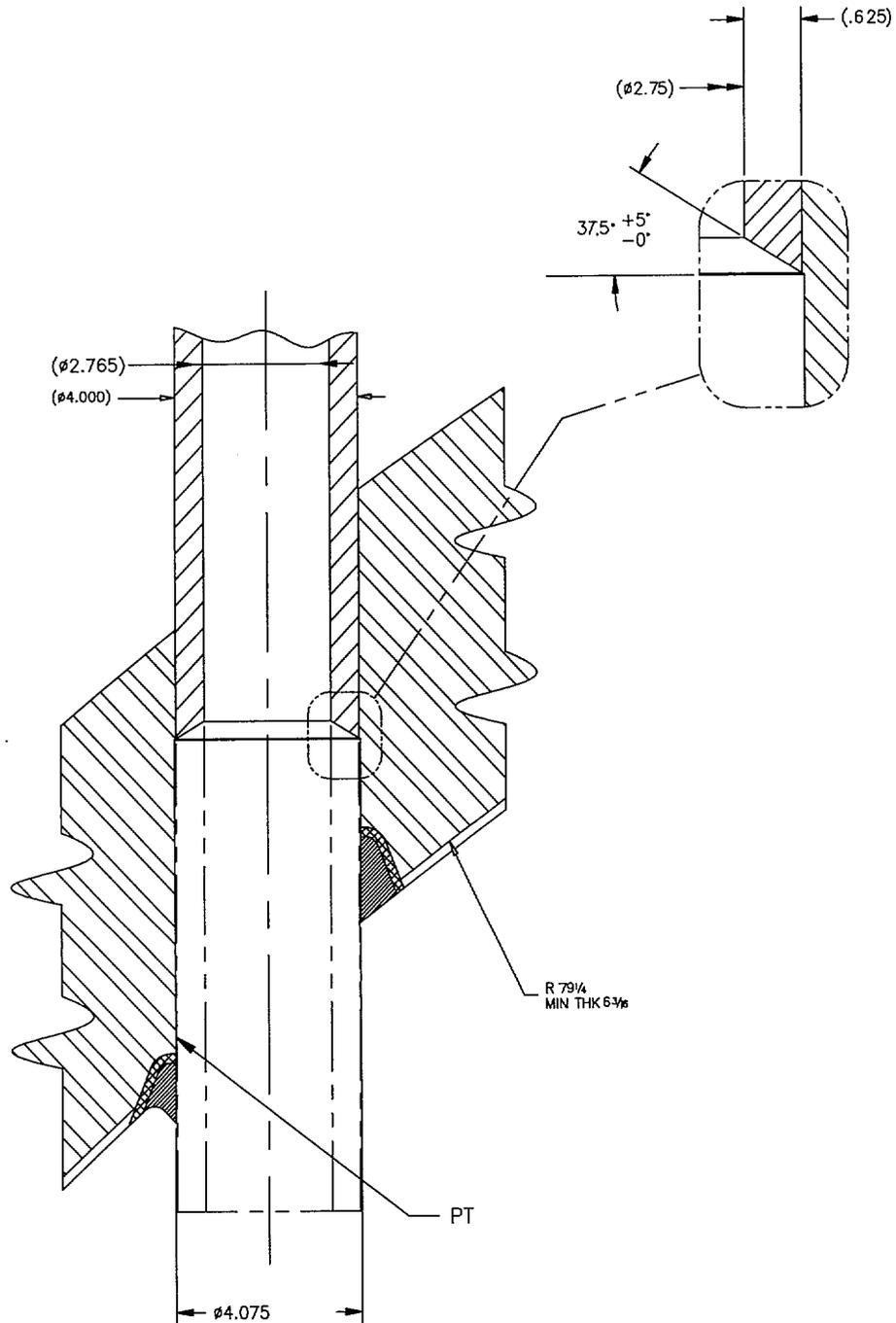
## VI Implementation Schedule

This Request for Alternate is associated with the repair that may be required if leaks or other unacceptable conditions are confirmed in the Unit 3 RV head CRDM nozzles. The inspections and any required repairs will be performed during the refueling outage that began November 10, 2001.

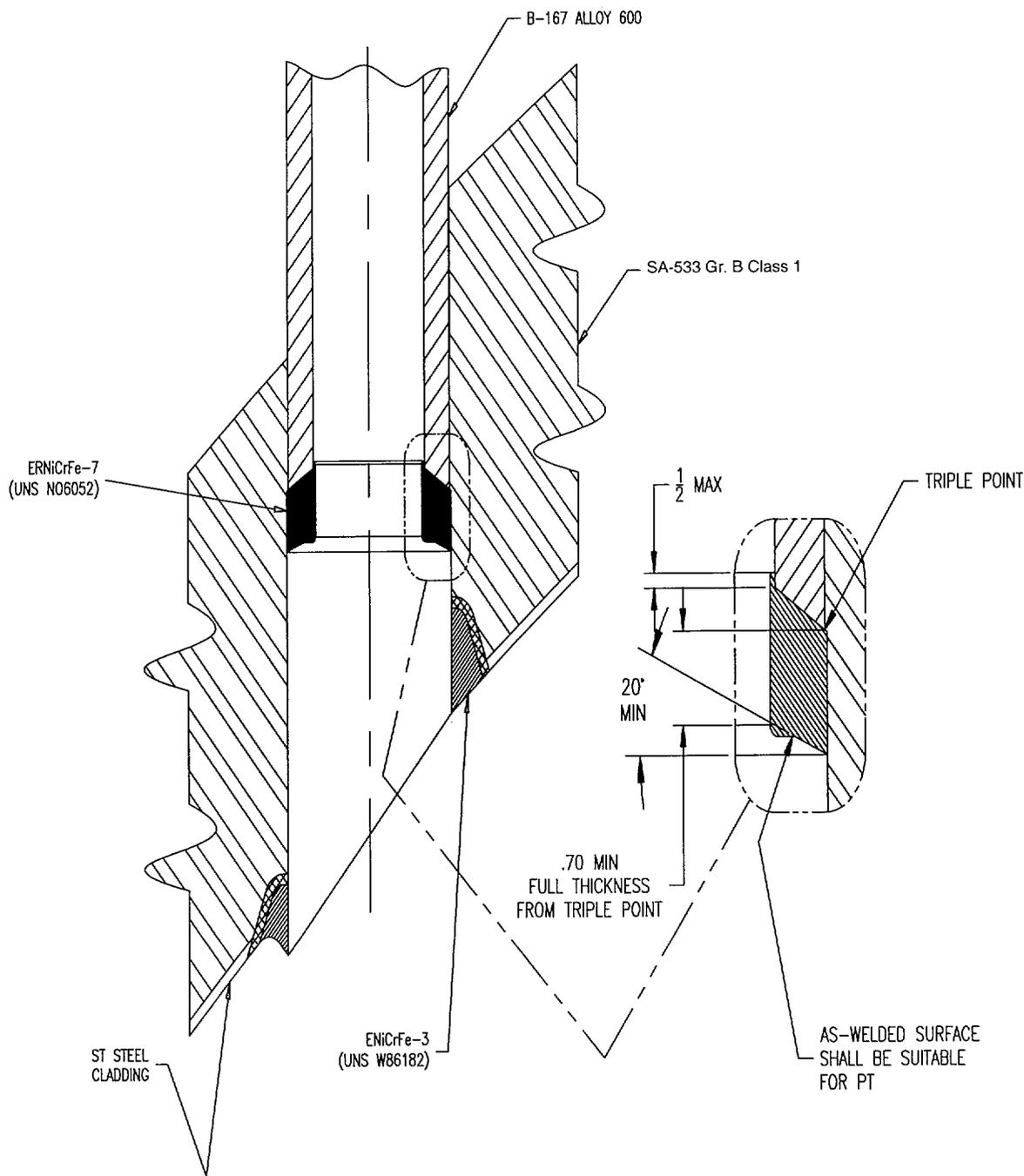
Originated By: C. R. Frye 11/16/01  
Charles R. Frye Date

Reviewed By: Melvin L. Arey Jr. 11/16/01  
Melvin L. Arey Jr. Date

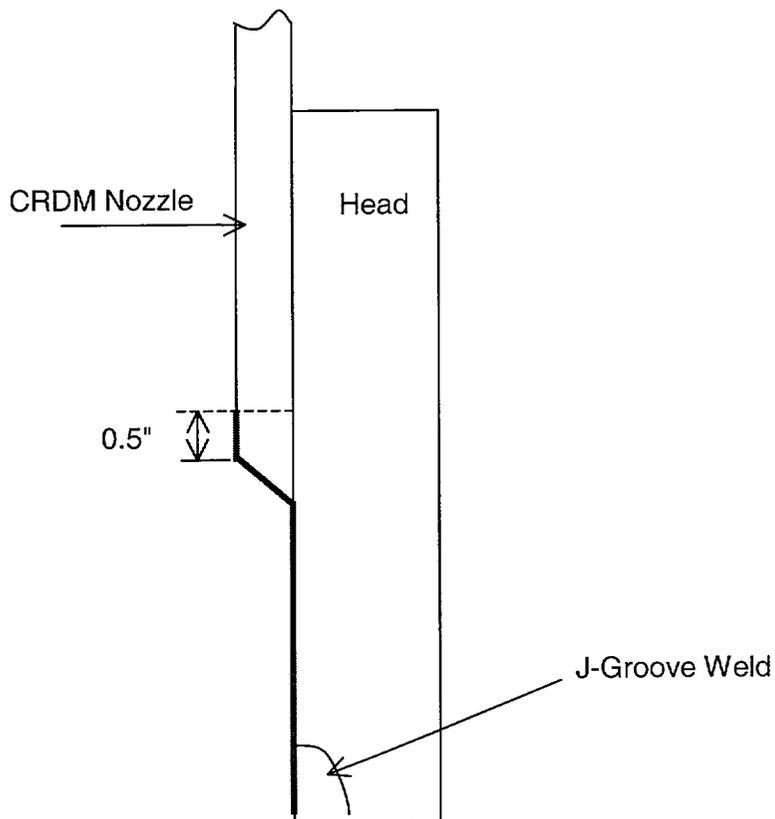
<b>Angle/Mode</b>	<b>Freq.</b>	<b>Size</b>	<b>Focal Depth</b>	<b>Beam Direction</b>
0° L-wave	2.25 MHz	.15" x .30"	0.45"	N/A
45° L-wave	2.25 MHz	.30" x .20"	0.45"	Axial
70° L-wave	2.25 MHz	.72" x .21"	0.69"	Axial
45° L-wave (effective)	2.25 MHz	.30" x .20"	0.45"	Circ.



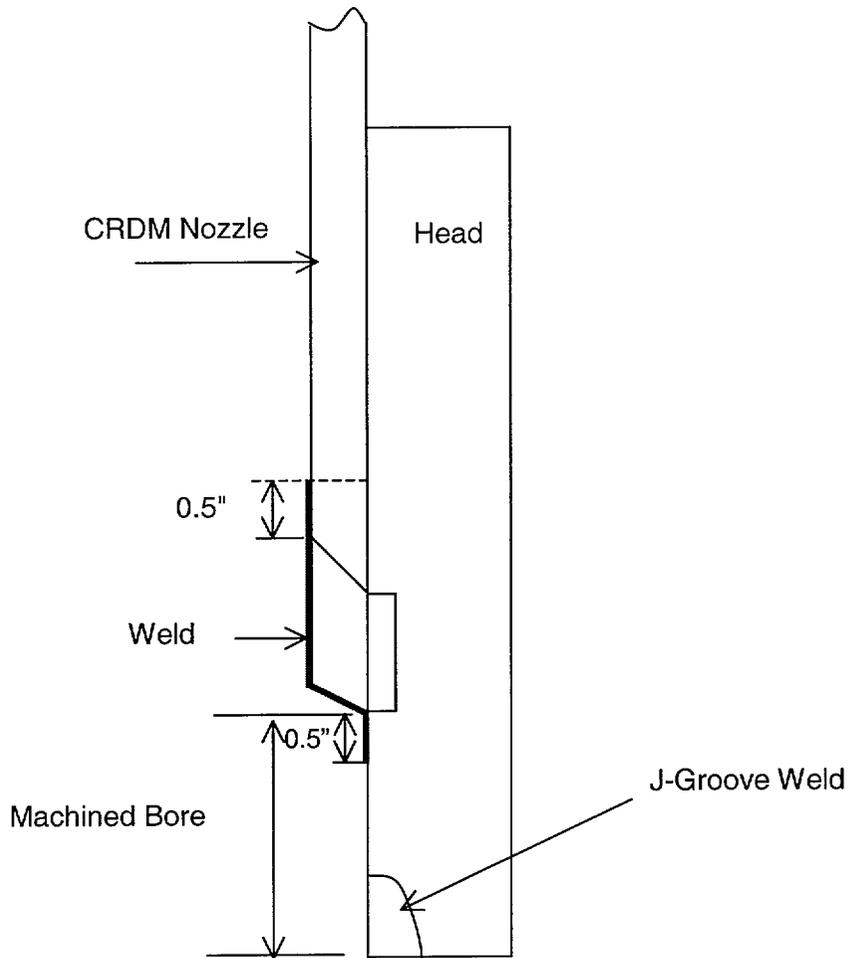
**Figure 1:**  
**New Ocone 3 CRDM**



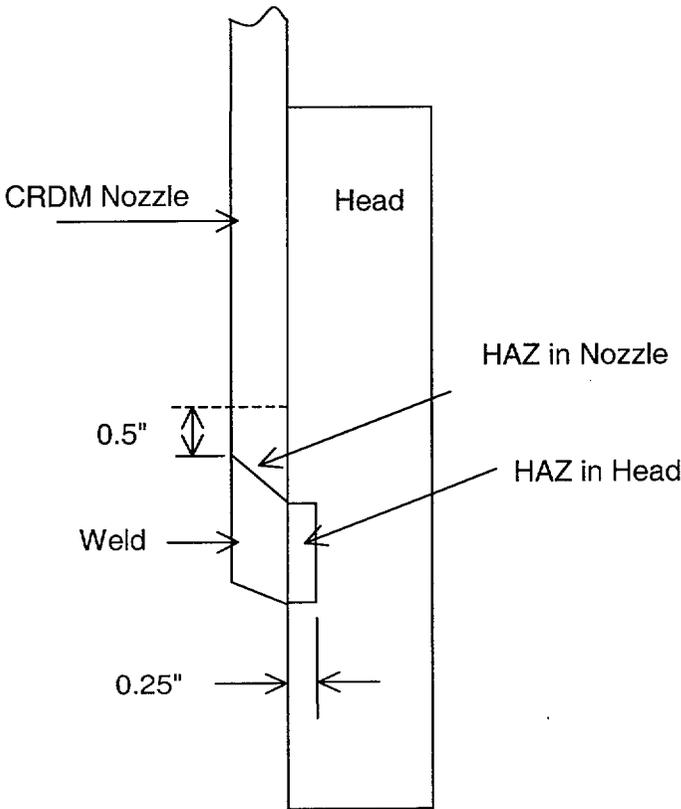
**Figure 2:**  
**New Oconee 3 CRDM Pressure Boundary Weld**



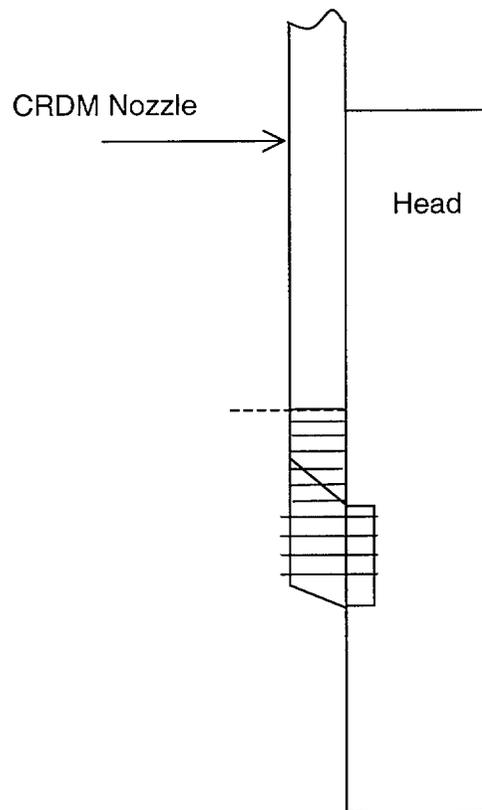
**Figure 3:  
Oconee 3 CRDM Temper Bead Weld Repair,  
PT Coverage Prior to Welding**



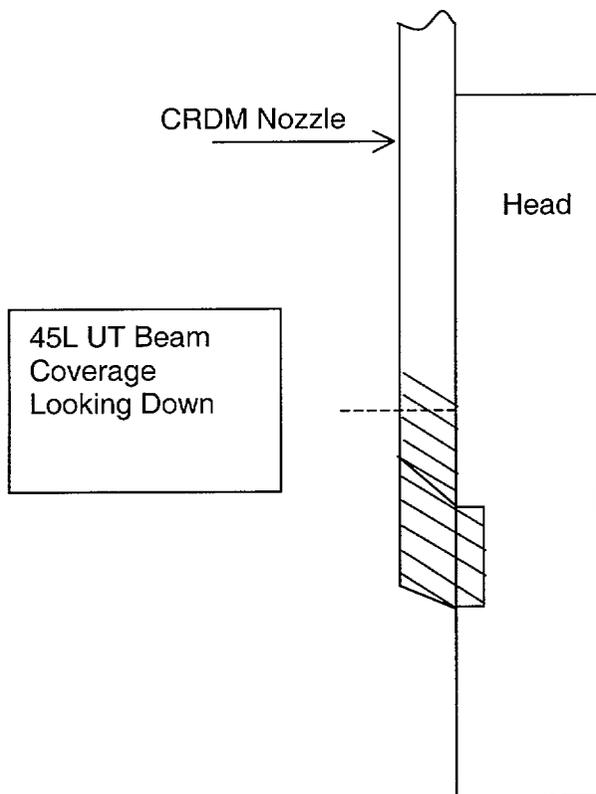
**Figure 4:  
Oconee 3 CRDM Temper Bead Weld Repair,  
PT Coverage after Welding**



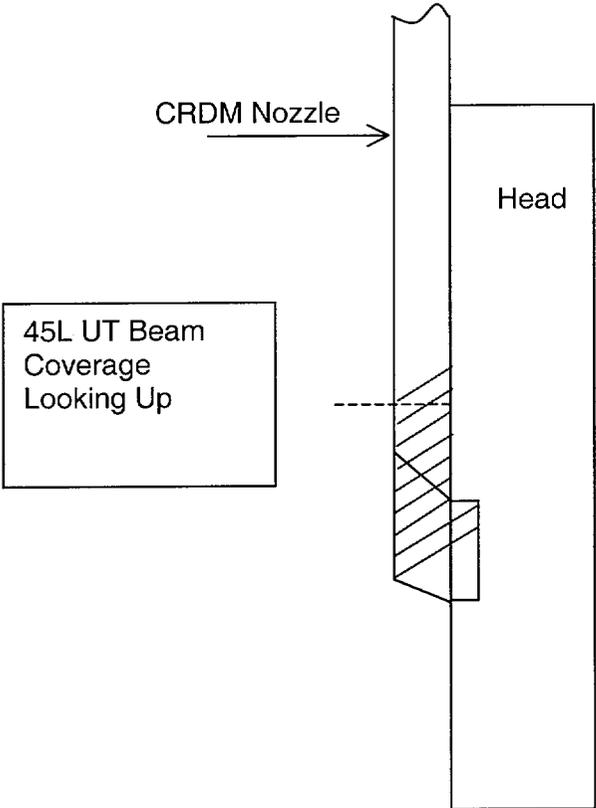
**Figure 5:  
Oconee 3 CRDM Temper Bead Weld Repair  
Areas to be Examined**



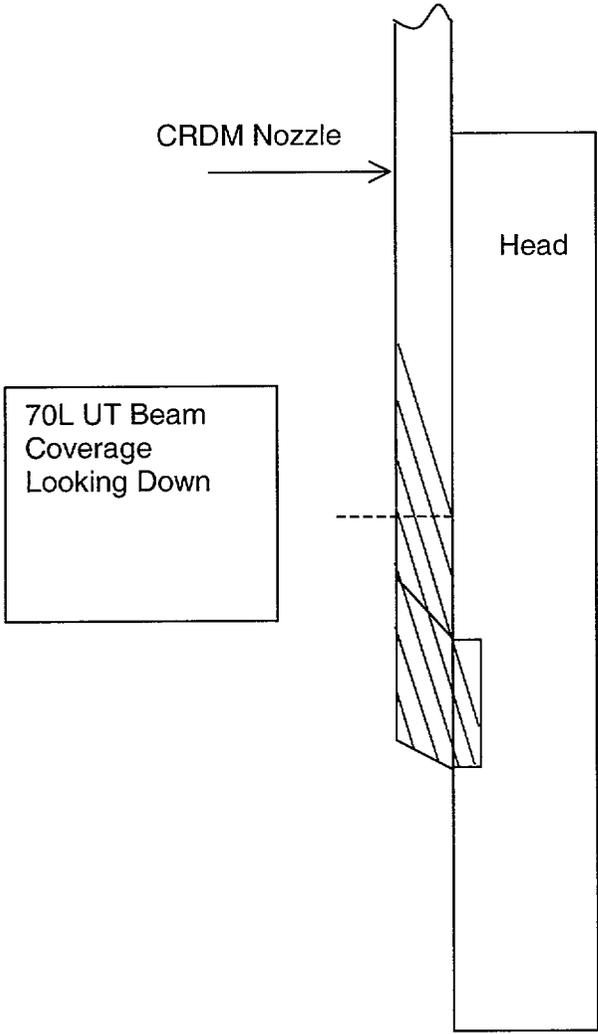
**Figure 6:  
Oconee 3 CRDM Temper Bead Weld Repair,  
UT 0 degree and 45L Beam Coverage  
Looking Clockwise and Counter-Clockwise**



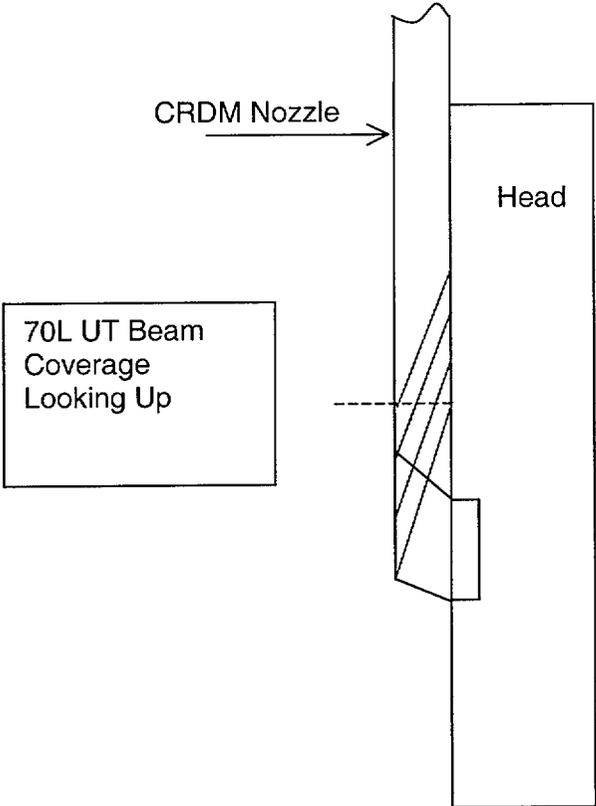
**Figure 7:  
Oconee 3 CRDM Temper Bead Weld Repair,  
45L UT Beam Coverage Looking Down**



**Figure 8:  
Oconee 3 CRDM Temper Bead Weld Repair,  
45L UT Beam Coverage Looking Up**



**Figure 9:  
Oconee 3 CRDM Temper Bead Weld Repair,  
70L UT Beam Coverage Looking Down**



**Figure 10:  
Oconee 3 CRDM Temper Bead Weld Repair, 70L  
UT Beam Coverage Looking Up**

**ENCLOSURE 1**

**INSERVICE INSPECTION  
OCONEE UNIT 3  
RELIEF REQUEST 01-14, REVISION 1  
THIRD TEN-YEAR INTERVAL**

## Enclosure 1

### Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique

Duke plans to perform CRDM nozzle penetration repairs by welding the RPV head (P-No. 3 base material) and CRDM 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. An additional welding procedure qualification for welding P-No. 43 base material with F-No. 43 filler will also be used for welding to the lower end of the CRDM nozzle.

- (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 E1.
- (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.

## 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 E2, steps 1 through 3, with the heat input for each layer controlled to within  $\pm 10\%$  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 HAZ and ferritic weld metal are 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).

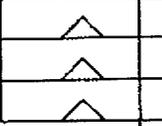
## 4.0 Examination

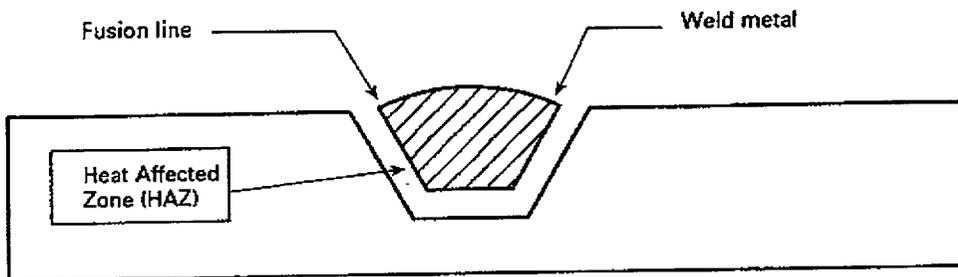
- (a) Prior to welding, a surface examination will be performed on the area to be welded.
- (b) The final weld surface and adjacent HAZ shall be examined using surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours.
- (c) The purpose for the examination 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 reactor vessel head material due to the welding process. Liquid penetrant (PT) coverage is shown in Figures 3 and 4. 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 CRDM 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.

- (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

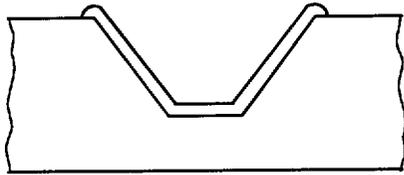
Repairs will be documented on Form NIS-2.

Discard		
Transverse Side Bend		
Reduced Section Tensile		
Transverse Side Bend		
		HAZ Charpy V-Notch
Transverse Side Bend		
Reduced Section Tensile		
Transverse Side Bend		
Discard		

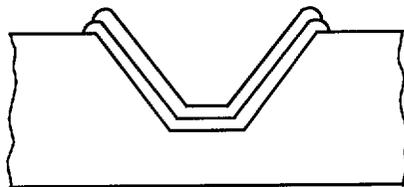


GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

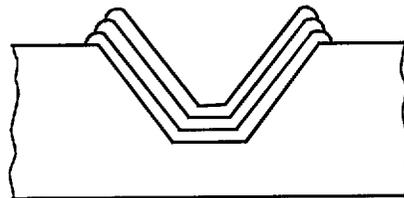
**Figure E1 Qualification Test Plate**



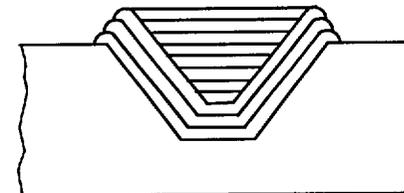
Step 1: Deposit layer one with first layer weld parameters used in qualification.



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: The illustration above is for similar-metal welding using a ferritic filler material. For dissimilar-metal welding, only the ferritic base metal is required to be welded using steps 1 through 3 of the temperbead welding technique.

**Figure E2** AUTOMATIC OR MACHINE (GTAW) TEMPERBEAD WELDING

**ATTACHMENT B**

**INSERVICE INSPECTION  
OCONEE UNIT 3  
RELIEF REQUEST 01-15, REVISION 1  
THIRD TEN-YEAR INTERVAL**

**OCONEE UNIT 3  
INSERVICE INSPECTION  
RELIEF REQUEST 01-15, REVISION 1  
THIRD TEN-YEAR INTERVAL**

**REFERENCE CODE:**

The original code of construction for Oconee Unit 3 is ASME Section III, 1965 Edition with Addenda through Summer, 1967. The ISI Code of record for Oconee Nuclear Station, Unit 3, third 10-year interval is the 1989 Edition of the ASME Code. 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 Section III and 1992 Section XI codes.

**I System/Component(s) for Which Relief is Requested:**

- a) Name of component:  
Reactor Pressure Vessel (RPV) Closure Head Control Rod Drive Mechanism (CRDM) nozzle penetrations. There are 69 Vessel Head Penetrations (VHP) welded to the RPV Closure head (RVCH).
- b) Function:  
These welds serve as the pressure boundary weld for the CRDM nozzle and Reactor Vessel Head penetration.
- c) ASME Code Class:  
The RPV and CRDM Nozzle Penetrations are ASME Class 1.
- d) Category:  
Examination Category B-E, Pressure Retaining Partial Penetration Welds in Vessels; Item No. B4.12.

**II Current Code Requirement and Relief Request:**

In accordance with the provisions of ASME B&PV Code, Section XI, 1989 Edition, IWA-4120(c), Duke Energy Corporation (Duke) will use the 1992 Edition of ASME B&PV Code, Section XI for IWA-4310.

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.

Pursuant to 10 CFR 50.55a(g)(5)(iii), relief is requested from ASME XI IWA-3300 (b), IWB-3142.4 and IWB-3420, which require flaw characterization.

Subarticle IWA-3300 contains criteria for characterizing flaws. None of the nondestructive evaluation techniques that can be performed on the remnant of the J-groove weld that will be left on the vessel 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 based on that flaw.

Sub-subparagraph 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. 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 any event, head replacement is planned for the end of the next fuel cycle obviating the need for successive inspections.

Paragraph IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300. As previously stated, characterization in accordance with those rules is impractical. As an alternative, a conservative, worst case flaw will be assumed to exist and will be evaluated to establish the minimum remaining service life of the reactor vessel head.

Section III, subsection NB-5330(b) requires that "Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length."

Duke is requesting relief from the requirements of NB-5330(b). The new pressure boundary weld that will connect the remaining portion of the CRDM nozzles to the low alloy RV closure 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 (52/152) 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 690 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.

Duke has determined that the proposed alternative will provide an acceptable level of quality and safety, while allowing significant dose reductions.

### **III Alternate Criteria for Acceptability:**

In lieu of the requirements of IWA-3300, per 10 CFR 50.55a(a)(3)(ii) the following alternative is proposed:

The planned repair for the subject CRDM 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, Duke has used worst-case assumptions to conservatively estimate the crack extent and orientation. The postulated crack extent and orientation has been evaluated using the rules of IWB-3600.

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

#### **IV Basis for Relief:**

Inspections of the reactor vessel (RV) closure head during the current refueling outage in accordance with the ONS-3 response to NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," has discovered small amounts of boron emanating from four CRDM nozzles where they interface with the outside radius of the closure RV head. Supplemental examinations of nozzle numbers 26, 39, 49 and 51 will be performed to confirm the existence of through-wall cracks that may exist in the original J-groove partial penetration welds or in the CRDM nozzle base material at these locations. There are also three nozzles (2, 10 and 46) that do not have the characteristic boron emanations but for which further inspection is warranted based on the presence of boron that may be leakage either at that nozzle or from a nearby nozzle. 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.

Experience gained from the earlier repairs to the Oconee Unit 1 and Unit 3 CRDM nozzles indicated that removal and repair of the defective portions of the original J-groove partial penetration welds were time consuming and radiation dose intensive. The previous repairs indicated that more remote automated repair methods were needed to reduce radiation dose to repair personnel. For the Oconee Unit 3 (ONS-3) repairs, a remote semi-automated repair method will be used for each of the subject nozzles. Using a remote tool from above the RV head, each of the nozzles requiring repair will first receive a roll expansion into the RV head base material to insure that the nozzle will not move during subsequent repair operations. Second, a semi-automated machining tool from underneath the RV 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 CRDM nozzles. Third, a semi-automated weld tool, utilizing the machine Gas Tungsten-Arc Welding (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 RV 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 CRDM nozzle to closure 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. In addition, this chamfer meets the intent of ASME Section III

paragraph NB-3352.4(d)(3) that requires the corners of the end of each nozzle to be rounded to a radius.

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 were obtained using finite element analysis of the RV closure head. Since hoop stresses were calculated to be the dominant stress, 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 was assumed to begin at the intersection of the RV closure head inner diameter surface and the CRDM nozzle bore and propagate slightly into the RV closure 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 CRDM nozzle to closure 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 NiCrFe weld and the low alloy steel closure head increases the UT difficulty. Furthermore, due to limited accessibility from the closure head outer surface and the proximity of adjacent nozzle penetrations, it is impractical to scan from this surface on the closure head base material to detect flaws in the vicinity of the original weld. Duke proposes to accept these flaws by analysis of the worst case that might exist in the J-groove. Since the worst case condition has been 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 CRDM 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. 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. It was postulated that a radial crack in the Alloy 182 weld metal would propagate by Primary Stress Corrosion Cracking (PWSCC) through the weld and butter, to the interface with the low alloy steel head. It is fully expected that such a crack would then 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 head would be very deep, up to about 1-3/4 inch at the outermost row of nozzles.

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 head material are low, it was conservatively assumed that a small flaw could initiate in the low alloy steel material and grow by fatigue. It was postulated that a small flaw in the 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 head by fatigue crack growth under cyclic loading conditions associated with heatup and cooldown.

Residual stresses were not included in the flaw evaluations since it was demonstrated by analysis that these stresses are compressive 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 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. Hoop stresses were used since they are perpendicular to the plane of the crack. Fatigue crack growth, calculated for 150 heat-up/cool-down cycles was minimal (about 0.100 inch), and the final flaw size met the fracture toughness requirements of the ASME Code using an upper shelf value of 200 ksi/in for ferritic materials.

Based on the analysis performed, it is acceptable to leave the postulated cracks in the attachment weld (J-groove) and buttering. The calculations performed show the remaining flaws within the base material are acceptable for 150 heat-up/cool-down cycles which is far in excess of the single heat-up/cool-down cycle expected prior to replacement of the head at the end of the next fuel cycle. The only driving mechanism for fatigue crack growth of the base material is heat-up/cool-down cycles. The fracture mechanics evaluation assumes a radial (with respect to the penetration centerline) crack exists with a length equal to the partial penetration weld preparation depth. Based on industry experience and operating stress levels, there is no reason for service related cracks to exist in the ferritic material.

An additional evaluation was made to determine the potential for debris from a cracking J-groove partial penetration weld. 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 is considered remote. There are no forces that would drive a transverse crack. The radial cracks would relieve the potential transverse crack driving forces. Hence, it is unlikely that a series of transverse cracks could intersect a series of radial cracks resulting in any fragments becoming dislodged.

The cited evaluations provide an acceptable level of safety and quality in insuring that the RV closure head remains capable of performing its design function for 150 heat-up/cool-down cycles, with flaws existing in the original J-groove weld.

For the reasons described above, areas containing flaws accepted by analytical evaluation will not be reexamined as required by IWB-3142.4. Additionally, Duke has previously committed to replace the Oconee Units 1, 2, and 3 RVHs. The Unit 3 RVH replacement is currently scheduled for the refueling outage (end-of-cycle 20) planned for the Spring of 2003.

Welding solidification is an inherent problem when using high NiCr alloys in the presence of a notch located at the so-called triple point. IWA-4170 mandates that the repair design meets the original construction code or the adopted 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 provide justification, in accordance with Section XI of the ASME Code, for operating with the postulated weld anomaly described above. The anomaly was modeled as a 0.1 inch semi-circular "crack-like" defect, 360 degrees around the circumference at the "triple point" location. 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 that traverses the CRDM tube wall thickness from the 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 were used to ensure that another potential path through the HAZ between the new repair weld and the Alloy 600 tube material is bounded.

For completeness, two types of flaws were postulated at the outside surface of the tube. A 360 degree continuous circumferential flaw, lying in a horizontal plane, was considered to be a conservative representation of crack-like defects that may exist in the weld anomaly. This flaw was subjected to axial stresses in the tube. An axially oriented semi-circular outside surface flaw was 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 RV head. A semi-circular cylindrically oriented flaw was 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 RV head material.

The results of the analysis demonstrated that a 0.10 in. weld anomaly is acceptable for a 20 year design life of the CRDM ID temper bead weld repair. Significant fracture toughness margins were obtained for both of the flaw propagation paths considered in the analysis. The minimum calculated fracture toughness margins, 10.8 for path 1 and 25.2 for path 2, are significantly greater than the required margin of  $\sqrt{10}$  per Section XI, IWB-3612. Fatigue crack growth is minimal. The maximum final flaw size is 0.1003 in. 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 showed limit load margins of 9.83 and 6.95 for normal/upset conditions and emergency/faulted conditions, respectively. These are significantly greater than the required margins of 3.0 and 1.5 for normal/upset conditions and emergency/faulted conditions, respectively, per Section XI, IWB-3642.

This evaluation was prepared in accordance with ASME Section XI and demonstrated that for the intended service life of the repair, the fatigue crack growth was acceptable and the crack-like indications remained stable. These two findings satisfied the Section XI criteria but do not

include considerations of stress corrosion cracking such as primary water stress corrosion cracking (PWSCC) or residual stresses.

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 rates from PWSCC are not applicable regardless of residual stresses.

Residual stresses may also require consideration for ductile tearing when operating stresses are superimposed. The residual stress field by itself cannot promote ductile tearing or it would not be stable during welding. The anomalies have been shown to be stable by welding mock-ups simulating the actual geometry and materials. Even though the residual stresses for this type of weld would be very complex, it is apparent that by the size of the weld and the nature of the restraint that the residual stresses would have limited effect on driving a crack. The weld residual stresses are not like piping thermal expansion stresses where there may be considerable stored energy in long runs of pipe. The weld residual stresses are imposed by the inability of the weld bead to shrink to a nominal strain condition upon cooling. The attachment of the weld to the surrounding material generally promotes tensile stresses in the bead upon cooling. Even though the stresses are generally at the yield strength, the accompanying strains are not large due to the limited size of the beads and in this case the total size of the weld.

It is concluded that the residual stress field could produce a minimal ductile tearing driving force in the Ni-Cr-Fe materials that are extremely crack-tolerant when not in an aggressive environment. The Section XI evaluation performed is adequate, residual stresses need not be considered because PWSCC effects are not applicable, and the geometry is not conducive to sustained ductile tearing.

The twenty-year design life exceeds the time planned for replacement of the Unit 3 RV closure head (i.e. replacement planned for the Spring of 2003).

For the reasons described above, areas containing flaws accepted by analytical evaluation will not be reexamined as required by IWB-3142.4. Additionally, Duke has previously committed to replace the Oconee Units 1, 2, and 3 RVHs: The Unit 3 RVH replacement is currently scheduled for the refueling outage (end-of-cycle 20) planned for the Spring of 2003 obviating the need for additional inspections.

### **Justification for Granting Relief**

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 RV head impedes crack growth by PWSCC. Duke believes the alternative described 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, it has been determined that the assumed worst-case crack size would not grow to an unacceptable depth into the RV head low alloy steel. Thus, the RV 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 closure head CRDM 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 NiCrFe 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 Oconee Unit 3. The only qualified method currently available would involve extensive manual welding that would result in radiation doses estimated to be on the order of 30 REM per nozzle as compared to the 5 to 7 REM estimated for each nozzle repaired by the proposed process.

## **V Duration of the Proposed Alternative**

Due to the previous repairs to the Oconee Unit 1 thermocouple nozzles and CRDM nozzle 21, the Unit 2 CRDM nozzles, the Unit 3 CRDM repairs described herein, and Primary Water Stress Corrosion Cracking concerns throughout the nuclear industry, Duke is planning to replace the Oconee Units 1, 2 and 3 RV heads. Orders for the new RV heads have been placed. The RV head for Unit 3 will be replaced at the end-of-cycle 20 refueling outage in the Spring of 2003.

In the interim, visual inspections of the RV closure head will continue during any planned outage. The inspection schedule is based on the service life of the repairs described herein. A Framatome ANP evaluation has determined the time for a crack to grow 75% through-wall in the Alloy 600 nozzle material above the repair weld. The evaluation considered CRDM nozzles both in the as-repaired condition and following abrasive water jet (AWJ) remediation. The evaluation is for initiation and crack growth due to primary water stress corrosion cracking (PWSCC). If AWJ mitigation is used, the estimated corrosion time to breach the AWJ compressive residual stress layer and the estimated crack growth time to 75% through-wall would yield 14.6 EFPY estimated service life. The current schedule includes AWJ for the Oconee Unit 3 CRDM repairs.

Flaw growth rates for evaluation were assumed to follow the 4 mm/year rate described in Reference 4, which bounds any variation in flaw growth through the Alloy 600 material as a result of the weld repair.

Given these results, the proposed inspection schedules given above and the planned replacement dates for the Oconee Unit 3 RV closure heads, the proposed alternatives to the ASME code requirements are justified.

The proposed alternatives are applicable to the repairs and examinations after repair to any Oconee Unit 3 RV head CRDM nozzles.

## VI Implementation Schedule

This Request for Alternate is associated with the repair that may be required if leaks or other unacceptable conditions are confirmed in the Unit 3 RV head CRDM nozzles. The inspections and any required repairs will be performed during the refueling outage that began November 10, 2001.

Originated By: C.R. Frye      11/16/01  
Charles R. Frye      Date

Reviewed By: Melvin L. Arey Jr.      11/16/01  
Melvin L. Arey Jr.      Date

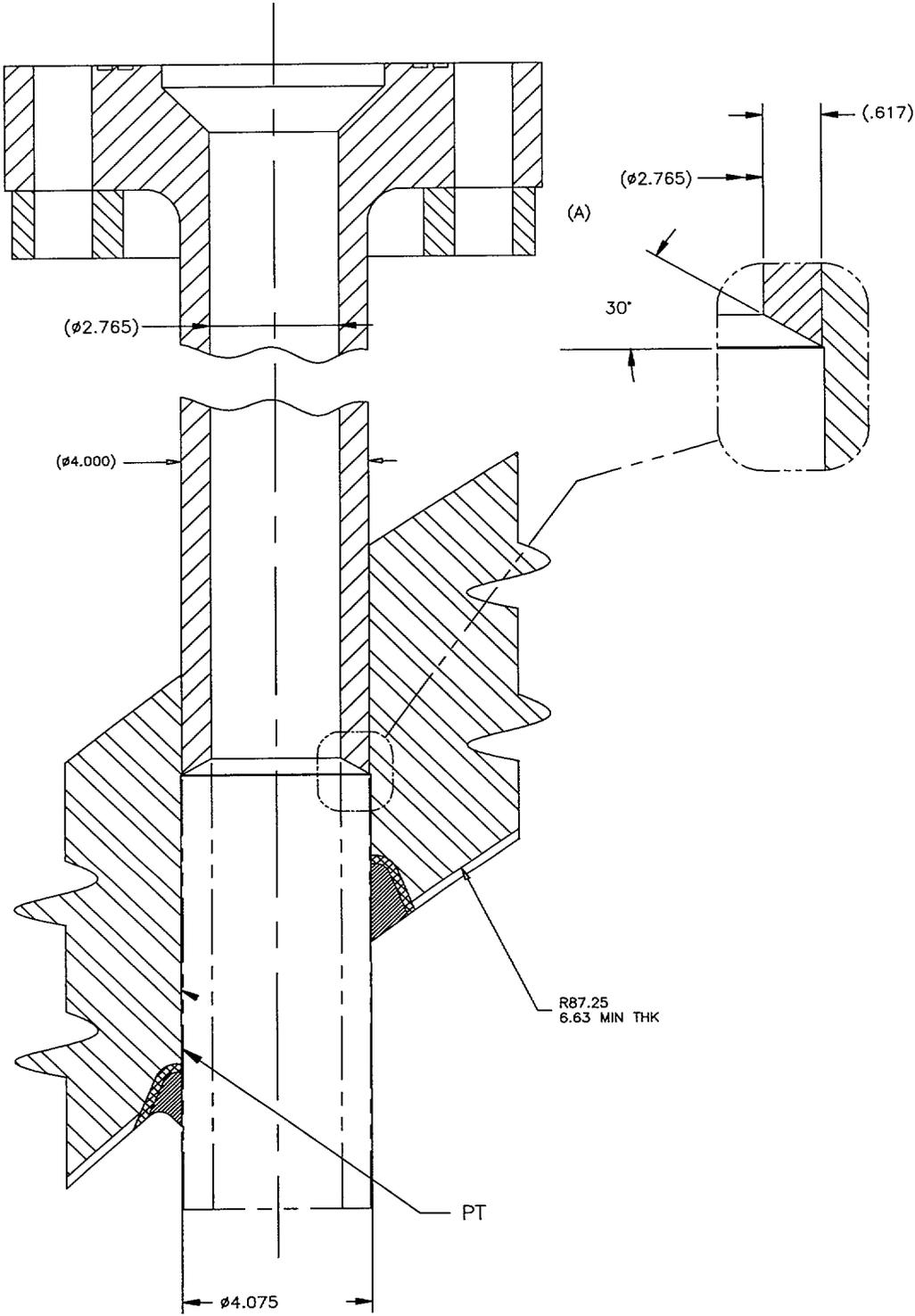


Figure 1:  
Oconee Unit 3 CRDM Machining

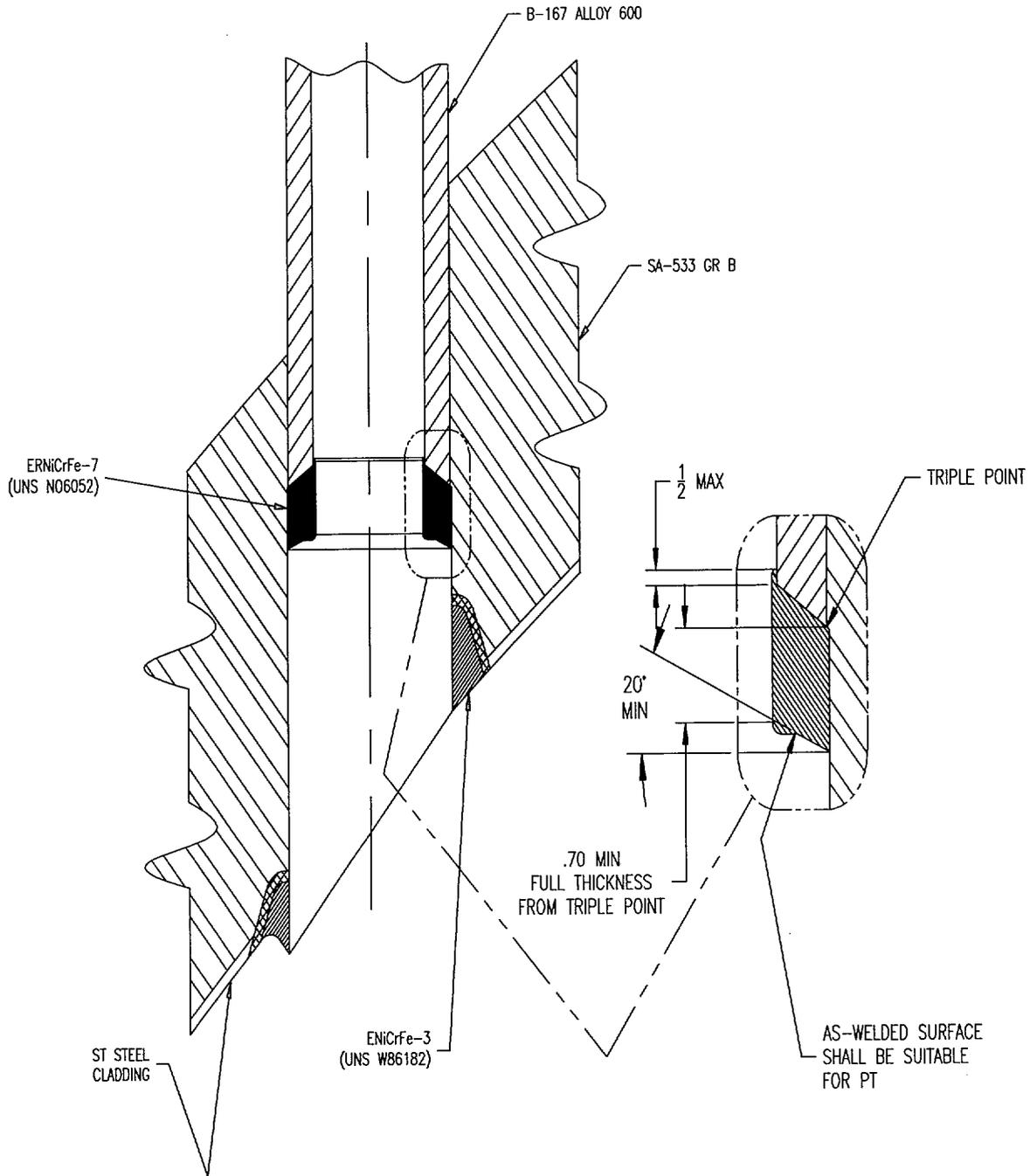


Figure 2:  
Oconee Unit 3 New CRDM Pressure Boundary Welds