October 1, 2002

Mr. David A. Christian
Senior Vice President - Nuclear
Virginia Electric and Power Company
5000 Dominion Blvd.
Glen Allen, Virginia 23060

SUBJECT: SURRY POWER STATION UNITS 1 AND 2 - ASME SECTION XI, INSERVICE INSPECTION (ISI) PROGRAM RELIEF REQUESTS SR-27, SR-28, SR-32 AND SR-33 RELATED TO REPAIR TECHNIQUE FOR REACTOR VESSEL HEAD PENETRATIONS (TAC NOS. MB3185 AND MB3186)

Dear Mr. Christian:

This letter grants the relief you requested from the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Section XI for Surry Power Station, Units 1 and 2. The relief relates to an alternative repair technique for reactor vessel head penetrations.

By letter dated October 30, 2001, as supplemented December 3, 2001, and April 19, 2002, Virginia Electric and Power Company proposed relief from the requirements of the ASME B&PV Code Section XI to use an alternative technique for the repair of reactor vessel head penetrations. The alternative technique proposed is the ambient temperbead weld repair technique. The relief proposals were identified as SR-27 and SR-28 for Unit 1, and SR-32 and SR-33 for Unit 2.

Based on our evaluation (enclosed) of Relief Requests SR-27 and SR-32, the staff has concluded that the proposed alternative to use the ambient temperature temperbead process and the proposed in-process and post-repair examinations will assure adequate structural integrity provided no anomaly exists at the triple point. If an anomaly exists and you determine that the anomaly is acceptable for continued service, you must follow the provisions of IWB-2420(b) and (c) regarding successive inspections to ensure weld integrity. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), your proposed alternative as described in Relief Requests SR-27 and SR-32 is authorized for the third 10-year interval.

Based on our evaluation (enclosed) of Relief Requests SR-28 and SR-33, the staff has concluded that the proposal not to completely remove the flaws discovered in the remaining J-groove partial penetration welds is acceptable. IWA-4310 requires that the flaws be evaluated using the appropriate flaw evaluation rules of Section XI. Because no additional inspections are planned, the flaws will not be fully characterized. VEPCO will use worst-case assumptions to conservatively estimate the crack extent and orientation. The postulated crack extent and orientation will be evaluated using the rules of IWB-3500. Your proposed actions provide assurance of structural integrity. Therefore, pursuant to 10 CFR 50.55a(g)(6)(i), Relief Requests SR-28 and SR-33 are authorized for the third 10-year interval.

The staff has completed its evaluation of this request; therefore, we are closing TAC Nos. MB3185 and MB3186.

Sincerely,

***/RA/***

John A. Nakoski, Chief, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-280 and 50-281

Enclosure: Safety Evaluation

cc w/encl: See next page

October 1, 2002

provide assurance of structural integrity. Therefore, pursuant to 10 CFR 50.55a(g)(6)(i), Relief Requests SR-28 and SR-33 are authorized for the third 10-year interval.

The staff has completed its evaluation of this request; therefore, we are closing TAC Nos. MB3185 and MB3186.

Sincerely,

***/RA/***

John A. Nakoski, Chief, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-280 and 50-281

Enclosure: Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

INSERVICE INSPECTION RELIEF REQUESTS SR-27, SR-28, SR-32, AND SR-33

SURRY POWER STATION UNITS 1 AND 2

VIRGINIA ELECTRIC AND POWER COMPANY

DOCKET NUMBERS 50-280 AND 50-281

## 1.0 INTRODUCTION

The Inservice Inspection (ISI) of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Class 1, Class 2, and Class 3 components is to be performed in accordance with Section XI of the ASME Code and applicable edition and addenda as required by 10 CFR 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). 10 CFR 50.55a(a)(3) states, in part, that alternatives to the requirements of paragraph (g) may be used, when authorized by the NRC, if the licensee demonstrates that: (i) the proposed alternatives would provide an acceptable level of quality and safety, or (ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) will meet the requirements, except the design and access provisions and the preservice examination requirements, set forth in the ASME Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that inservice examination of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) 12 months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein. The ISI Code of record for the third 10-year ISI interval at Surry, Units 1 and 2, is the 1989 Edition of Section XI of the ASME Code.

By letter dated October 30, 2001, as supplemented December 3, 2001, and April 19, 2002, the Virginia Electric and Power Company (VEPCO, the licensee) requested relief from certain ASME welding repair requirements. Specifically, the licensee requested relief from the temper bead technique for dissimilar metal welding, and from the complete removal of flaws prior to weld repair. The letter dated October 30, 2001, superseded the licensee’s letter dated October 17, 2001. The relief is requested for the third 10-year ISI interval at Surry, Units 1 and 2.

ENCLOSURE

## 2.0 EVALUATION OF RELIEF REQUESTS SR-27 AND SR-32, AMBIENT TEMPERATURE TEMPER BEAD WELDING OF DISSIMILAR METAL WELD

The components affected by this request for relief are the penetrations and welds joining the control rod drive mechanism (CRDM) nozzles to the reactor pressure vessel (RPV) head.

### 2.1 Code Requirements for which Relief is Requested

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, 1968. Surry Units 1 and 2 are currently in their third inspection intervals using the 1989 Edition of ASME Section XI. 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. 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. Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee requested 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. Specifically, the licensee requested an alternative to the requirements of NB-4622.11, “Temper Bead Weld Repair to Dissimilar Metal Welds or Buttering.” NB-4622.11 states that “whenever PWHT is impractical or impossible, limited weld repairs to dissimilar metal welds or P-No. 1 and P-No. 3 material or weld filler metal A-No. 8 (Section IX, QW-442) or F-No. 43 (Section IX, QW-432) may be made without PWHT or after the final PWHT provided the requirements of the following subparagraphs are met.” The licensee stated it will satisfy the Code requirements of Sub-subsections NB-4622.11(a), NB-4622.11(b), NB-4622.11(c)(1), NB-4622.11(e), and NB-4622.11(g). The licensee is seeking to use an alternative to the following requirements of NB-4622.11:

- NB-4622.11(c)(2) that states “The weld metal shall be deposited by the shielded metal arc welding process (SMAW) using A-No. 8 weld metal (Section IX, QW-442) for P-No. 8 to P-No. 1 or P-No.3 weld joints or F-No. 43 weld metal (Section IX, QW-432) for either P-No. 8 or P-No. 43 to P-No.1 or P-No.3 weld joints. The maximum bead width shall be four times the electrode core diameter.”

- NB-4622.11(c)(3) that states “All covered electrodes used for qualification test and repair welding shall be from unopened, hermetically sealed packages or heated ovens maintained between 225°F and 350°F. Electrodes withdrawn from hermetically sealed containers or ovens for longer than 8 hr. shall be discarded.”

- NB-4622.11(c)(4) that states “During the repair, the electrode may be maintained in heated ovens in the repair area. The oven temperature shall be maintained between 225°F and 350°F. Electrodes exposed to the atmosphere for more than 8 hr shall be discarded.”

- NB-4622.11(c)(5) that states "The weld area plus the band around the weld repair of 1½ times the component thickness or 5 in., whichever is less, shall be preheated and maintained at a minimum temperature of 350°F during welding...."

- NB-4622.11(c)(6) that states "All areas of the ferritic base material, exposed or not, on which weld metal is to be deposited, shall be covered with a single layer of weld deposit using 3/32 inches (in.) diameter electrode. The weld bead crown surface shall be removed by grinding before depositing the second layer...."

- NB-4622.11(c)(7) that states "After at least 3/16 in. of weld metal has been deposited, the preheated area as defined in (c)(5) above shall be maintained in the range of 450°F-660°F for 4 hr as a minimum."

- NB-4622.11(c)(8) that states "Subsequent to the heat treatment, the balance of the welding may be performed at a minimum preheat temperature of 100°F and a maximum interpass temperature of 350°F."

- NB-4622.11(d)(1) that states "After the heat treatment specified in (c)(7) above has been completed, the repaired area shall be examined by the liquid penetrant method."

- NB-4622.11(d)(2) that states "The repaired area and preheated band... shall be examined by the liquid penetrant method after the completed weld has been at ambient temperature for a minimum of 48 hours. The repaired region shall be examined by the radiographic method and, if practical, by the ultrasonic method."

- NB-4622.11(d)(3) that states "All nondestructive examination shall be in accordance withNB-5000."

- NB-4622.11(f) that states "The test assembly materials for the welding procedure qualification shall be of the same P-Number and Group Number, including a post weld heat treatment that is at least equivalent to the time and temperature applied to the materials being repaired. The depth of cavity in the test assembly shall be a minimum of one-half the depth of actual repair but not less than 1 in.... the test assembly dimensions surrounding the cavity shall be equal to the test assembly thickness, but not less than 6 in....."

Further, the licensee is seeking relief from the following requirements:

- NB-4453.4(a) that states "The examination of a weld repair shall be repeated as required for the original weld, except that when the defect was originally detected by the liquid penetrant or magnetic particle method, and when the repair cavity does not exceed the lesser of 3/8 in. or 10 percent of the thickness, it need only be reexamined by the liquid penetrant or magnetic particle method.... (b) When repairs to welds joining P-No. 1 and P-No. 3 materials require examination by radiography as prevents meaningful radiographic examination, ultrasonic examination may be substituted provided:...."

- NB-5245 that states “Partial penetration welds, as permitted in NB-3352.4(d), and as shown in Figs. NB-4244(d)-1 and NB-4244(d)-2, shall be examined progressively using either the magnetic particle or liquid penetrant methods. The increments of examination shall be the lesser of one-half on the maximum weld dimension measured parallel to the center line of the connection or ½ in.”

- IWA-4700(a) that states “After repairs by welding on the pressure retaining boundary, a system hydrostatic test shall be performed in accordance with IWA-5000.”

2.2 Licensee’s Proposed Alternative to Code

The licensee’s proposed alternative to the requirements of the Code is presented below, as described by the licensee in its submittal dated October 30, 2001.

- Repairs to reactor vessel head penetration J-groove attachment welds that are required when 1/8-in. 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, 4700, and 4800 of the 1989 Edition of ASME Section XI.

- The requirements of paragraphs NB-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)[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-4622.11 discusses temper bead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs as follows.....

- 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 either the A-No. 8 or 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 as covered electrodes may.

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[1] Enclosure 1 is contained in the licensee’s submittal dated October 30, 2001, and is not included as part of this Safety Evaluation.

- 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 that 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 temper bead alternative does not require 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 in., 1/8 in. and 5/32 in. 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 as a minimum after 3/16 in. 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 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 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 un-sharpness 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(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 procedure qualification record (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).....

- 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 ½ the maximum weld thickness or ½-in., 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.....

- IWA-4700 requires a system hydrostatic test in accordance with IWA-5000 for welded repairs to the pressure-retaining boundary. As discussed in detail (in the Basis for Relief), the proposed alternative will utilize a system leakage test per IWA-5211(a) in lieu of the system hydrostatic test.

Per the 1989 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 nondestructive examination (NDE) performed after welding will serve as a preservice examination record if needed in the future. Furthermore, the ISI requirement from Table IWB-2500-01, “Examination Category B-E...,” is a VT-2 visual inspection of the external surfaces of 25 percent of the nozzles each interval with IWB-3522 as the acceptance standard. Currently, a visual examination, VT-2, of 100 percent of the nozzles is performed 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.

The licensee stated that, based on the above information, it may be concluded that using the proposed alternative ambient temperature temperbead weld technique (Enclosure 1)[2] 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).

2.3 Licensee's Basis for Relief

In the submittal dated December 3, 2001, the licensee stated that "The repair of 6 CRDM penetrations on the Surry Unit 1 vessel head using the machine ambient temperbead welding process incurred a total personnel exposure of 118 man-rem or about 20 man-rem per weld. Because of the difficulty encountered in gaining access to the surface of the head due to the design of the insulation, it is estimated that removal of insulation, placement and removal of heating blankets, and conducting the necessary heating operations would add about 10 percent to 15 percent to personnel exposure. Experience at other plants, most notably Oconee, indicate that performing the repairs with purely manual techniques, which could involve preheat and post weld heating, could increase personnel exposure as much as another 50 percent." In the submittal dated October 30, 2001, the licensee stated that:

> The alternative to NB-4622 requirements being proposed involves the use of an ambient temperature temper bead 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[3], "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique" and specifies that all other requirements of IWA-4000, are met. The alternative will be used to make welds of P-No. 3, RPV 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.)[4]. 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

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[2] Enclosure 1, ibid.

[3] Enclosure 1, ibid.

[4] Enclosure 2 is referenced in the licensee's submittal dated October 30, 2001, and is not included in this Safety Evaluation.

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 (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 Nation 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 procedures require a 350$^{o}$F preheat and a postweld soak at 450$^{o}$F - 550$^{o}$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 ($H_2$) and no more than 0.5 PPM (parts per million) of water vapor ($H_2O$). A typical argon flow rate would be about 15 to 50 CFH and would be adjusted to assure adequate shielding of the weld without creating a venturi affect that might draw oxygen or water vapor from the ambient atmosphere into the weld.

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 a combination of 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-in. limit on repair depth in the ferritic materials, 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 highly 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 proposed alternative 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.

| PQR 7164 | Unaffected Base Material | HAZ |
|---|---|---|
| 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 (5%) | 30, 25, 30 | 40, 40, 65 |
| 80°F absorbed energy (ft-lbs.) | 78, 83, 89 | 189,165, 137 |
| 80°F lateral expansion (mils) | 55, 55, 63 | 75, 69, 60 |
| 80°F shear fracture (5%) | 35, 35, 55 | 100, 90, 80 |

The absorbed energies, 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 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 described below.

The licensee provided PQR 55-PQ7164 in its October 30, 2001, submittal. This PQR is for welding the ambient temperature temperbead using F-No. 43 filler wire on P-No. 3 Group No. 3 base material. The PQR 55-PQ7164 groove (cavity) in the P-No. 3 Group No. 3 base material coupon was 2-3/4 in. deep with a 3/4 in. wide root and 30 degree side bevels (60 degree included angle). All the effects of welding 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.

The licensee provided PQR 55-PQ7183-01 in its April 19, 2002 submittal. This PQR is for welding P-No. 43 to P-No. 3 Group No. 3 with F-No. 43 filler metal. The test coupon consists of a 1.50 in. cavity machined in a 3.625 in. thick, SA-533, Grade B, Class 1 bar stock. The cavity reduced the bar stock thickness from 3.625 to 2.125 inches and a piece of 1.50 in., SB-168, Alloy 600, bar stock was attached to the reduced end to form the opposite side of the cavity. All the effects of welding the P-3 to a P-43 base material using F-No. 43 filler metal have been verified by full thickness impact and transverse tensile tests and full thickness transverse side bend tests.

The licensee further stated in its October 30, 2001, submittal the following:

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 percent weld bead overlap required to properly execute the temperbead technique.

   A welding mockup on the full size Midland RVCH [reactor vessel closure head], which is similar to the Surry Units 1 and 2 RVCHs, was used to demonstrate the welding technique described herein....

10) UT will be performed in lieu of RT due to the repair weld configuration. Meaningful RT cannot be performed .... 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 in., 0.15 in. and 0.25 in. 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 proved 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 underbead 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 percent of the weld surface will be scanned by UT. Approximately 83 percent of the RVCH ferritic steel HAZ will be covered by the UT. The transducers to be used are shown in Table 1 [of the submittal]. The UT coverage volumes are shown in Figures 7 through 12 [of the submittal] 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....

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 for Figures 4, 5, and 6 [from the submittal] 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 in. 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.

## 2.4 Evaluation

The requirements of paragraphs NB-4451, 4452, 4453, and 4622 of the 1989 Edition of ASME, Section III, are applicable to the contemplated repairs. As an alternative to the PWHT time and temperature requirements of NB-4622, the requirements of Enclosure 1 of the licensee's October 30, 2001, submittal entitled, "Similar and Dissimilar Metal Welding Using Ambient Using Ambient Temperature Machine GTAW Temper Bead Technique," will be used. These requirements were supplemented by the submittals dated December 3, 2001, and April 19, 2002. The staff's evaluation of the alternatives proposed by the licensee are discussed below.

NB-4622.11 states that "Whenever PWHT is impractical or impossible, limited weld repairs to dissimilar metal welds of P-No. 1 and P-No. 3 material or weld filler metal A-No. 8 (Section IX, QW-442) or F-No. 43 (Section IX, QW-432) may be made without PWHT or after the final PWHT provided the requirements of the following subparagraphs are met." The licensee will be using F-No. 43 Inconel filler rod weld material to join Inconel pipe to the P-No. 3 carbon steel reactor pressure vessel head. In order to perform PWHT of the repairs, the licensee would have to remove insulation to gain access to the vessel head, install heating pads and thermocouples, perform the heat cycle, remove the pads and thermocouples, and replace the insulation. The repair of six CRDM penetrations on the Surry Unit 1 vessel head using the machine ambient temperbead welding process incurred a total personnel exposure of 118 man-rem or about 20 man-rem per weld. Surry estimated the necessary heating operations for PWHT would add about 10- percent to 20-percent to the total man-rem exposure. Experience at Oconee indicates that performing purely manual techniques for repairs that involve preheat and post-weld heating could increase personnel exposure as much as 50 percent. Although a PWHT is not impractical or impossible, it would create a hardship.

The function of PWHT is to minimize hydrogen cracking after welding, and to a lesser extent, reduce stresses associated with the transformation from austenitic to ferritic microstructures. The temperbead is expected to reduce transformation stresses. The licensee contends that the tight controls necessary for automatic temperbead GTAW creates a low hydrogen environment during the welding process. The GTAW process uses bare welding electrodes with no flux to trap moisture, and shields the molten puddle with high purity argon gas (99.999% pure). The repair area is essentially free of hydrocarbons and moisture. In addition, the combined effects from the confined welding location under the head, the absence of external winds, the confined area within the penetration, and hydrogen preference for hydrogen crack-resistant austenitic weld metal reduces the likelihood of hydrogen cracking. Based on the above discussion, PWHT of the CRDM J-groove vessel head entails significant extra effort by the licensee with little or no noticeable effect over the same repair made without PWHT. The welding procedures used by the licensee were qualified or will be qualified without PWHT. Therefore, the staff finds that a PWHT will result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The licensee will satisfy the Code requirements of Sub-subsections NB-4622.11(a), NB-4622.11(b), NB-4622.11(c)(1), NB-4622.11(e), and NB-4622.11(g).

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 these requirements. Initially, the licensee requested relief from QW-424 of Section IX because they did not have a welding PQR for welding P-No. 43 to P-No. 3 Group No. 3 with F-No. 43 filler metal. In April 19, 2002, the licensee submitted a copy of the Code-required PQR for welding the CRDM to the RPV head.

- NB-4622.11(c)(2) requires the use of the SMAW process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative utilizes GTAW with bare electrodes meeting either the A-No. 8 or 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 pickup 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 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 a period of 4 hours minimum. 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 and requires the area to be welded be at least 50°F prior to welding. These limitations have been demonstrated to be adequate to produce sound welds.

- NB-4622.11(d)(1) requires a PT examination after the hydrogen bake-out described in NB-4622.11(c)(7). The proposed alternative does not require the hydrogen bake-out nor does it require the in-process PT examination.

- NB-4622.11(d)(2) requires the finished weld be PT and RT examined. For an effective RT examination, the radioactive source and film must be placed in a location such that the material thickness between them is fairly constant and that exposure to extraneous radiation is minimized. This special designed weld configuration is not conducive to RT examinations. The proximity of other penetrations would limit the ability to place a source. The RPV head curvature would interfere with the source to film alignment causing image distortion and geometric unsharpness. The effect of the RPV head geometry would involve continuous variation in material thickness from one edge of the radiograph to the other with consequent difficulty in achieving acceptable film densities. Also, the radiation field on contact with the head would result in fogging of the RT film and affect the interpretation of the results. Therefore, examinations by the ultrasonic method will be used in lieu of examinations by the radiographic method defined by IWA-4533.

- 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. 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).

Based on the above discussions, the staff has determined that the proposed alternative to use the ambient temperature temperbead process in lieu of the Code-required temperbead process will produce sound, permanent repair welds to assure adequate structural integrity and that compliance with the specified Code requirements would result in hardship or difficulty without a compensating increase in the level of quality and safety.

For the repair welds, the licensee stated that in lieu of the progressive surface examinations required by subparagraph NB-4453.4 and paragraph NB-5245, the examination of the repair weld will include the use of dye penetrant testing (PT) and ultrasonic testing (UT). ASME, Section III, 1989 Edition, Paragraph NB-5245, gives the nondestructive examination (NDE) requirements for partial penetration welds. The requirements are to conduct progressive magnetic particle or PT examinations. The finished surface is also to be examined by one of these methods. However, the licensee has proposed to eliminate the progressive surface examinations and to conduct a surface examination and a UT examination of the finished surface after the completed weld has been at ambient temperature for at least 48 hours. The staff finds that the progressive examinations would be difficult to conduct because of interferences caused by the presence of the automatic GTAW welding equipment. The surface examinations will identify any surface penetrating flaws. The UT examinations should find construction and repair-related flaws when performed using appropriately qualified processes and personnel.

The staff has concluded that NB-5245 is not the appropriate Code section that applies to the repair since the weld configuration is not that of a partial penetration weld. The repair weld is actually a specially designed pressure boundary, structural weld used to reestablish the pressure boundary between the CRDM nozzle and RPV head. The weld configuration is not addressed by the ASME Code. For analysis purposes, the licensee has evaluated the weld to meet the structural requirements of a partial penetration weld, and for integrity purposes, the weld is surface and volumetrically examined. The staff has determined that the proposed surface and volumetric examinations of the repair welds are acceptable.

It is stated in IWA-4710(a) and IWA-5214 that after a repair weld is made on a pressure-retaining boundary or the installation of a replacement by welding, a system hydrostatic test shall be performed in accordance with IWA-5000. The licensee has proposed to perform a system leakage test in lieu of the system hydrostatic test, similar to that which is described in Code Case N-416-1 for ISI requirements. The NRC has endorsed the use of Code Case N-416-1. One of the conditions imposed by CC-N416-1 for use of a system leakage test is that the NDE requirements of the applicable subsection of ASME, Section III, 1992 Edition, be met. Since the weld configuration of the proposed weld is not addressed in Section III, no Code-required NDE can be referenced, and therefore, the proposed NDE is acceptable for this purpose. Based on the above discussion, the staff finds the performance of a system leakage test as proposed by the licensee to be an acceptable alternative to the Code-required post-repair system hydrostatic test.

As part of the preparation for the weld repair[5], the licensee's contractor fabricated a weldment for demonstrating a CRDM field repair. An examination of an as-welded cross-section revealed a defect identified by the contractor as a weld solidification anomaly. This anomaly is located where three different metals come together (triple point): Alloy 600 CRDM, carbon steel RPV, and Alloy 690 weld metal. A cross-section made of the triple point showed a void between the CRDM and RPV head extending into the weld metal. The void surface was jagged with two crack-like projections curving into the weld metal. The cross-section magnification was insufficient to identify the cause of the curved crack-like projections. The existence of the void and crack-like projections create an indeterminate condition (anomaly). Because of the limited information pertaining to the origin of the anomaly, the staff considers it a defect that must be monitored, analyzed, or a combination thereof to determine its effects on weld integrity.

In the October 30, 2001, submittal, the licensee requested relief from paragraph QW-424, "Base Metals Used for Procedure Qualifications." In lieu of the Code-required PQR for welding

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[5] See Framatome ANP, "CRDM Nozzle ID Temper Bead Weld Repair Process Qualification," BAW-2409P, September 2001.

P-No. 43 to P-No. 3 Group No. 3 with F-No. 43 filler metal, the licensee proposed using an alternative. After the October 30, 2001, submittal, the licensee performed the Code-required PQR (55-PQ7183-01) for welding P-No. 43 to P-No. 3 Group No. 3 with F-No. 43 filler metal. The licensee included PQR 55-PQ7183-01 in its submittal dated April 19, 2002. Therefore, relief from paragraph QW-424 is no longer needed.

Based on the above evaluation, the staff finds that compliance with the Code-required in-process and repair examination requirements would result in hardship or difficulty without a compensating increase in the level of quality and safety. In lieu of the Code-required repair examination, the staff finds that the licensee's proposed alternative to perform surface and ultrasonic examinations of the repair weld area is acceptable provided no anomaly exists at the triple point.

Per the 1989 Edition of ASME Section XI, Paragraph IWB-2200(a), no preservice examination is required for repairs to the 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 ISI requirement from Table IWB-2500-01, "Examination Category B-E," is a VT-2 visual inspection of the external surfaces of 25 percent of the nozzles each interval with IWB-3522 as the acceptance standard. Currently, the licensee performs visual examination, VT-2, of 100 percent of the nozzles each refueling outage. However, due to the limited experience with the repair joint configuration in CRDM penetration applications, any anomaly at the triple point must be subject to the provisions of IWB-2420(b) and (c) beginning with the next scheduled refueling outage. Bulletin 2001-01 and ongoing deliberations in Code committees will be monitored to determine the necessity of performing any additional or augmented inspections.

2.5 <u>Conclusion</u>

Based on the discussion above for Relief Requests SR-27 and SR-32, the staff has concluded that the proposed alternative to use the ambient temperature temper-bead process and the proposed in-process and post-repair examinations as described by the licensee, will assure adequate structural integrity, provided no anomaly exists at the triple point. If an anomaly exists and the licensee determines that the anomaly is acceptable for continued service, the licensee must follow the provisions of IWB-2420(b) and (c) regarding successive inspections to ensure weld integrity. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), the licensee's proposed alternative as described in Relief Requests SR-27 and SR-32 is authorized for the third 10-year interval.

3.0 <u>EVALUATION OF RELIEF REQUESTS SR-28 AND SR-33, CHARACTERIZATION OF REMAINING FLAWS</u>

The components affected by this request for relief are the Reactor Vessel Closure Head Penetrations.

3.1 <u>Code Requirements for which Relief is Requested</u>

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

- IWA-3300 states that “(a) Flaws detected by the preservice and inservice examinations shall be sized by the bounding rectangle or square for the purpose of description and dimensioning. The dimensions of a flaw shall be determined by the size of a rectangle or square that fully contains the area of the flaw....”

- IWB-3142.4 states that “Components containing relevant conditions shall be acceptable for continued service if an analytical evaluation demonstrates the component’s acceptability. The evaluation analysis and evaluation acceptance criteria shall be specified by the Owner. Components accepted for continued service based on analytical evaluation shall be subsequently examined in accordance with IWB-2420(b) and (c).”

- IWB-2420(b) states that “If flaw indications or relevant conditions are evaluated in accordance with IWB-3132.4 or IWB-3142.4, respectively, and the component qualifies as acceptable for continued service, the areas containing such flaw indications or relevant conditions shall be reexamined during the next three inspection periods listed in the schedules of the inspection programs of IWB-2410.”

- IWB-3420 states that “Each detected flaw or group of flaws shall be characterized by the rules of IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance of IWA-3500.”

3.2 Licensee’s Proposed Alternative to Code

In its October 30, 2001, submittal, the licensee stated:

> 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....

The above assumption regarding flaws was modified in the December 3, 2001, submittal, in which the licensee stated that “After the lower portion of the penetration tube is machined away and prior to repair welding, the area from ½ in. above the repaired weld to the bottom of the remnant J-groove weld will be liquid penetrant inspected. Any indications noted in the remnant weld will be recorded. Subsequent to the chamfering operation of the remnant weld, it will be assumed that a corner flaw exists equal in depth to the original J-groove weld width minus the removed material (about 1.053 inches in the worst case).”

In addition, the licensee's October 30, 2001, submittal stated:

> 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[s]. 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.

3.3 <u>Licensee's Bases for Relief</u>

The licensee provided as its basis for the relief the following:

> 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 [of the October 30, 2001, submittal]. 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 and PWR conditions. SCC of steels constraining up to 5 percent 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 (Oconee Nuclear Station) and VC Summer....
>
> 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 the submittal dated December 3, 2001, the licensee provided detailed structural evaluations of the CRDM housing weld repair at Surry 1, of the CRDM nozzle inside diameter temperbead weld anomaly, and of the flaws remaining in the J-groove weld. The licensee stated that evaluations included “configurations analyzed, loading conditions, design criteria, and code compliance. The details of stresses, cumulative usage factors, flaw tolerance and flaw growth analyses are presented. Based upon the results of these conservative analyses, the design life of the repair is predicted to be at least five years. The life of the repair is dependent on the size of the remaining J-groove weld, where the analysis conservatively postulated an initial flaw through the remaining thickness of the weld.”

3.4 Evaluation

The repair being proposed by the licensee will move the pressure boundary from the J-groove weld to the temperbead repair weld. The licensee conducted a finite element analysis of the penetration with the flaw blunting when it enters the low alloy steel vessel material. The licensee conducted a fracture mechanics analysis and proposed that the only way that the flaw could propagate was by thermal fatigue caused by heat-up/cool-down cycles and that the flaw size would remain acceptable. The licensee evaluated the possibility of debris generation as a result of leaving the flaws in service and could not find a plausible mechanism for generating debris.

The staff has determined that examination of any flaws in the J-groove weld region with volumetric methods is impractical due to the configuration. The angle of incidence from the outer surface of the closure head base material does not permit perpendicular interrogation by ultrasonic shear wave techniques of circumferentially oriented flaws and the physical proximity of the nozzle does not allow for longitudinal scrutiny of the area of interest. Cladding will provide an acoustic interface that will severely limit a confident examination of the weld material. Radiography of this area is impractical due to orientation of circumferentially oriented flaws being perpendicular to gamma and x-rays. Although dye penetrant and magnetic particle examinations will provide reference points on the surface, they can only be used for inference of crack growth.

IWA-3300(a) of the ASME Code states that flaws detected by the preservice and inservice examinations shall be sized by the bounding rectangle or square for the purpose of description and dimensioning. IWA-3300(b) of the ASME Code states that flaws shall be characterized in accordance with IWA-3310 through IWA-3390, as applicable.  IWB-3132.4(a) of the ASME Code states that components whose volumetric or surface examination reveals flaws that exceed the acceptance standards listed in Table IWB-3410-1 shall be acceptable for service without the flaw removal, repair, or replacement if an analytical evaluation, as described in IWB-3600, meets the acceptance criteria of IWB-3600.  In the case of the as left J-groove weld, the licensee has performed an analytical evaluation for a flaw based on the worst-case assumptions.

IWB-3132.4(b) of the ASME Code states where the acceptance criteria of IWB-3600 are satisfied, the area containing the flaw shall be subsequently reexamined in accordance with IWB-2420(b) and (c).  IWB-2420(b) states if the flaw indications or relevant conditions are evaluated in accordance with IWB-3132.4 or IWB-3142.4, respectively, and the component qualifies as acceptable for continued service, the areas containing such flaw indications or relevant conditions shall be reexamined during the next three inspection periods listed in the schedules of the inspection programs of IWB-2410.  The remaining flaws (if any are present) are no longer in a pressure-retaining weld and, based on industry experience, they would arrest at the junction of the clad, ferritic metal interface.  The licensee has analyzed the flaw as acceptable for continued service based on the flaw growing to this size.  Successive nondestructive examination would not provide any meaningful information as far as characterizing the flaws based on the impracticality of the examination as described above. Therefore, compliance with the specified requirements is impractical.

3.5  Conclusion

Based on the discussion above for Relief Request Nos. SR-28 and SR-33, the staff has concluded that the proposal not to completely remove the flaws discovered in the remaining J-groove partial penetration welds is acceptable.  IWA-4310 requires that the flaws be evaluated using the appropriate flaw evaluation rules of Section XI.  Since no additional inspections are planned, the flaws will not be fully characterized.  VEPCO will use worst-case assumptions to conservatively estimate the crack extent and orientation.  The postulated crack extent and orientation will be evaluated using the rules of IWB-3500.  The licensee’s actions provide assurance of structural integrity; therefore, pursuant to 10 CFR 50.55a(g)(6)(i), Relief Requests SR-28 and SR-33 are granted for the third 10-year interval.

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