Duke Energy

W. R. McCollum, Jr.
Vice President

Duke Energy
Oconee Nuclear Station
7800 Rochester Highway
Seneca, SC 29672
(864) 885-3107 OFFICE
(864) 885-3564 FAX

November 20, 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 Request 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. In response to an NRC request, on November 16, 2001 Duke submitted Revision 1 of RR 01-14 and RR 01-15 as Attachments A and B respectively. These revisions replaced prior submittals in their entirety.

Enclosed is RR 01-15, revision 2 to replace Attachment B of Duke's November 16, 2001 submittal in its entirety. RR 01-15, revision 2 provides additional detail concerning implementation of ASME, Section III, paragraph NB-3352.4(d)(3) at the request of an insurance inspector. The change to the request is indicated by a bar in the left margin of pages 3 and 4.

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

Enclosure

A047.

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 B

INSERVICE INSPECTION
OCONEE UNIT 3
RELIEF REQUEST 01-15, REVISION 2
THIRD TEN-YEAR INTERVAL

OCONEE UNIT 3
INSERVICE INSPECTION
RELIEF REQUEST 01-15, REVISION 2
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 warrented 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. 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 1/2 t_n. or 3/4" which ever is smaller. The functionally equivalent 1/8" minimum chamfer discussed above will be used in lieu of the 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$\sqrt{}$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: David E. Whitaker for 11/19/01
Charles R. Frye Date

Reviewed By: Melvin L. Arey Jr. 11/19/01
Melvin L. Arey Jr. Date

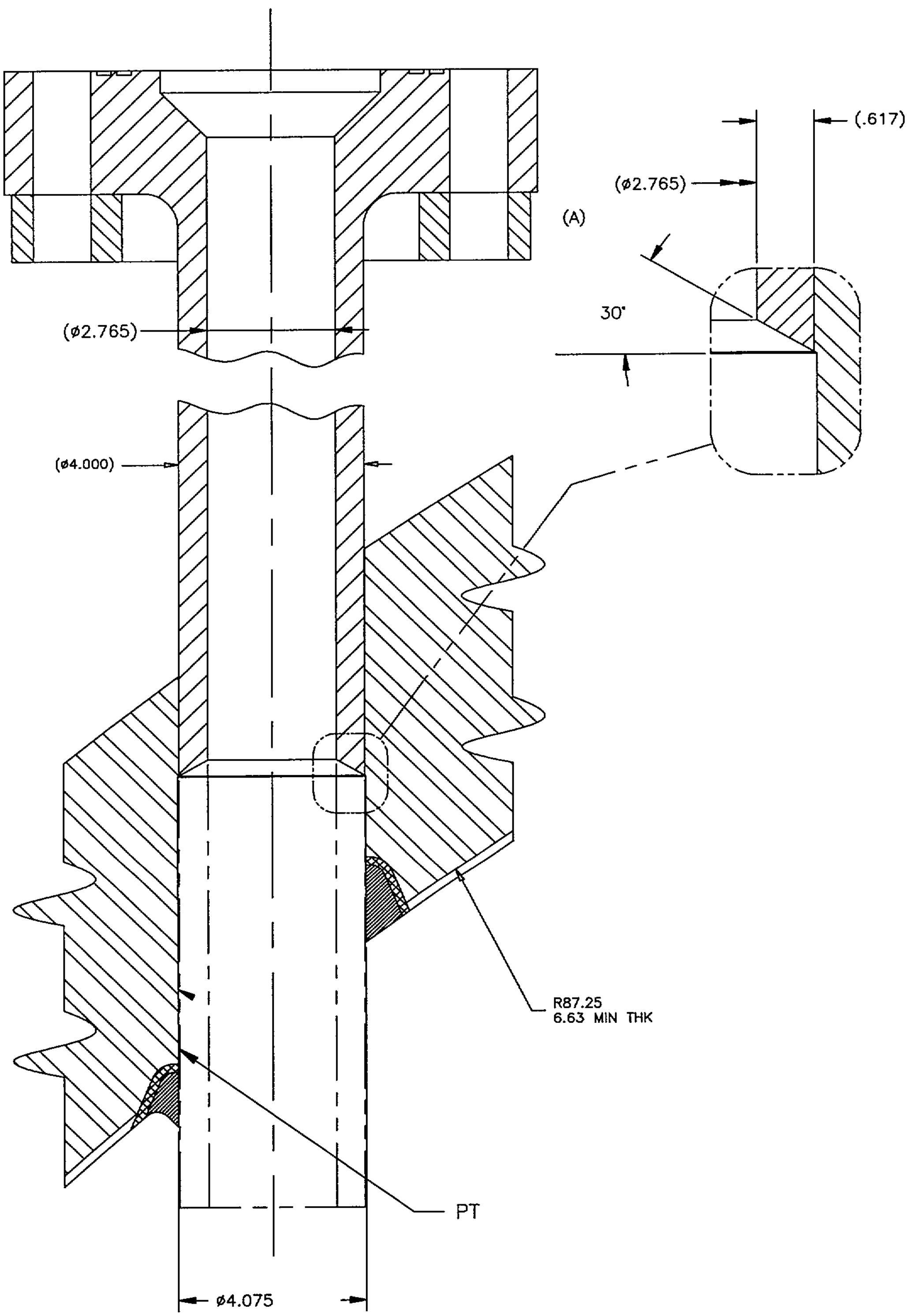

Figure 1:
Oconee Unit 3 CRDM Machining

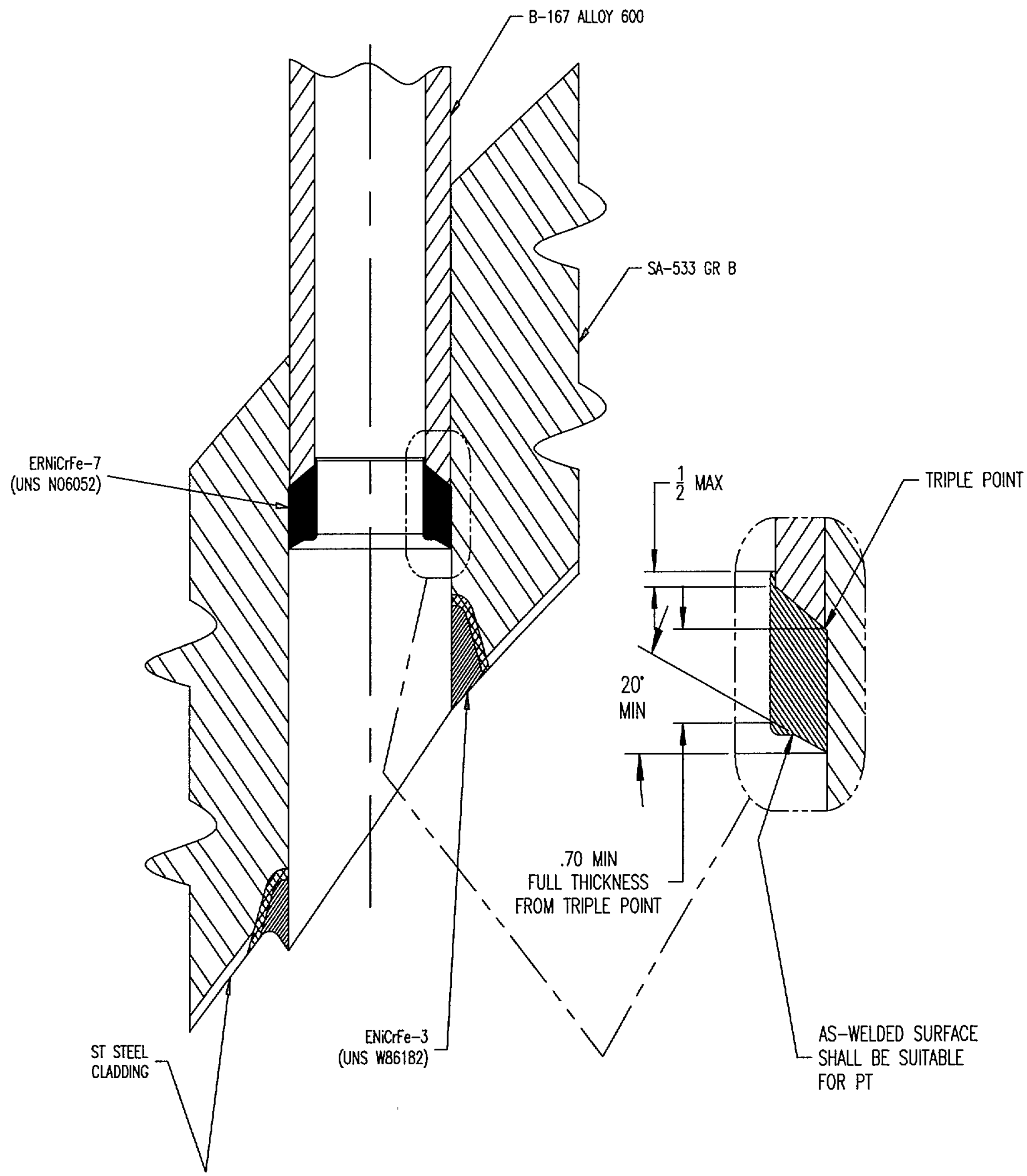

Figure 2:
Oconee Unit 3 New CRDM Pressure Boundary Welds