

**VIRGINIA ELECTRIC AND POWER COMPANY**  
**RICHMOND, VIRGINIA 23261**

October 30, 2001

U.S. Nuclear Regulatory Commission  
Attention: Document Control Desk  
Washington, D.C. 20555

Serial No. 01-637A  
NL&OS/ETS R0  
Docket Nos. 50-280  
50-281  
License Nos. DPR-32  
DPR-37

Gentlemen:

**VIRGINIA ELECTRIC AND POWER COMPANY**  
**SURRY POWER STATION UNITS 1 AND 2**  
**ASME SECTION XI RELIEF REQUESTS SR-27, 28, 32 and 33**  
**REVISED RELIEF REQUESTS**  
**ALTERNATIVE REPAIR TECHNIQUE - REACTOR VESSEL HEAD**

In a letter dated October 17, 2001 (Serial No. 01-637), Virginia Electric and Power Company (Dominion) requested relief (Relief Requests SR-27 and SR-28 for Surry Unit 1 and SR-32 and SR-33 for Surry Unit 2) to use alternative repair techniques in the event that any flaws requiring repair in reactor vessel head penetrations were discovered during inspections. These inspections are in progress during the current Surry Unit 1 refueling outage. At this time we have identified two reactor vessel head penetrations with through-wall crack indications that will require NRC approval of the relief requests in order to effect the repair.

During a telephone conference call on October 25, 2001 with the NRC staff to discuss the subject relief requests, additional clarifying information was requested by the NRC. As an outcome of the conference call, we are providing revised relief requests for the ambient temperbead weld repair technique (SR-27 and SR-32) and flaw characterization requirements (SR-28 and SR-33) in Attachments 1 and 2, respectively. The additional ASME Code references and other clarifying information requested by the NRC staff have been incorporated into the revised relief requests. Using the provisions of these relief requests as an alternative to Code requirements will produce sound, permanent repair welds and an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i) and 10 CFR 50.55a(g)(5)(iii) we request relief from the specific ASME Code requirements identified in the attached relief requests.

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Repair activities on Unit 1 are currently scheduled to commence October 31, 2001. Therefore, Dominion requests expedited approval of these relief requests. Please contact Mr. Leslie Spain at (804) 273-2602 or Mr. Thomas Shaub at (804) 273-2763, if there are any questions about this submittal.

Very truly yours,



Leslie N. Hartz  
Vice President – Nuclear Engineering

Commitments made in this letter: None

Attachments:

1. Relief Requests SR-27 and 32
2. Relief Requests SR-28 and 33

cc: U.S. Nuclear Regulatory Commission  
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Mr. R. A. Musser  
NRC Senior Resident Inspector  
Surry Power Station

Mr. R. Smith  
Authorized Nuclear Inspector  
Surry Power Station

**Attachment 1**

**Relief Requests 27 and 32  
Weld Repair of Reactor Vessel Head Penetrations  
Ambient Temperature Temperbead Weld repair Technique**

**Surry Power Station Units 1 and 2  
Virginia Electric and Power Company  
(Dominion)**

**RELIEF REQUESTS SR-27 (Surry 1) and SR-32 (Surry 2)**  
**WELD REPAIR OF REACTOR VESSEL CLOSURE HEAD PENETRATIONS**

**I. Component Identification:**

Surry Units 1 and 2  
Reactor Vessel Closure Head (RVCH) Penetrations, Class 1  
Drawing Nos. 11448-WMKS-RC-R-1.2 (Surry 1)  
11548-WMKS-RC-R-1.2 (Surry 2)

**II Code Requirement:**

The Construction Code of record for the Surry reactor vessels and heads is the 1968 Edition of ASME Section III with Addenda through the Winter of 1968. Surry Units 1 and 2 are currently in their third inspection intervals using the 1989 Edition of ASME Section XI. ASME Section XI, paragraph IWA-4120, stipulates the following:

“Repairs 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-4500 and the following may be used: (1) IWB-4000 for Class 1 Components;...”

For the contemplated repairs to the reactor vessel head penetrations, paragraph N-528.2 of the 1968 Edition with Winter of 1968 Addendum of Section III requires repairs be postweld heat treated (PWHT) in accordance with paragraph N-532. The PWHT requirements set forth therein would be impossible to attain on a reactor vessel head in containment without distortion of the head. In addition, the existing penetration to head welds were not qualified with PWHT and cannot be so qualified at this time.

Consequently, the proposed repairs will be conducted in accordance with the 1989 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**

Surry Units 1 and 2 will perform inspections which may indicate the need to repair flaws which may be discovered in the reactor vessel head (RVH) penetration tubes. Per subarticle IWA-4120 of Section XI, repair welding must be done in accordance with the original Construction Code. Therefore, for any repair to the ferritic material of the vessel

head, paragraph N-532 of the 1968 Edition of Section III would require PWHT for the repair weld. As pointed out above, the PWHT parameters required by N-532 would be difficult to achieve on a reactor vessel head in containment and pose significant risk of distortion to the geometry of the head and vessel head penetrations, in addition to exposing the existing J-groove welds to PWHT for which they were not qualified.

Because of the inability to comply with the requirements of the original Construction Code, the rules of ASME Section III, 1989 Edition will apply to the repairs. Therefore, for any reactor vessel head (RVH) penetration flaws that resulted in a repair within 1/8-inch of the ferritic material of the vessel head, paragraph NB-4622 of Section III would require a postweld stress relief heat treatment (PWHT) for the repair weld or the use of a temperbead weld technique. The temperbead procedure requirements, including preheat and postweld heat soaks contained in NB-4622, likewise would be difficult to achieve in containment and are not warranted by the need to produce a sound repair weld given the capabilities of the proposed alternative temperbead procedure proposed below. Therefore, pursuant to 10 CFR 50.55a (a)(3)(i), Virginia Electric and Power Company (Dominion) requests relief to use an ambient temperature temperbead method of repair as an alternative to the requirements of the 1989 Edition of ASME Section III, NB-4622.

The requirements of paragraphs 4622, and 5245, of the 1989 Edition of ASME Section III, IWA-4700 of the 1989 Edition of Section XI, and QW-424 of Section IX are also applicable to the contemplated repairs. As an alternative to these requirements, the requirements of, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temperbead Technique," (Enclosure 1) will be used. Specifically, alternatives are being proposed for the following articles, subarticles, paragraphs, and subparagraphs of ASME Section III, Section IX, and Section XI:

NB-4622.1 establishes the requirement for postweld heat treatment (PWHT) of welds including repair welds. In lieu of the requirements of this subparagraph, we propose to utilize a temperbead 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 temperbead 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 temperbead 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 temperbead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs.

- 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 for the stipulations of paragraph QW-424 of Section IX. 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. The proposed ambient temperature temperbead alternative does not require an elevated temperature preheat.
- NB-4622.11(c)(6) establishes requirements for electrode diameters for the first, second, and subsequent layers of the repair weld and requires removal of the weld bead crown before deposition of the second layer. Because the proposed alternative uses 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 temperbead 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 temperbead 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 proposed alternative will comply with that requirement.
- 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. (Refer to the discussion for paragraph QW-424 below.) 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 as 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.

- Paragraph QW-424 of ASME Section IX requires that each P-No. material in a dissimilar metal weld be welded to each other in the procedure qualification process. For the proposed alternative, multiple procedure qualifications have been performed on each base metal to itself which taken together demonstrate that sound welds can be achieved by the proposed process.
- Subarticle IWA-4700 requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure-retaining boundary. As discussed in more detail below, the proposed alternative will utilize a system leakage test per IWA-5211(a) in lieu of the system hydrostatic test.

#### **IV. Basis for Relief**

The alternative to NB-4622 requirements being proposed involves the use of an ambient temperature temperbead welding technique that avoids the necessity of traditional PWHT preheat and postweld heat soaks. The features of the alternative that make it applicable and acceptable for the contemplated repairs are enumerated below:

- 1) The proposed alternative will require the use of an automatic or machine gas tungsten arc welding (GTAW) temperbead technique without the specified preheat or postweld 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 Temperbead 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.
- 2) The use of a GTAW temperbead welding technique to avoid the need for postweld heat treatment is based on research that has been performed by EPRI and other organizations. (Reference Enclosure 2, EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temperbead Applications," dated November 1998.) The research demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the heat affected zones (HAZ) of the base material and preceding weld passes. Data presented in Tables 4-1 and 4-2 of the report show the results of procedure qualifications performed with 300°F preheats and 500°F post-heats, as well as with no preheat and post-heat. From that data, it is clear that equivalent toughness is achieved in base metal and heat affected zones in both cases. The temperbead process has been shown effective by research,

successful procedure qualifications, and many successful repairs performed since the technique was developed. Many acceptable Procedure Qualifications Records (PQRs) and Welding Procedure Specifications (WPSs) presently exist and have been used to perform numerous successful repairs. These repairs have included all of the Construction Book Sections of the ASME Code, as well as the National Board Inspection Code (NBIC). The use of the automatic or machine GTAW process utilized for temperbead welding allows more precise control of heat input, bead placement, and bead size and contour than the manual shielded metal arc welding (SMAW) process required by NB-4622. The very precise control over these factors afforded by the alternative provides more effective tempering and eliminates the need to grind or machine the first layer of the repair.

- 3) The NB-4622 temperbead 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 mitigates this propensity without the use of elevated preheat and postweld hydrogen bake out.

The NB-4622 temperbead procedure requires the use of the SMAW welding process with covered electrodes. Even the low hydrogen electrodes, which are required by NB-4622, may be a source of hydrogen unless very stringent electrode baking and storage procedures are followed. The only shielding of the molten weld puddle and surrounding metal from moisture in the atmosphere (a source of hydrogen) is the evolution of gases from the flux and the slag that forms from the flux and covers the molten weld metal. As a consequence of the possibility for contamination of the weld with hydrogen, NB-4622 temperbead procedures require preheat and postweld hydrogen bake-out. However, the proposed alternative temperbead 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.

- 4) The F-No. 43 (ERNiCrFe-7) filler metal that would be used for the repairs is not

subject to hydrogen embrittlement cracking.

- 5) Final examination of the repair welds would be by surface examination (liquid penetrant) and ultrasonic examination and would not be conducted until at least 48 hours after the weld had returned to ambient temperature following the completion of welding. Given the 3/8-inch limit on repair depth in the ferritic material, the delay before final examination would provide ample time for any hydrogen that did inadvertently dissolve in the ferritic material to diffuse into the atmosphere or into the nonferritic weld material which has a higher solubility for hydrogen and is much less prone to hydrogen embrittlement cracking. Thus, in the unlikely event that hydrogen induced cracking did occur, it would be detected by the 48-hour delay in examination.
- 6) 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, Procedure Qualification Record (FRA-ANP PQR 7164) using P-No. 3, Group No. 3 base material exhibited improved Charpy V-notch properties in the HAZ from both absorbed energy and lateral expansion perspectives, compared to the unaffected base material.

<u>PQR 7164</u>	<u>Unaffected Base Material</u>	<u>HAZ</u>
50°F absorbed energy (ft-lbs.)	69, 55, 77	109, 98, 141
50°F lateral expansion (mils)	50, 39, 51	59, 50, 56
50°F shear fracture (%)	30, 25, 30	40, 40, 65.
80°F absorbed energy (ft-lbs.)	78, 83, 89	189, 165, 127
80°F lateral expansion (mils)	55, 55, 63	75, 69, 60
80°F shear fracture (%)	35, 35, 55	100, 90, 80.

The absorbed energy, lateral expansion, and percent shear fracture were significantly greater for the HAZ than the unaffected base material at both test temperatures. It is clear from these results that the GTAW temperbead process has the capability of producing acceptable repair welds.

- 7) Procedure qualification, performance qualification, welding procedure specifications, examination, and documentation requirements would be as stipulated in the proposed alternative procedure and as described below.

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 temperbead 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.

Since there is no ASME IX welding procedure qualification requirement specifying proximity of one base material to another different base material, the effects of welding the base materials of different P-Nos. to each other is not specifically required. A groove weld is permitted to be qualified with a wide root gap between the base materials.

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.

Based on the above information, it may be concluded that the proposed

alternative ambient temperature temperbead weld technique (Enclosure 1) provides a technique for repairing flaws in the CRDM and reactor head vent 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.

- 8) IWA-4700 requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure retaining boundary. In lieu of a system hydrostatic test which must be conducted at pressures exceeding normal operating pressure, the proposed alternative relies on a system leak test at normal operating pressure coupled with nondestructive testing of the proposed weld that offers an equivalent or higher confidence of the soundness of the weld. As discussed previously, NB-5245 requires progressive surface examination of the proposed partial penetration welds while the alternative requires final surface examination (liquid penetrant inspection) and volumetric examination (ultrasonic inspection) which will provide added assurance of sound welds when done in conjunction with the planned system leak test. Since the proposed testing is similar to the provisions of approved ASME Code Case 416-1 it is concluded that the proposed alternative provides an acceptable level of quality and safety.
- 9) 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 temperbead technique.

A welding mockup on the full size Midland RVCH, which is similar to the Surry Units 1 and 2 RVCHs, 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.

- 10) 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 temperbead 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 7 through 12 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 4, 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 7 through 12 and Table 1.

- 11) 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 4, 5 and 6 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.

- 12) 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.

The automated repair method described above leaves a band of ferritic low alloy steel

exposed to the primary coolant. The effect of corrosion on the exposed area, both reduction of reactor pressure vessel head thickness and primary coolant Iron (Fe) release rates, has been evaluated by Framatome-ANP (FRA-ANP). The results of this evaluation concluded that the total corrosion would be insignificant when compared to the thickness of the RVCH. FRA-ANP has estimated that the total estimated Fe release from a total of 69 repaired CRDM nozzles would be significantly less than the total Fe release from all other primary sources. Since Surry Units 1 and 2 have only 65 CRDM nozzles, this estimate is bounding.

## **V. Alternate Requirements**

Repairs to reactor vessel head penetration J-groove attachment welds, which are required when 1/8-inch or less of nonferritic weld deposit exists above the original fusion line, will be made in accordance with the requirements of paragraphs IWA-4110, 4120, 4130, 4140, 4210, 4330, 4340, 4400, 4600, and 4800 of the 1989 Edition of ASME Section XI.

The requirements of paragraphs 4622, and 5245, of the 1989 Edition of ASME Section III, IWA-4700 of the 1989 Edition of Section XI, and QW-424 of Section IX are also applicable to the contemplated repairs. As an alternative to these requirements, the requirements of, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temperbead Technique," (Enclosure 1) will be used. Specifically, alternatives are being proposed for the following articles, subarticles, paragraphs, and subparagraphs of ASME Section III, Section IX, and Section XI:

NB-4622.1 establishes the requirement for postweld heat treatment (PWHT) of welds including repair welds. In lieu of the requirements of this subparagraph, we propose to utilize a temperbead 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 does 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 establishes 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. This sub-subparagraph does not apply because the ambient temperature temperbead 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 temperbead 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.

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 temperbead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs as follows.

- 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 welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy these requirements, except for the stipulations of paragraph QW-424 of Section IX as explained in the discussion, Basis for Relief, above. In addition, NB-4622.11(c) requires 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 (SMAW) process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative utilizes gas tungsten arc welding (GTAW) with bare electrodes meeting the 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 because bare electrodes will not pick up moisture from the atmosphere as covered electrodes may.
- 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. The proposed ambient temperature temperbead alternative does not require an elevated temperature preheat.
- NB-4622.11(c)(6) establishes requirements for electrode diameters for the first, second, and subsequent layers of the repair weld and requires removal of the weld bead crown before deposition of the second layer. Because the proposed alternative uses 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 from 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 temperbead 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 350°F (maximum) and requires the area to be welded be at least 50°F prior to welding. This approach has been demonstrated to be adequate to produce 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 out because it is unnecessary for the very low hydrogen GTAW temperbead 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 (due to limitations on access for source and film placement and the likelihood of unacceptable geometric unsharpness and film density), 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 proposed alternative will comply with that requirement.
- NB-4622.11(f) establishes requirements for the procedure qualification test plate. 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. See the discussion for paragraph QW-424 below. 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 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 any concern about obstructions, which might interfere with the welder's abilities because all such 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 exam (PT or MT) at the lesser of 1/2 the maximum weld thickness or 1/2-inch, as well 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. The volumetric inspection coupled with surface examination

will provide a high level of confidence that the proposed welds are sound and defect free.

- Paragraph QW-424 of ASME Section IX requires that each P-No. material in a dissimilar metal weld be welded to each other in the procedure qualification process. For the proposed alternative, multiple procedure qualifications have been performed of each base metal to itself which taken together demonstrate that sound welds can be achieved by the proposed process, as discussed in detail in the Basis for Relief, above.
- Subarticle IWA-4700 requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure-retaining boundary. As discussed in detail above, the proposed alternative will utilize a system leakage test per IWA-5211(a) in lieu of the system hydrostatic test.

Per the 1988 Edition of ASME Section XI, paragraph IWB-2200(a), no preservice examination is required for repairs to the partial penetration J-groove welds between the vessel head and its penetrations (Examination Category B-E). However, the NDE performed after welding will serve as a preservice examination record if needed in the future. Furthermore, the inservice inspection requirement from Table IWB-2500-01, "Examination Category B-E...", is a VT-2 visual inspection of the external surfaces of 25% of the nozzles each interval with IWB-3522 as the acceptance standard. Currently, we perform visual examination, VT-2, of 100% of the nozzles each refueling outage. Ongoing vessel head penetration inspection activities undertaken as a result of NRC Bulletin 2001-01 and ongoing deliberations in Code committees will be monitored to determine the necessity of performing any additional or augmented inspections.

Based on the above information, it may be concluded that using the proposed alternative ambient temperature temperbead 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).

## Enclosure 1

### Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temperbead Technique

Dominion 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 1.
- (e) Ferritic base material for the procedure qualification test will meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material, at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in subparagraph (f) below, but shall be in the base metal.
- (f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) will be performed at the same temperature as the base metal test of subparagraph (e) above. Number, location, and orientation of test specimens will be as follows:
  - 1. The specimens will be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The test coupons for HAZ impact specimens will be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimens will be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen will be inclined to allow the root of the notch to be aligned parallel to the fusion line.

2. If the test material is in the form of a plate or a forging, the axis of the weld will be oriented parallel to the principal direction of rolling or forging.
  3. The Charpy V-notch test will be performed in accordance with SA-370. Specimens will be in accordance with SA-370, Figure 11, Type A. The test will consist of a set of three full-sized 10-mm x 10-mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens will be reported in the Procedure Qualification Record.
- (g) The average values of the three HAZ impact tests will be equal to or greater than the average values of the three unaffected base metal tests.

## 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 2, 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

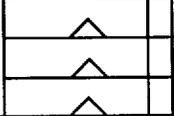
- (a) Prior to welding, a surface examination will be performed on the area to be welded.

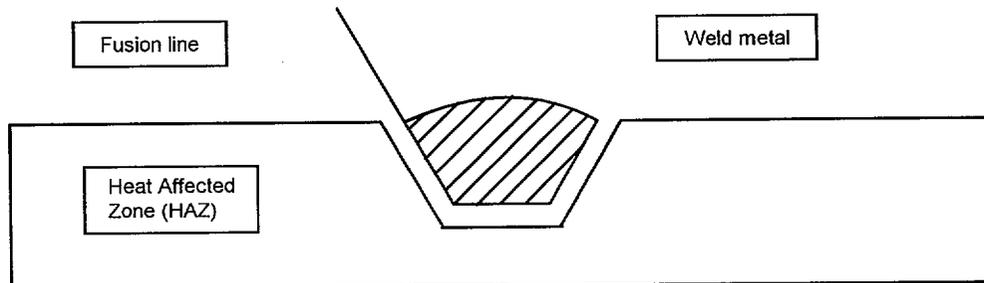
- (b) The final weld surface and adjacent HAZ shall be examined using surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours.
- (c) The purpose for the examination of the band is to assure all flaws associated with the weld repair area have been removed 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 5 and 6. 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.

<b>Table 1: Surry CRDM Replacement Weld UT Search Unit Transducer Characteristics</b>				
<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.

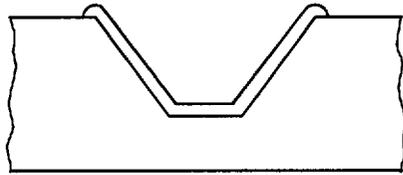
Discard		
Transverse Side Bend		
Reduced Section Tensile		
Transverse Side Bend		
		HAZ Charpy V-Notch
Transverse Side Bend		
Reduced Section Tensile		
Transverse Side Bend		
Discard		



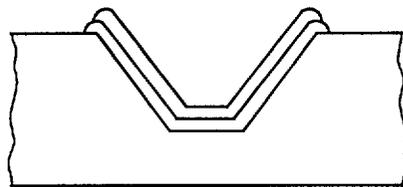
GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

QUALIFICATION TEST PLATE

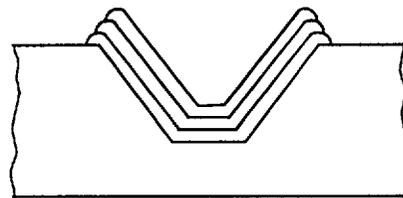
Figure 1



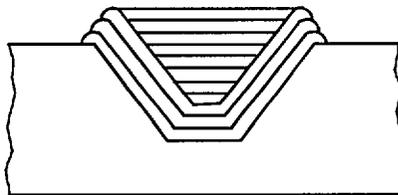
Step 1: Deposit layer one with first layer weld parameters used in qualification.



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



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

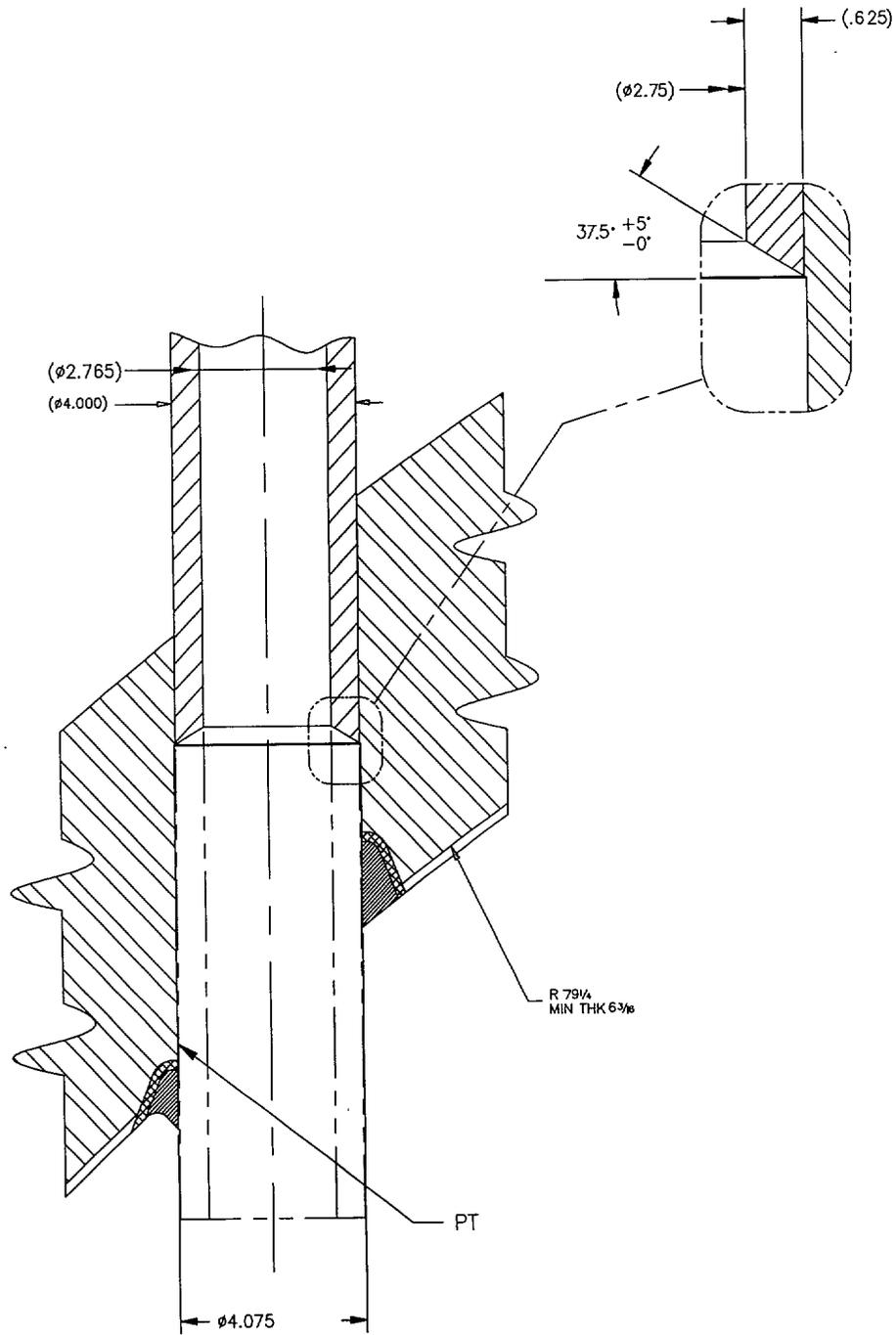


Step 4: Subsequent layers to be deposited as qualified, with heat input less than or equal to that qualified in the test assembly. NOTE: Particular care shall be taken in application of the fill layers to preserve the temper of the weld metal and HAZ.

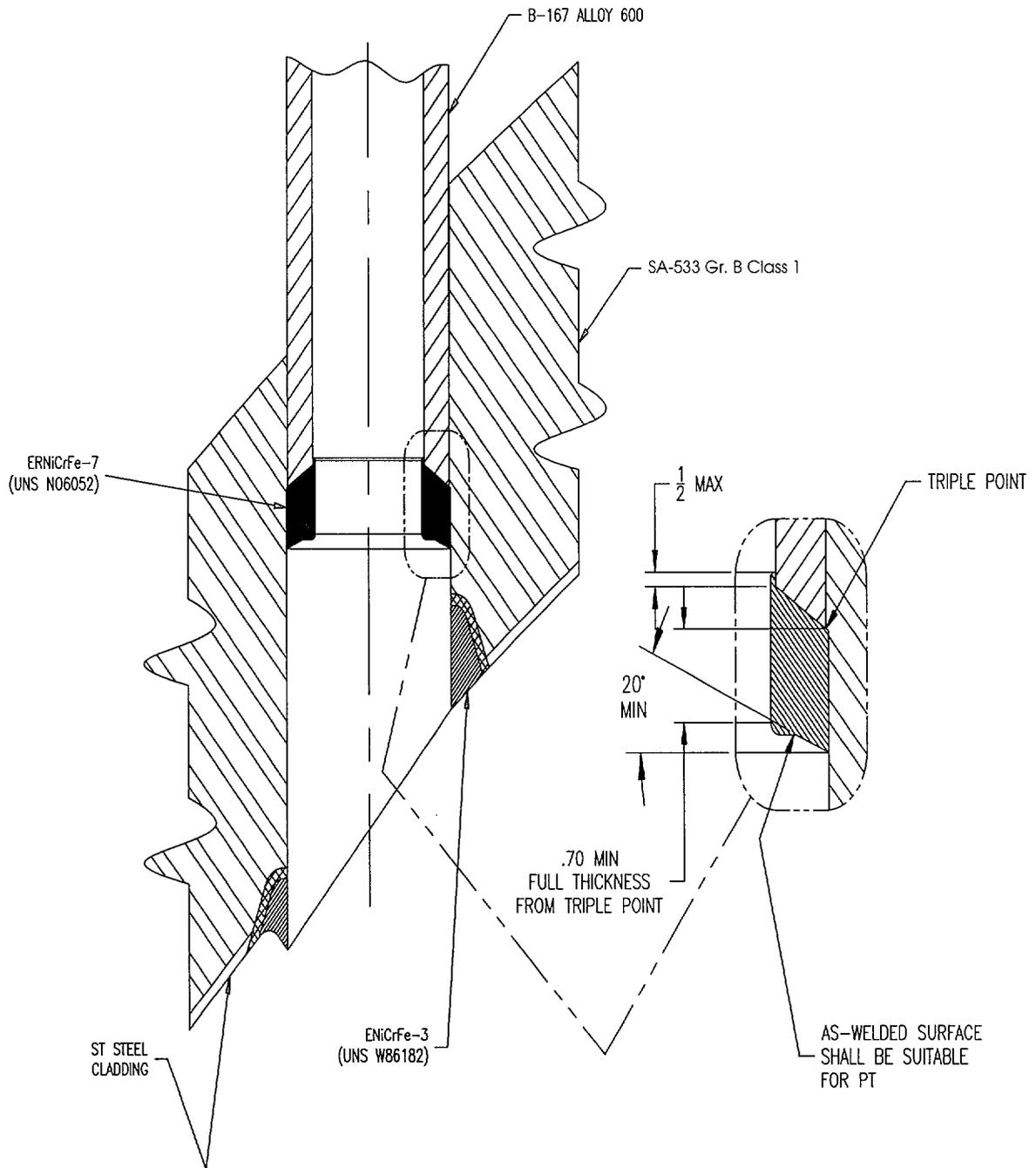
GENERAL NOTE: The illustration above is for similar-metal welding using a ferritic filler material. For dissimilar-metal welding, only the ferritic base metal is required to be welded using steps 1 through 3 of the temperbead welding technique.

#### AUTOMATIC OR MACHINE (GTAW) TEMPERBEAD WELDING

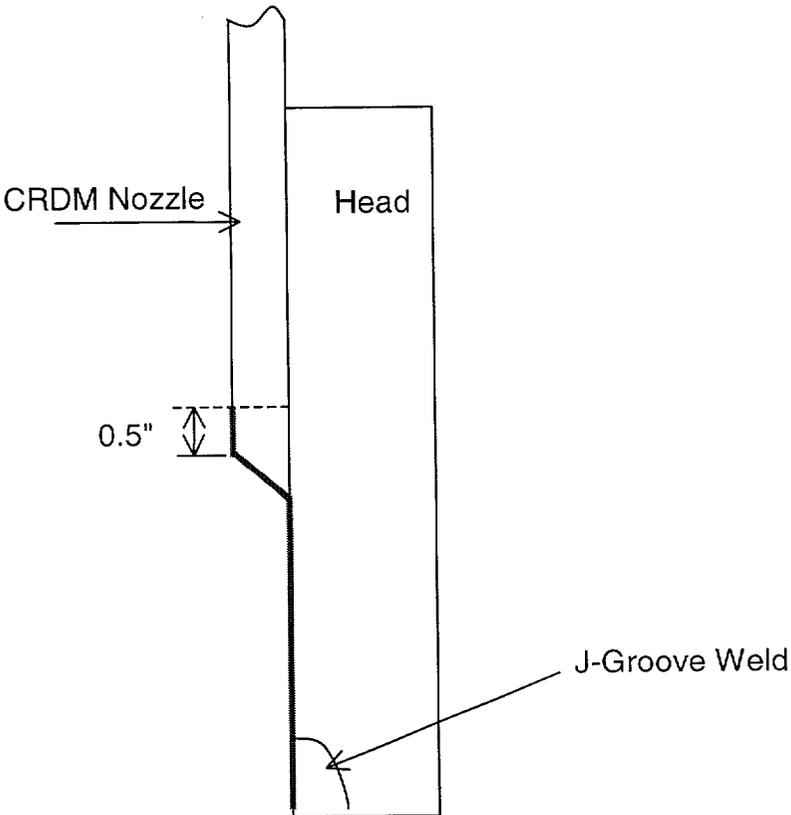
Figure 2



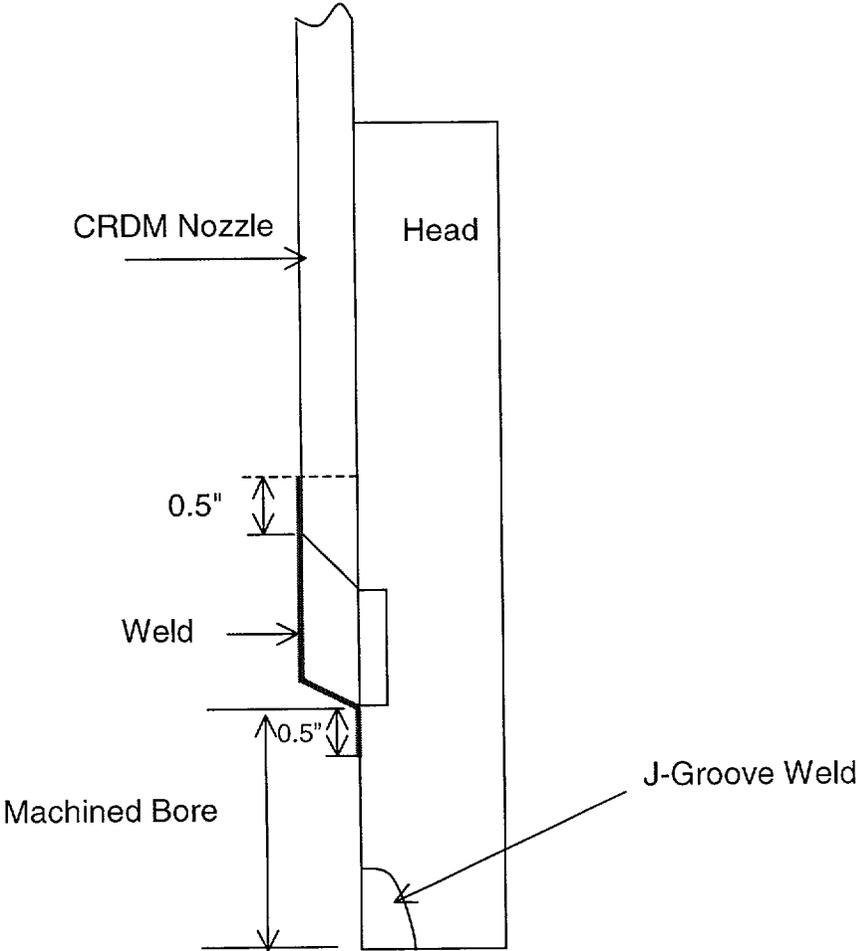
**Figure 3:  
New Surry CRDM**



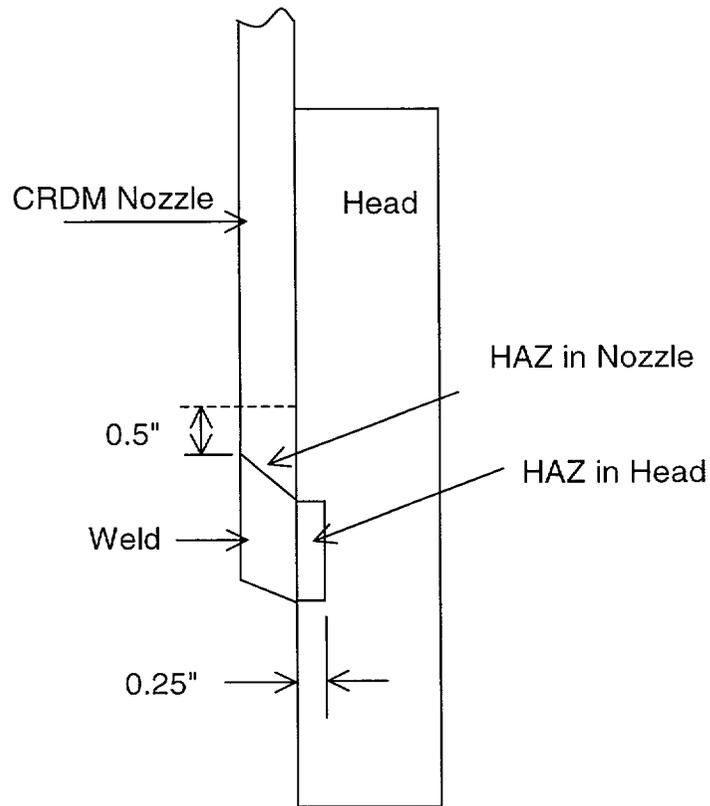
**Figure 4:  
New Surry CRDM Pressure Boundary Weld**



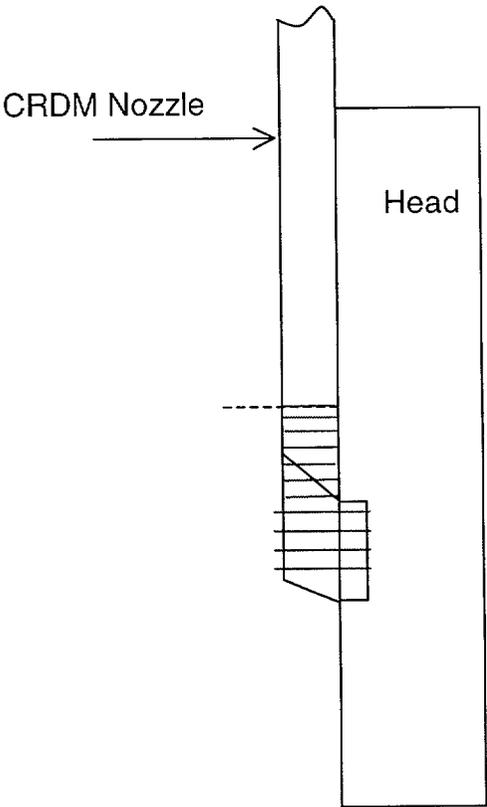
**Figure 5:  
Surry 1 CRDM Temperbead Weld Repair,  
PT Coverage Prior to Welding**



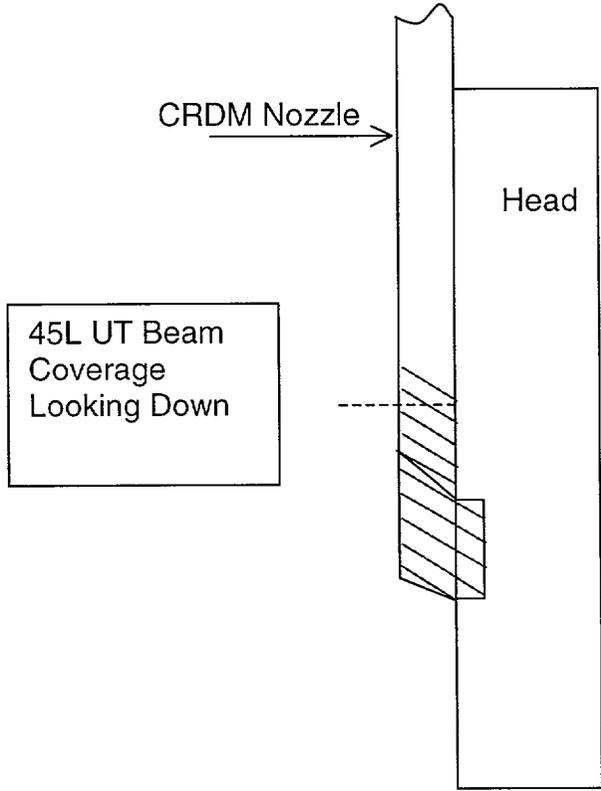
**Figure 6:  
Surry 1 CRDM Temperbead Weld Repair,  
PT Coverage after Welding**



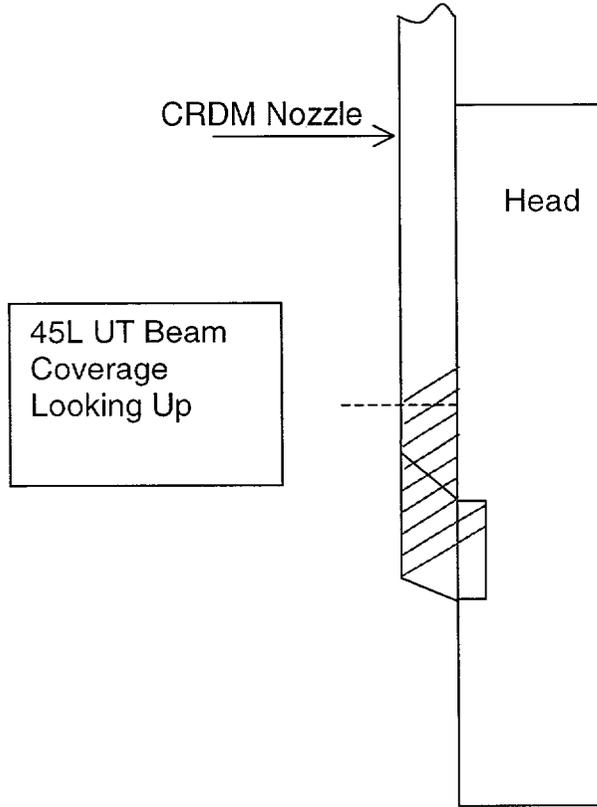
**Figure 7:  
Surry 1 CRDM Temperbead Weld Repair  
Areas to be Examined**



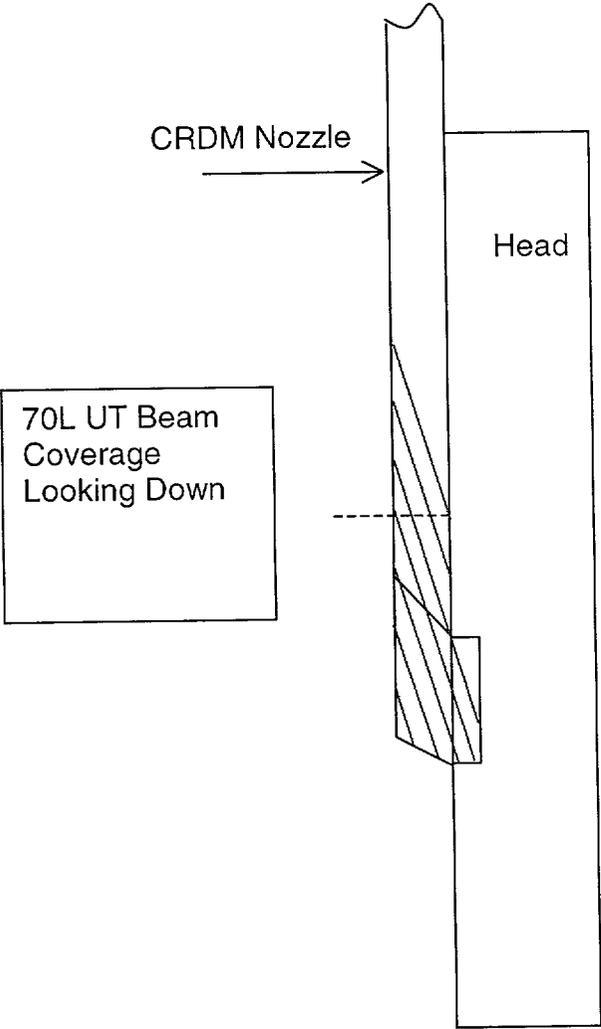
**Figure 8:**  
**Surry 1 CRDM Temperbead Weld Repair,**  
**UT 0 degree and 45L Beam Coverage**  
**Looking Clockwise and Counter-Clockwise**



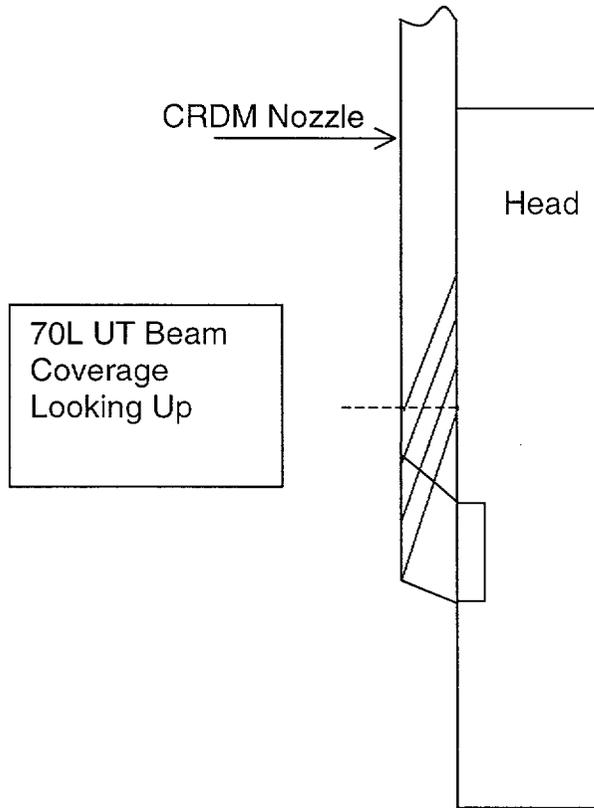
**Figure 9:**  
**Surry 1 CRDM Temperbead Weld Repair,**  
**45L UT Beam Coverage Looking Down**



**Figure 10:  
Surry 1 CRDM Temperbead Weld Repair,  
45L UT Beam Coverage Looking Up**



**Figure 11:  
Surry 1 CRDM Temperbead Weld Repair,  
70L UT Beam Coverage Looking Down**



**Figure 12:  
Surry 1 CRDM Temperbead Weld Repair, 70L UT  
Beam Coverage Looking Up**

**Attachment 2**

**Relief Requests 28 and 33  
Weld Repair of Reactor Vessel Head Penetrations  
Flaw Characterization**

**Surry Power Station Units 1 and 2  
Virginia Electric and Power Company  
(Dominion)**

## Relief Request SR-28 (Surry 1) and SR-33 (Surry 2) Characterization of Remaining Flaws

### I. Component Identification

Reactor Vessel Closure Head (RVCH) Penetrations, Class 1  
Drawing Nos. 11448-WMKS-RC-R-1.2 (Surry 1)  
11548-WMKS-RC-R-1.2 (Surry 2)

### II. Code Requirement:

The Construction Code of record for the Surry reactor vessels and heads is the 1968 Edition of ASME Section III with Addenda through the Winter of 1968. Surry Units 1 and 2 are currently in their third inspection intervals using the 1989 Edition of ASME Section XI with no Addenda. IWB-2500, Examination Category B-E, "Pressure Retaining Partial Penetration Welds in Vessels," Item B4.12, is applicable to the inservice examination of the vessel head to penetration welds. IWA-3300, IWB-3142.4, IWB-3420, would be applicable to any flaws discovered during inservice inspection.

### III. Code Requirement for Which Relief Is Requested:

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 if a nozzle must be partially removed 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.

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.

#### **IV. Basis for Relief**

If inspection of the reactor vessel head penetrations reveals flaws affecting the J-groove attachment welds, it will be impractical to characterize these flaws by NDE and it will be impractical to perform any successive examinations.

ASME Section XI calculations will be performed to show the flaws are acceptable.

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. It has therefore been assumed, for analysis purposes, that a flaw(s) may exist in this weld that extends from the weld surface to the weld to closure head base material interface. 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 worst-case assumption on flaw size is based on maximum crack growth by primary water stress corrosion cracking (PWSCC). Although a crack propagating through the J-groove weld by PWSCC would eventually grow to the low alloy steel reactor vessel head, continued growth by PWSCC into the low alloy steel is not expected to occur. Stress corrosion cracking (SCC) of carbon and low alloy steels is not a problem under BWR or PWR conditions. SCC of steels containing up to 5% chromium is most frequently observed in caustic and nitrate solutions and in media containing hydrogen sulfide. Based on this information, SCC is not expected to be a concern for low alloy steel exposed to primary water. Instead, an interdendritic crack propagating from the J-groove weld area is expected to blunt and cease propagation. This has been shown to be the case for interdendritic SCC of stainless steel cladding cracks in charging pumps and by recent events with PWSCC of Alloy 600 weld materials at ONS-1 and VC Summer.

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 all support the assumption that the flaws would blunt at the interface of the NiCrFe weld to ferritic base material.

It will be shown to be acceptable to leave the postulated cracks in the original NiCrFe housing nozzle penetration J-prep buttering, or in the original NiCrFe CRDM housing to RVCH attachment weld. The evaluations performed in support of this relief provide an acceptable level of quality and safety without performing flaw characterization required in ASME Section XI 1989, IWA-3300, IWB-3142.4 and IWB-3420.

ASME Section XI stress calculations in accordance with IWB-3610 will be performed to show the flaws are acceptable for a number of years. The only driving mechanism is fatigue crack growth. The evaluation will assume a radial (with respect to the penetration centerline) crack exists with a length equal to the partial penetration weld preparation depth (throat). The depth of the assumed flaw will be based on the amount of the original partial penetration weld width that actually remains attached to the RVCH after repair activities, including some grinding to improve the contour in the area, are complete.

In addition, an analysis of the new pressure boundary welds will be performed using a three-dimensional model of a CRDM nozzle located at the most severe hillside orientation. The software program ANSYS (general purpose finite element program that is used industry-wide) will be used for this analysis. Per FRA-ANP internal procedures, the ANSYS computer code is independently verified as executing properly, by the solution of verification problems using ANSYS and then comparison of the results to independently determined values.

The analytical model will include the Reactor Vessel Closure 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 Surry Units 1 and 2 design specifications. The resulting maximum thermal gradients will be applied to the model along with the coincident internal pressure values. The ANSYS program will then calculate the stresses throughout the model (including the repair welds). The stresses will be post-processed by ANSYS routines to categorize stresses 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 will be assumed for the new pressure boundary weld.

A primary stress analysis for design conditions will be performed. A maximum Primary General Membrane Stress Intensity ( $P_m$ ) will be calculated and shown to be less than

the maximum allowed by the ASME Code = 27.0 ksi. This value will actually be for the RVCH 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 will be calculated for the point at the intersection of the bottom of the repair weld and the penetration bore and the crevice between the CRDM nozzle outside surface and the RVCH bore. Allowable years of future plant operation will be based on the maximum allowed ASME Code usage factor criterion of 1.0. It is anticipated that the limiting location for this value is the point at the intersection of the bottom of the repair weld and the penetration bore. At the bottom of the crevice between the CRDM nozzle outside surface and the RVCH bore, the calculated fatigue usage factor for 40 years of future operation will not be limiting to the fatigue life of the repair.

Additionally, a fracture mechanics evaluation will be 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 will be postulated that a radial crack in the Alloy 182 weld metal would propagate due to PWSCC, through the weld and butter, to the interface with the low alloy steel RVCH. It is fully expected that such a crack would then blunt and arrest at the butter-to-head interface. 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 RVCH material are low, it will be assumed that a small flaw could initiate in the low alloy steel material and grow by fatigue. It will be postulated that a small flaw in the RVCH would combine with a large stress corrosion crack in the weld to form a radial corner flaw that would propagate into the low alloy steel RVCH by fatigue crack growth, under cyclic loading conditions associated with heatup and cooldown, plant loading and unloading, and rapid transients.

Residual stresses will not be 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 will be performed for a postulated radial corner crack on the RVCH 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 will be used since they are perpendicular to the plane of the crack. Fatigue crack growth, calculated for the remaining operational life, will be small (less than 1/2"), and the final flaw size will be shown to meet the fracture toughness requirements of the ASME Code using an upper shelf value of 200 ksi $\sqrt{\text{in}}$  for ferritic materials.

The CRDM nozzle repair configuration is illustrated in Figures 1 and 2. The repair process is described below:

### Repair Process

- (a) Inspections for leakage/boric acid deposits of CRDM nozzle penetrations will be conducted during the ongoing Surry Unit 1 refueling outage and a subsequent Surry Unit 2 outage.
- (b) CRDM nozzles that are determined to have through-wall leakage will be repaired. Remote machine repair processes are planned.
- (c) Nondestructive examinations using ultrasonic methods are planned for the base metal of the nozzles determined to have through-wall leakage.
- (d) The thermal sleeves will be removed by remote machining.
- (e) Using a remote tool from below the RVCH, each of the leaking nozzles will first receive a roll expansion into the RVCH base material to insure that the nozzle will not move during the repair operations.
- (f) A semi-automated machining tool operating underneath the RVCH will remove the entire lower portion of the CRDM nozzle to a depth above the existing J-groove partial penetration weld. The machining tool will also form the CRDM nozzle repair weld preparation. The operation will sever the existing J-groove partial penetration weld from the CRDM nozzles.
- (g) The machined surface will be cleaned, and then subjected to liquid penetrant examination (PT).
- (h) The repair weld will be performed with a remotely operated machine GTAW weld head using the ambient temperature temperbead process to install the new ERNiCrFe-7 (Alloy 52) pressure boundary weld between the shortened nozzle and the inside bore of the RVCH base material with 50°F minimum preheat temperature.
- (i) The final weld face, not including the taper transition, will be machined.
- (j) The final weld will be liquid penetrant and ultrasonically examined prior to the abrasive water jet conditioning, to preclude masking by the water jet process.
- (k) The final inside diameter surface of the CRDM nozzle near the new weld and the new weld will then be conditioned by abrasive water-jet conditioning to create a final surface that is in compression, to produce optimum resistance to primary water stress corrosion cracking.

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.

Based on the discussion above, it can be seen that it is impractical to characterize flaws in the J-groove weld by NDE and that it is impractical to show the flaws do not extend into the ferritic head base material. Nevertheless, the evaluations discussed above provide an acceptable level of quality and safety without performing flaw characterization as required in ASME Section XI 1989, IWA-3300 (b), IWB-3142.4 and IWB-3420.

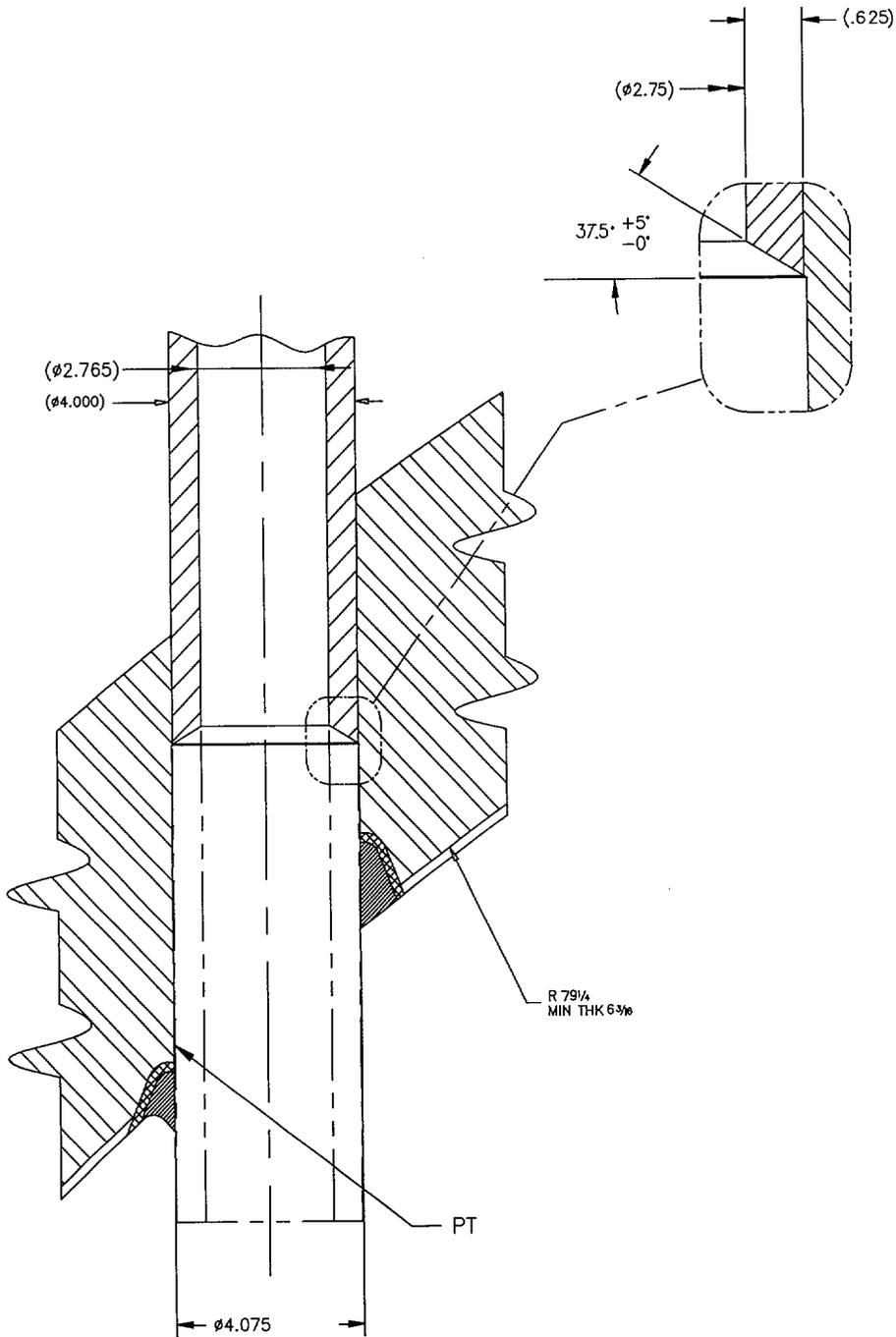
#### **V. Alternate Requirements**

Subarticle IWA-3300 contains criteria for characterizing flaws. None of the nondestructive evaluation techniques that can be performed on the remnant of J-groove weld that will be left on the vessel head if a nozzle must be partially removed can be used to characterize flaws in accordance with any of the paragraphs or subparagraphs of IWA-3300. As an alternative to characterizing any flaws discovered per the requirements of IWA-3300, a worst case flaw shall be assumed to exist and appropriate fatigue analyses will be performed based on that flaw, as discussed in detail above.

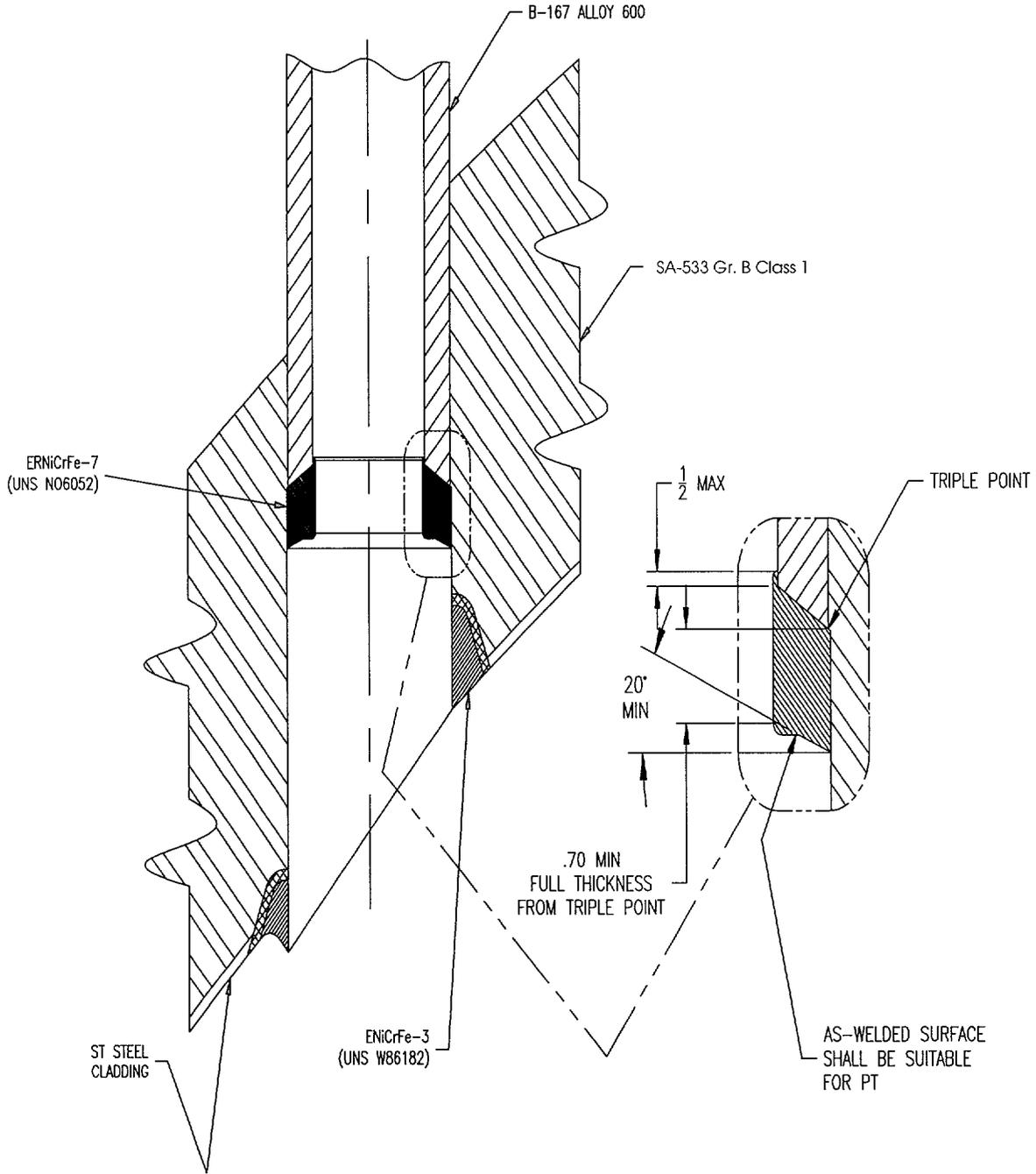
Subsubparagraph IWB-3142.4 allows for analytical evaluation to demonstrate that a component is acceptable for continued service. It also requires that components found acceptable for continued service by analytical evaluation be subject to successive examination. Analytical evaluation of the worst case 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. The alternative, which is based on very conservative assumptions of the PWSCC flaw size and the equally conservative assumption that the flaw would propagate as a fatigue crack in the head base metal, provides assurance of the continued safe operation of the reactor vessel head.

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.

It is concluded, therefore, that the alternative to flaw characterization and subsequent examinations discussed above and used in lieu of existing Code requirements will provide an acceptable level of quality and safety.



**Figure 1:**  
**CRDM Machining**



**Figure 2:**  
**New CRDM Pressure Boundary Welds**