January 23, 2003

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

SUBJECT: NORTH ANNA POWER STATION, UNIT 2 - ASME SECTION XI, INSERVICE INSPECTION (ISI) PROGRAM RELIEF REQUESTS NDE-048 AND NDE-049 RELATED TO REPAIR TECHNIQUE FOR REACTOR VESSEL HEAD PENETRATIONS (TAC NO. MB3204)

Dear Mr. Christian:

This letter grants the reliefs you requested from the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Section XI for North Anna Power Station, Unit 2.

By letter dated October 18, 2001, as supplemented November 9, November 16, and November 29, 2001, and May 28, 2002, Virginia Electric and Power Company submitted requests for relief from the requirements of the ASME B&PV Code, Section XI to use the embedded flaw and the ambient temperature temperbead weld repair techniques to repair the reactor vessel head penetration nozzles and J-groove welds at North Anna, Unit 2. These relief requests were identified as NDE-048 and NDE-049.

Based on our enclosed Safety Evaluation of Relief Request NDE-048, the NRC staff has concluded that using the embedded flaw technique to perform repairs to the outside diameters of the control rod drive mechanism and head vent penetrations, and to the J-groove welds of these penetrations will provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), your proposed alternative is authorized for the second 10-year ISI interval at North Anna Power Station, Unit 2.

Based on our enclosed Safety Evaluation of Relief Request NDE-049, the NRC staff concludes that your proposed alternative to use the ambient temperature temperbead weld repair technique provides an acceptable level of quality and safety. In addition, the NRC staff concludes that the Code-required radiographic examination associated with the proposed alternative is impractical to perform, and your proposed examinations provide reasonable assurance of structural integrity. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i) and 10 CFR 50.55a(g)(6)(i), the NRC staff authorizes the proposed alternative for the second 10-year ISI interval at North Anna Power Station, Unit 2. The NRC staff has determined that granting relief is authorized by law and will not endanger life or property or the common defense and security and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility.

The staff has completed its evaluation of these requests; therefore, we are closing TAC No. MB3204.

Sincerely,

/RA/

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

Docket No. 50-339

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 NDE-048 AND NDE-049

NORTH ANNA POWER STATION, UNIT 2

VIRGINIA ELECTRIC AND POWER COMPANY

DOCKET NUMBER 50-339

1.0 INTRODUCTION

By letter dated October 18, 2001, as supplemented November 9, November 16, and November 29, 2001, and May 28, 2002, Virginia Electric and Power Company (the licensee) submitted requests for relief from the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI for the North Anna Power Station, Unit 2. The licensee requested approval to use the embedded flaw repair technique (Relief Request NDE-048) and the ambient temperature temperbead weld repair technique (Relief Request NDE-049) to repair the Reactor Pressure Vessel (RPV) Head-to-Control Rod Drive Mechanism (CRDM) and Reactor Head Vent penetrations on the RPV head.

2.0 BACKGROUND

The inservice inspection (ISI) of the ASME 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 applicant 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 applicable edition of Section XI of the ASME Code for the North Anna Power Station, Unit 2, second 10-year ISI interval is the 1986 Edition.

Enclosure

3.0 RELIEF REQUEST NDE-048 - USE OF EMBEDDED FLAW REPAIR TECHNIQUE FOR UPPER HEAD CRDM AND HEAD VENT PENETRATIONS

3.1 Code Requirements for which Relief is Requested

ASME Code Section XI, subarticle IWA-4120, specifies that 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. As required by subarticle IWA-4120, any repairs would be performed in accordance with Section III of the ASME Code. The Construction Code of record for North Anna, Unit 2, is the 1968 Edition of ASME Section III with Addenda through the winter of 1968.

Subarticle NB-4453.1 of this edition of the ASME Code requires the licensee to remove the flaw prior to welding. After removal of the flaw, the excavated area must meet the acceptance standards of subarticles NB-5340 or NB-5350, which do not allow for incomplete fusion or cracks in the excavation. Finally, this area is required to be examined by either a liquid penetrant (PT) or magnetic particle (MT) method in accordance with subarticle NB-5110.

Service-induced flaws that exceed the ASME Code Section XI acceptance criteria for continued service must comply with the following requirements of subarticle IWB-3132.4, "Acceptance by Analytical Evaluation:" (a) 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 subarticle IWB-3600, meets the acceptance criteria of subarticle IWB-3600; and (b) Where the acceptance criteria of subarticle IWB-3600 are satisfied, the area containing the flaw shall be subsequently reexamined in accordance with paragraphs IWB-2420(b) and (c).

3.2 Licensee's Proposed Alternative to the Code Requirements

The licensee proposes to conduct the repairs in accordance with the 1989 Edition of ASME Code Section III without removing flaws in their entirety as required by NB-4453.1. The licensee's alternative states certain unacceptable defects, as defined by the acceptance criteria of Westinghouse Topical Report WCAP-14552, Revision 2, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: North Anna and Surry Units," will not be completely removed. The licensee proposes that the defects be embedded with a weld overlay to achieve isolation from the reactor coolant system that might cause primary water stress corrosion cracking (PWSCC).

Finally, the licensee proposes to perform one successive inspection of the embedded flaw repair areas on the J-groove weld rather than the three required by IWB-2420 of ASME Code Section XI. The licensee has requested relief from the successive inspection requirements of paragraphs IWB-2420(b) and (c) for embedded flaws.

3.3 Licensee's Basis for Relief

The licensee's request to use the embedded flaw technique to repair cracks on the inside diameter (ID) of CRDM penetration tubes was previously approved by the NRC on

February 5, 1996. Relief Request NDE-048 expands the scope of the previous submittal to include repair of cracks on the outer diameter (OD) of the penetration tubes and the J-groove attachment welds of these penetrations.

The licensee stated that the 1995 Edition of Section XI with 1996 Addendum, subarticle IWA-4611, permits the use of Section XI flaw evaluation criteria that would not require the complete removal of a flaw unless repairs were being undertaken in accordance with the temperbead welding procedures of subarticle IWA-4620, or subarticles IWA-4630 and IWA-4640 with the flaw penetrating the base metal. The flaw evaluation criteria of ASME Code Section XI, Table IWB-3514-2, established acceptance criteria for surface-connected and embedded flaws.

In response to NRC Bulletin 2001-01, “Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles,” the licensee performed visual inspection (VT) of the reactor vessel head at North Anna, Unit 2, during a mid-cycle outage in the fall of 2001. As a result of possible leakage that was identified by these inspections, the licensee performed additional inspections of the reactor vessel head. Eddy current (ET) and ultrasonic (UT) examinations were performed on the ID of CRDM penetrations, and PT examinations were performed on the OD of CRDM penetrations and J-groove welds. These inspections identified flaws at the J-groove weld to butter interface on three penetrations (63, 62, and 51) that required repair because they exceeded the ASME Code Section XI acceptance criteria. These flaws appear to be associated with the lack of fusion defects at the weld and cladding interface that have existed in the welds since original construction.

Excavation of several of the flaws performed during the fall 2001 mid-cycle outage indicate the flaws are confined to the fusion zone between the welds and the buttering. This relief request will permit the flaws on J-groove attachment welds to be repaired using embedded flaw repair techniques documented in Westinghouse Topical Report WCAP-13998, Rev. 1, “RV Closure Head Penetration Tube ID Weld Overlay Repair.” Topical Report WCAP-13998, Rev. 1, contains an evaluation of the structural integrity of the welds that shows that in the worst case only 15 percent of the fused area of the J-groove weld between the weld and the vessel head is required to satisfy ASME Code strength requirements. Regarding the three penetrations in question (63, 62, and 51), penetration 63 contained the worst-case flaws that involved approximately 30 to 40 percent of the penetration weld fusion zone, leaving 60 to 70 percent of the fused area intact.

The licensee considers the embedded flaw repair technique a permanent repair lasting through plant life extension for the following reasons. First, as long as a PWSCC flaw remains isolated from the primary water (PW) environment, it cannot propagate. Since Alloy 52 (equivalent base metal is Alloy 690) weldment is considered highly resistant to PWSCC, a new PWSCC crack should not initiate and grow through the Alloy 52 overlay to reconnect the PW environment with the embedded flaw. The resistance of the Alloy 690 material has been demonstrated by laboratory testing where no cracking of the material has been observed in simulated PWR environments. This includes approximately 10 years of operational service in steam generator tubes, where likewise no PWSCC has been found. This experience has been documented in Electric Power Research Institute (EPRI) Report TR-109136, “Crack Growth and Microstructural Characterization of Alloy 600 PWR Vessel Head Penetration Materials.” Second, the residual stresses produced by the embedded flaw technique have been measured and found to be relatively low. This implies that no new cracks should initiate and grow in the area adjacent to the repair weld. Finally, there are no other known mechanisms for significant crack propagation in this region because the cyclic fatigue loading is considered negligible based, in part, on a small cumulative usage factor (CUF). By letter dated October 18, 2001, the licensee indicated the CUF in the upper region of the head was calculated to be 0.068.

The licensee provided information stating thermal expansion properties of Alloy 52 weld metal are not specified in the ASME Code, as is the case for other weld metals. In this case, the properties of the equivalent base metal (Alloy 690) should be used. For that material, the thermal expansion coefficient at 600^{o}F is 8.2E-6 in/in/^{o}F as found in the ASME Code, Section II, Part D. The Alloy 600 base metal has a coefficient of thermal expansion of 7.8E-6 in/in/^{o}F. The effect of this small difference is that the weld metal will contract more than the base metal when it cools, thus producing a compressive stress on the Alloy 600 tube or the attachment weld, where the crack may be located. This beneficial effect has already been accounted for in the residual stress measurements reported in the technical basis for the embedded flaw repair.

The licensee considers the small residual stress produced by the embedded flaw weld to act constantly and not have any impact on the fatigue effects in the CRDM region. Since the stress would be additive to the maximum as well as the minimum stress, the stress range would not change, and the already negligible CUF, noted above, for the region would not change at all.

By letter dated November 16, 2001, the licensee stated subarticle IWB-3600, “Analytical Evaluation of Flaws,” is not applicable to the proposed embedded flaw repairs because it contains no acceptance criteria for the components and material type in question. In addition, the licensee does not believe subarticles IWB-3132 and IWB-3142 are applicable to the proposed embedded flaw repairs since these paragraphs discuss requirements related to Code-imposed examinations, based on subarticle IWB-3130, “Inservice Volumetric and Surface Examinations.” The licensee also believes that the nondestructive examinations that identified the need for embedded flaw repairs were in excess of the Code-mandated inspection for the reactor head penetration attachment welds. As a consequence of the inapplicability of subarticles IWB-3132 and IWB-3142, the licensee’s position is that subarticle IWB-2420, which deals with successive inspections, is not applicable either, since it specifically discusses flaw evaluations performed in accordance with paragraphs IWB-3132.4 or IWB-3142.4. On this basis, the licensee argues that successive inspections are not required.

3.4 Staff Evaluation

3.4.1 Rules and Code Requirements

The licensee stated that the Construction Code of record for North Anna, Unit 2, is the 1968 Edition of ASME Section III with Addenda through the winter of 1968. It proposes to conduct the repairs using the 1989 Edition of ASME Code Section III modified with alternatives that are discussed in Sections 3.2 and 3.3 of this Safety Evaluation (SE). The licensee’s basis is that IWA-4120 allows them to use a later edition of ASME Code Section III than the original Construction Code. The NRC staff’s review of the 1986 version of IWA-4120 indicates that the repairs shall be conducted to the original Construction or design Code and that later Editions and Addenda of the Construction Code or of Section III, either in their entirety or portions thereof, may be used. The NRC staff concludes that using the 1989 Edition of ASME Code Section III as the basis for conducting the repairs is acceptable.

IWA-4310 of the 1989 Edition of Section III, which was mistakenly referred to as the 1986 Edition in the licensee's submittal, dated October 18, 2001, references subarticles NB-4453, NB-5351, and NB-5352. Subarticle NB-4453 defines the removal of defects by mechanical means, reinspection of the excavation area, and repair to the guidance and acceptance criteria outlined in subarticles NB-5351 and NB-5352.

The licensee stated that subarticle IWB-3600, "Analytical Evaluation of Flaws," is not applicable to the proposed embedded flaw repairs because it contains no acceptance criteria for the components and material type in question. The NRC staff agrees that there are no analytical procedures or acceptance standards for CRDM tubes and J-groove welds since subarticle IWB-3610 addresses ferritic material greater than 4-inches thickness and austenitic piping materials under subarticle IWB-3640. However, IWB-3600 provides acceptance criteria and analytical procedures to follow when evaluating a flaw that exceeds the size of allowable flaws in subarticle IWB-3500. Pursuant to subarticle IWB-3522, for Code Category B-E, "Pressure-Retaining Partial Penetration Welds in Vessels," the acceptance criteria is no leakage. Since no flaw acceptance criteria is provided by the Code, the NRC staff concludes that the licensee is required to provide alternative acceptance criteria, which the licensee has submitted with this request for relief.

By letter dated February 5, 1996, the NRC staff approved the embedded flaw repair technique for CRDM ID flaws that exceeded the flaw acceptance criteria stated in Westinghouse Topical Report WCAP-14024, Revision 1, "Inspection Plan Guidelines for Industry/Plant Inspection of Reactor Vessel Closure Head Penetration Tubes," and Westinghouse Topical Report WCAP-14519, "RV Closure Head Penetration ID Weld Overlay Repair."

3.4.2 Flaw Evaluation

3.4.2.1 WCAP-14552

The licensee proposes to expand the previously approved embedded flaw technique to unacceptable flaws discovered on the OD of the CRDM penetration tubes in the vicinity of the J-groove weld. WCAP-14552 provides the basis for the relief request and the acceptance criteria for the licensee to apply to North Anna, Unit 2. Detailed finite element stress analyses of the CRDM penetration tubes at the outermost, next to outermost, and center locations, and a proposed crack growth rate for Alloy 600 material are used to provide input to the flaw tolerance evaluation of the tubes.

Because circumferential cracking above the J-groove weld has the potential to pose a safety risk due to the possibility of CRDM ejection, WCAP-14552 proposes to treat circumferential cracking at and above the J-groove weld on a case-by-case basis. As a result, the NRC staff will not consider information related to these circumferential cracks in WCAP-14552 as relevant to the relief request. This evaluation will only discuss ID and OD circumferential cracks below the J-groove weld and ID and OD axial cracks at various locations. The NRC staff has completed the review of WCAP-14552, and with the exception of the crack growth rate (CGR) and the proposed repair for axial OD flaws on and extending into the J-groove weld, the NRC staff found the following to be acceptable:

The maximum allowable depth for continuous flaws on the ID of the penetration at or above the weld is 75 percent of the penetration wall thickness. WCAP-14552 states that axial ID flaws found below the J-groove weld are acceptable regardless of depth as long as their upper extremity does not reach the bottom of the weld during the period of service until the next inspection. Axial flaws that extend above the weld are limited to 75 percent of the wall thickness. Axial flaws on the OD of the penetration below the J-groove weld are acceptable regardless of depth, as long as they do not extend into the J-groove weld during the period of service until the next inspection. Axial OD flaws above the J-groove weld must be evaluated on a case-by-case basis and must be discussed with the NRC.

WCAP-14552 further states that circumferential flaws located below the weld are acceptable regardless of their depth, provided the length is less than 75 percent of the circumference for the period of service until the next inspection. Intersecting axial and circumferential flaws shall be removed or repaired due to loose parts concerns. Circumferential flaws at and above the weld must be discussed with the NRC staff on a case-by-case basis. Finally, flaws located in the J-groove welds themselves are not acceptable regardless of their depth. This is because the crack propagation rate is several times faster than that of the Alloy 600 tube material, and also because depth sizing capability does not yet exist for indications in the weld. Regarding possible repair methods, WCAP-14552 mentioned flaw excavation and the embedded flaw repair as possible methods of disposition for flaws found in the J-groove weld but did not provide any recommendations.

As to the CGR, the NRC staff considers the proposed CGR for Alloy 600 material under PWSCC environment to be unacceptable. WCAP-14552 proposed an equation, $da/dt = 1.473 \times 10^{-12} (K - 9)^{1.16}$ m/sec, to calculate the crack growth in Alloy 600 due to PWSCC, where K is the stress intensity factor for the assumed flaw. The proposed equation is based on a crack growth model developed by Peter Scott of Framatome for pressurized-water reactor (PWR) steam generator materials. Peter Scott developed a crack growth equation, $da/dt = 2.8 \times 10^{-11} (K - 9)^{1.16}$ m/sec, by fitting the test data reported by McIlree and Smialowska. McIlree and Smialowska's testing was performed at a temperature of 330°C on flattened steam generator tubes. The licensee divided Scott's equation by a factor of 10 to account for the effect of cold working. The licensee further corrected the Scott equation by a factor of 0.526 to adjust for the change in the operating temperature of 330°C to the North Anna and Surry head penetration temperature of 316°C. The temperature correction factor is derived by using an activation energy of 33 Kcal/mole.

The NRC staff has determined that the licensee's proposed equation to calculate the crack growth rate in RPV head penetrations, which are made of Alloy 600 materials, at the North Anna and Surry Units is not conservative since it is based upon a limited database. The licensee referenced only one Westinghouse test program to support the use of the proposed equation for the head penetration material. Furthermore, there is a large scatter in the database that was used to support the evaluation of the temperature dependency of the CGR. In view of the concerns discussed above, the NRC staff concludes that conservatism should be applied to the proposed crack growth equation so that the resulting CGR is approximately the 75th percentile curve of the materials reliability program (MRP) database for Alloy 600 material, with ASME Code margins applied and a bounding value of stress intensity. Thus, the acceptable interim crack growth equation for the calculation of crack growth in Alloy 600 RPV head penetrations at the North Anna and Surry Units is $da/dt = 2.67 \times 10^{-12} (K - 9)^{1.16}$ m/sec.

The MRP Alloy 600 Issue Task Group has proposed a crack growth equation for Alloy 600 material exposed to PWR primary water environment. The NRC staff is currently evaluating the adequacy of the proposed equation for crack growth calculation. After completion of the evaluation, the NRC staff will endorse a crack growth equation that can be used for the calculation of crack growth in Alloy 600 material due to PWSCC. During the interim, the licensee should use the crack growth equation as stated above.

3.4.2.2 NDE-048

The NRC staff reviewed the licensee's alternative approach to determine if it took into consideration the guidelines of WCAP-14552 that are acceptable to the NRC staff when considering the appropriate repairs with respect to flaw orientation and location. For instance, the licensee stated that they would completely remove postulated OD circumferential flaws found in the J-groove weld and the resultant cavity would be repaired with Alloy 52. The NRC staff considers this approach conservative because it is responsive to the higher failure rates encountered in the J-groove weld. Furthermore, performing a weld repair after complete removal of the J-groove circumferential flaw removes safety concerns for CRDM ejection and is, therefore, acceptable.

In addition, the licensee proposed to overlay unacceptable OD axial or circumferential flaws below the J-groove weld with Alloy 52 without excavating the flaw. This approach did not require machining because clearance for CRDM internals was not an issue as it was with ID-related repairs. The NRC staff considered this approach reasonable because (1) it removes the flaws from the environment (seal weld), (2) it prevents loose parts issues should a portion of the CRDM tube break away due to a through-wall flaw, and (3) the CUF was low in the upper head region with low cyclic fatigue loading. Furthermore, by letter dated November 16, 2001, the licensee provided information that indicated that the flaw will be placed in a compressive stress field after seal welding due to differences in thermal expansion properties between the weld metal and base metal. Based on the above, the NRC staff concludes that applying the seal weld over CRDM tube OD flaws below the J-groove weld area provides an acceptable level of quality and safety.

3.4.2.3 Applying the Embedded Flaw Technique

Based on the NRC staff's evaluation of the licensee's application of the embedded flaw technique to the CRDM penetration tube repair as stated above, the NRC staff has made the following conclusions as described in the paragraphs below.

ID Axial Flaws

The embedded flaw repair technique can be applied to the ID axial flaws. The proposed excavation and weld repair using Alloy 52 weldment would isolate the remaining crack from the effects of PWSCC and prevent future crack growth. The interim crack growth rate stated in Section 3.4.2.1.1 of this SE shall be used to ensure that an ID axial crack will not grow to 75 percent of the tube thickness at the next scheduled inspection should the licensee choose not to apply the weld repair.

OD Axial or Circumferential Flaw Below the J-groove Weld

The embedded flaw repair technique can be applied to the OD axial or circumferential flaw below the J-groove weld because this type of OD crack is located at a distance from the pressure boundary, and the proposed repair method of sealing off the crack with Alloy 52 weldment would isolate the crack from the effects of PWSCC. The interim crack growth rate stated by the NRC staff in Section 3.4.2.1 shall be used to ensure that an axial crack will not reach the J-groove weld, and a circumferential crack will not exceed 75 percent of the tube circumference should the licensee choose not to apply the weld overlay.

Radial OD Flaws on the J-groove Weld

The embedded flaw repair technique can be applied to radial OD flaws on the J-groove weld only when the licensee can demonstrate by UT that (1) the crack front of the radial OD flaw does not reach the annulus or the tube OD, and (2) there is no circumferential crack segment being developed inside the J-groove weld from the radial OD crack shown on the surface of the J-groove weld. This ensures that no damage has been made to the vessel head or tube OD even after the crack front of the radial OD flaw has reached the annulus or the interface between the J-groove weld and the penetration tube, and ensures that no circumferential crack segment has developed inside the J-groove weld. Since current UT technology has not demonstrated the capability of detecting/sizing flaws in the J-groove weld, it is expected that excavation shall be performed to such an extent that further excavation would have a negative impact to the structural integrity of the tube and the subsequent weld repair.

Axial OD Flaws Extending into the J-groove Weld

For this type of flaw, the focus is not on the crack segment on the tube OD, but on the segment inside the J-groove weld. Therefore, the disposition of axial OD flaws extending into the J-groove weld shall be the same as that specified above for the radial OD flaws on the J-groove weld, with the understanding that the proposed embedded flaw repair techniques are different for these two types of flaws.

The NRC staff concludes that excavation of any flaws in the J-groove weld is appropriate because of: (1) the inability of current UT technology to detect and size flaws in the J-groove weld; (2) difficulty of the current UT technology to determine if a circumferential crack segment is growing from an axial flaw in the J-groove weld; (3) potentially very high CGRs in the J-groove welds, which make prediction to critical flaw size difficult; and (4) consistency with the statement in WCAP-14552 where flaws located in the attachment welds themselves are not acceptable regardless of their depth because of higher CGR than the Alloy 600 tube material and limited depth sizing capability by UT.

3.4.3 Future Inspections

In its alternative, the licensee's original position was that successive inspections of the repaired areas were not required. The licensee stated it does not consider subarticles IWB-3132 and IWB-3142 to be applicable to the proposed embedded flaw repairs because these paragraphs discuss requirements related to Code-imposed examinations "as is clear" from their location in subarticle IWB-3130. The licensee's interpretation is that the examinations that are being performed, which may identify the need to perform embedded flaw repairs, are in excess of the

Code-mandated inspection for the reactor head penetrations and attachment welds. In addition, the licensee stated that the inservice examination requirements of Table IWB-2500-1 mandate a VT, from above the insulation, for 25 percent of the penetration welds using IWB-3522 as the acceptance standard (no leakage allowed). The licensee indicated that there was no ISI requirement for followup inspections of the repaired areas. However, to demonstrate the effectiveness of the repair, the licensee agreed to perform a UT on the OD of the penetration that is located immediately above any J-groove weld where an embedded flaw repair had been performed.

Although the NRC staff position differs from the licensee's proposal, the end result is still the same. The Code requires successive inspections performed when an unacceptable flaw is analyzed as acceptable for continued service. In the licensee's proposed alternative, the unacceptable flaw (as defined by the licensee) has a seal weld over it to prevent further growth and to make it acceptable for continued service. The NRC staff's position is neither the 1989 Edition of ASME Code Section XI nor ASME Code Section III permit a weld repair over, or to embed, an existing flaw. Furthermore, under ASME Code Section XI, any unacceptable flaws that are determined to be acceptable for continued service must be reexamined for three successive inspection periods to monitor for change in the size of the flaw. Taking into consideration the unacceptable flaw is still present but the seal weld has placed the flaw in compression and sealed it from the environment, the NRC staff concludes the licensee's proposed alternative of one successive UT inspection provides reasonable assurance of continued structural integrity of the area above the J-groove weld and is, therefore, acceptable. This approval is not to be construed as approval to perform repairs of circumferential flaws above the J-groove weld. As stated earlier, these repairs must be discussed with the NRC staff on a case-by-case basis.

In its submittal dated November 16, 2001, the licensee committed to perform one successive inspection of the CRDM penetrations and, where applicable, J-groove welds using PT, UT, and VT. These inspections were to be conducted during the next inspection period to monitor the behavior of the embedded flaws. The NRC staff finds this to be acceptable. The licensee also considered the embedded flaw technique to be a permanent repair lasting through plant life extension. However, due to the limited operational history for this type of repair, the NRC staff would normally require additional inspection history before obtaining a conclusion regarding the long-term effectiveness of the repair method.

NRC Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs," dated August 9, 2002, suggested that licensees perform additional inspections of the reactor vessel heads. As a result of the inspections conducted at North Anna, Unit 2, the licensee, in a letter dated October 18, 2002, committed to replacing the reactor vessel head during the fall 2002 refueling outage at North Anna, Unit 2. Since the repaired areas have been eliminated, the NRC staff has determined that future inspections will be conducted consistent with the provisions of Bulletin 2002-02.

3.5 Conclusion

Based on the discussion above for relief request NDE-048, the NRC staff has concluded that using the embedded flaw technique to perform repairs to the outside diameters of the CRDM and head vent penetrations and to the J-groove welds of these penetrations will provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the licensee's proposed alternative is authorized for the second 10-year ISI interval at the North Anna Power Station, Unit 2.

4.0 RELIEF REQUEST NDE-049 - USE OF AMBIENT TEMPERATURE TEMPERBEAD WELD REPAIR FOR UPPER HEAD CRDM AND HEAD VENT PENETRATIONS

4.1 Code Requirements for which Relief is Requested

The Construction Code of record for the North Anna, Unit 2, reactor vessel and head is the 1968 Edition of ASME Code Section III with Addenda through the winter of 1968. North Anna, Unit 2, is currently in its second inspection interval using the 1986 Edition of ASME Code Section XI. ASME Code Section XI, subarticle IWA-4120 specifies 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 ASME Section III, either in their entirety or portions thereof, and Code Cases may be used.

The licensee has chosen to use the 1989 Edition of ASME Code Section III for repairs.

North Anna, Unit 2, conducted VTs of the reactor vessel head during an outage in the fall of 2001. These VTs identified potential penetration nozzle leakage that resulted in additional under-the-head inspections being performed. Subsequent under-the-head inspections of the reactor vessel head penetrations revealed flaws in three penetrations (63, 62, and 51) that required repair as the flaws exceeded the ASME Code Section XI acceptance criteria. Specifically, subarticle IWA-4310 requires the repair of any flaw associated with the J-groove weld attaching the penetration to the head that cannot be accepted by the rules of the original Construction Code. In addition, subarticle IWA-4120 requires that repair welding must be done in accordance with the original Construction Code. Subarticle NB-4622 of Section III requires a postweld heat treatment (PWHT) for the repair weld, or the use of a temperbead weld technique, for any J-groove weld excavation that results in a repair within 1/8 inch of the ferritic material of the vessel head. Subparagraphs NB-4622.1 though NB-4622.8 define the controls necessary when performing a PWHT for a repair weld.

4.2 Licensee's Proposed Alternative to Code

The licensee states the PWHT parameters required by subarticle NB-4622 would be difficult to achieve on a reactor vessel head in containment and poses risk of distortion to the geometry of the head and vessel head penetrations. The temperbead procedure requirements, including preheat and postweld heat soaks contained in subarticle NB-4622, 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. Since the licensee proposed to utilize a temperbead weld procedure, the majority of the PWHT control requirements as stated in the subparagraphs of subarticle NB-4622 no longer apply.

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 the 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 gas tungsten arc welding (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, and requires the temperature of the area to be welded to be at least 50°F prior to welding. These limitations have been demonstrated to be adequate to produce sound welds.

NB-4622.11(d)(2) and NB-4453.4 require PT and radiographic test (RT) of the repair welds after a minimum time of 48 hours at ambient temperature. UT 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 PT and UT, if practical.

4.3 Licensee's Basis for Relief

The proposed alternative will require the use of an automatic or machine GTAW temperbead technique without the specified preheat or PWHT of the Construction Code. The proposed alternative will include the requirements stated in the licensee's submittal of October 18, 2001, Enclosure 1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temperbead Technique," that also specifies all other requirements of article IWA-4000 be met. The alternative may be used to make repairs to P-Nos. 1, 3, 12A, 12B, and 12C (except SA-302 Grade B) material and their associated welds, and P-No. 8 and P-No. 43 material to P-Nos. 1, 3, 12A, 12B, and 12C (except SA-302 Grade B) material. In this case, the reactor vessel head is a P-No. 3 material and the affected welds are those J-groove welds attaching the P-No. 43 vessel head penetrations to the vessel head. The J-groove welds were made with F-No. 43 filler material.

The use of a GTAW temperbead welding technique to avoid the need for PWHT is based on research that has been performed by EPRI and other organizations. EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temperbead Applications," dated November 1998, demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the heat-affected zones (HAZs) 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 postheats, as well as with no preheat and postheat. From that data, it is clear that equivalent toughness is achieved in base metal and HAZs in both cases.

The temperbead process has been shown to be effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed. Many acceptable Procedure Qualification 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. 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.

The subarticle 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 subarticle NB-4622 temperbead procedure requires the use of the SMAW welding process with covered electrodes. Even the low hydrogen electrodes, which are required by subarticle 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, subarticle 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 part per million (ppm) of Hydrogen (H_2) and no more than 0.5 ppm of water vapor (H_20). A typical argon flow rate would be about 55 cubic feet/hour 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.

After the electrical discharge machining process has been used to prepare the excavation for welding, the repair excavation and surrounding area would be cleaned by wire brushing to assure it is free of dust, sediments, oxides, boric acid residue, etc. Quartz halogen heat lamps would then be used to heat the area and ensure it is moisture-free. The F-No. 43 (ERNiCrFe-7) filler metal that would be used for the repairs is not subject to hydrogen embrittlement cracking.

Final examination of the repair welds would be a surface examination that 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.

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 produced ductile breaks in the weld metal. A typical set of Charpy test values showed average absorbed energies and lateral expansions of 76 ft-lbs and 45 mils for the base metal (a P-No. 3 GR. 3 material), 114 ft-lbs and 57 mils for the HAZ, and 254 ft-lbs and 84 mils for the weld metal (a F-No. 43 filler metal). It is clear from these results that the ambient temperature GTAW temperbead process has the capability of producing acceptable repair welds.

Procedure qualification, performance qualification, WPSs, examination, and documentation requirements would be as stipulated in the proposed alternative procedure.

By letter dated October 18, 2001, the licensee concluded that its proposed alternative ambient temperature temperbead weld technique provided sound and permanent repairs, and that the proposed relief is an alternative to Code requirements that will provide an acceptable level of quality and safety.

4.4 Staff Evaluation

The 1989 Edition of ASME Code Section III, paragraph NB-4622.11, “Temper Bead Weld Repair to Dissimilar Metal Welds or Buttering” 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 paragraphs NB-4622.11(a) through (g) are met.

The requirements of subarticles NB-4451, 4452, 4453, and 4622 of the 1989 Edition of ASME Code Section III are also applicable to the contemplated repairs. As an alternative to the PWHT time and temperature requirements of subarticle NB-4622, the requirements of “Similar and Dissimilar Metal Welding Using Ambient Using Ambient Temperature Machine GTAW Temper Bead Technique,” will be used. Specifically, alternatives are being proposed for the following subparagraphs of ASME Code Section III, subarticle NB-4622:

NB-4622.1 establishes the requirement for PWHT of welds, including repair welds. In lieu of the requirements of this subparagraph, the licensee proposes to utilize a temperbead weld procedure, obviating the need for post-weld 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 the 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 PWSCC-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 NB-4622.7(a) through NB-4622.7(f) are not applicable in this case because they pertain to conditions that do not exist for the proposed repairs. Sub-subparagraph NB-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 piping welds. Sub-subparagraph NB-4622.8(a) establishes criteria for exemption of PWHT for partial penetration welds. This is not applicable to the proposed repairs because the criteria involve buttering layers at least 1/4-inch thick that will not exist for the welds in question. Sub-subparagraph NB-4622.8(b) also does not apply because it discusses full-penetration welds, and the welds in question are specially designed pressure boundary structural 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 of 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 Article NB-5000 (NB-4622.11(d)(3)). The proposed alternative will include surface examination prior to repair consistent with Article NB-5000.

Sub-subparagraph NB-4622.11(b) contains requirements for the maximum extent of repair. 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 Code Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy these requirements. In addition, sub-paragraph NB-4622.11(c) requires the WPS include the following requirements:

NB-4622.11(c)(1) requires the area that will be welded to 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 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 sub-subparagraph 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 this requirement.

NB-4622.11(c)(7) requires the preheated area to be heated from 450°F to 660°F for a minimum period of 4 hours. 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 sub-subparagraph 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 to 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 sub-subparagraph 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) and NB-4453.4 require PT and RT of the repair welds after a minimum of 48 hours at ambient temperature. UT is required to be performed, if practical. The proposed alternative includes the requirement to inspect after a minimum of 48 hours at ambient temperature. The geometry of the RPV head and the orientation of the inner bore of the CRDM nozzles make effective RT impractical. The thickness of the RPV head limits the sensitivity of the detection of defects in the new pressure boundary weld. The density changes between the base and weld metal and residual radiation from the base metal would render the film image inconclusive. Due to the high area dose, which would cause fogging of the film and changing radius of the pressure vessel head, which would cause a geometric unsharpness condition, the NRC staff concludes that RT is impractical for this type of repair.

NB-4622.11(e) establishes the requirements for documentation of the weld repairs in accordance with subarticle 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. In addition, the location of the V-notch for the Charpy test is more stringently controlled in the proposed alternative than in subarticle NB-4622.11(f).

NB-4622.11(g) establishes requirements for the welder's 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 Code 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.

The use of a GTAW temperbead welding technique to avoid the need for PWHT is based on research that has been performed by EPRI and other organizations. The research demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the HAZ of the base material and preceding weld passes. Data presented in the EPRI report show the results of procedure qualifications performed with 300^{o}F preheats and 500^{o}F preheats, as well as with no preheat and postheat. From that data, it is clear in both cases that equivalent toughness is achieved in base metal and HAZs. The temperbead process has been shown effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed. Many acceptable PQRs and WPSs presently exist and have been utilized to perform numerous successful repairs. The use of the automatic or machine GTAW process that is utilized for temperbead welding allows for more precise control of heat input, bead placement, and bead size and contour than the manual SMAW process required by subarticle 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.

4.5 Conclusion

Based on the discussion above for Relief Request NDE-049, the NRC staff concludes that the licensee's proposed alternative to use the ambient temperature temperbead weld repair for the CRDM and head vent penetrations and to the J-groove welds of these penetrations will provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the NRC staff authorizes the proposed alternative for the second 10-year ISI interval at the North Anna Power Station, Unit 2. The NRC staff also concludes that the Code-required radiographic examination associated with the proposed alternative is impractical to perform, and the licensee's proposed examinations provide reasonable assurance of structural integrity. Therefore, relief is granted pursuant to 10 CFR 50.55a(g)(6)(i) for the second 10-year ISI interval. The NRC staff has determined that granting relief is authorized by law and will not endanger life or property or the common defense and security and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility.

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