September 29, 2004

Mr. Jeffrey S. Forbes
Site Vice President
Arkansas Nuclear One
Entergy Operations, Inc.
1448 S. R. 333
Russellville, AR 72801

SUBJECT: ARKANSAS NUCLEAR ONE, UNIT NO. 1 - RE: PROPOSED ALTERNATIVES TO WELD REPAIR AND EXAMINATION REQUIREMENTS FOR REPAIRS ON REACTOR VESSEL HEAD PENETRATION NOZZLES (TAC NO. MB9660)

Dear Mr. Forbes:

By letter dated June 6, 2003, as superseded by letter dated February 23, 2004, as supplemented by letters dated March 4, April 8 and 12, May 3 and 4, June 1, and September 16, 2004, Entergy Operations, Inc. (Entergy), submitted two requests for relief from the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Sections III and XI as applied to reactor pressure vessel head penetration nozzles at Arkansas Nuclear One, Unit 1 (ANO-1). Specifically, in ANO1-R&R-005 and ANO1-R&R-006, Entergy proposed using an alternative ambient temper bead welding method and alternatives to ASME Code nondestructive examinations and flaw evaluation requirements.

The U.S. Nuclear Regulatory Commission (NRC) staff has completed its review as documented in the enclosed Safety Evaluation (SE). For relief request number ANO1-R&R-005, the NRC staff determined that the alternative provides an acceptable level of quality and safety. For relief request number ANO1-R&R-006, the NRC staff determined that complying with the Code requirement would be impractical and the proposed inspection provides reasonable assurance of structural integrity of the reactor vessel head. Therefore, relief request number ANO1-R&R-005 is authorized pursuant to 50.55a(a)(3)(i) of Title 10 of the *Code of Federal Regulations* (10 CFR) and ANO1-R&R-006 is granted pursuant to 10 CFR 50.55a(g)(6)(i) for the third 10-year inservice inspection interval through the fall 2005 refueling outage. The NRC staff determined that granting relief pursuant to 10 CFR 50.55a(g)(6)(i) 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.

Pursuant to 10 CFR 2.390, the NRC staff determined that the enclosed SE does not contain proprietary information. However, we will delay placing the SE in the public document room for ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects only. If you believe that any information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.390.

In its review of the need for the reliefs during the past refueling outage, the NRC staff verbally authorized the use of ANO1-R&R-005 and ANO1-R&R-006 on May 6, 2004, due to the undue regulatory burden associated with the delay inherent in a written authorization. This letter documents our written authorization.

Sincerely,

/RA by M. Webb for R. Gramm/

Robert A. Gramm, Chief, Section 1
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-313

Enclosure: As stated

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

INSERVICE INSPECTION PROGRAM

RELIEF REQUESTS NOS. ANO1-R&R-005 AND ANO1-R&R-006

ENTERGY OPERATIONS, INC.

ARKANSAS NUCLEAR ONE, UNIT NO. 1

DOCKET NO. 50-313

1.0 INTRODUCTION

By letter dated June 6, 2003, as superseded by letter dated February 23, 2004, as supplemented by letters dated March 4, April 8 and 12, May 3 and 4, June 1, and September 16, 2004, Entergy Operations, Inc. (Entergy or the licensee) requested relief from certain welding repair requirements for repair of its reactor pressure vessel (RPV) head at Arkansas Nuclear One, Unit 1 (ANO-1). Specifically, the licensee requested relief from the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section III, 1989 Edition, NB-4622 and NB-5330(b). NB-4622 requires a post-weld heat treatment (PWHT) and NB-5330(b) prohibits weld flaw indications characterized as cracks, lack of fusion, or incomplete penetration. The licensee also sought relief from ASME Code, Section XI, 1992 Edition, IWA-4310 that requires defects be removed or reduced to an acceptable size. For NB-4622, the licensee proposed a repair using a remotely operated, gas tungsten-arc welding (GTAW) process. The licensee's proposed repair utilizes an ambient temperature temper bead method with a 50°F minimum preheat temperature and no PWHT. For NB-5330(b), the licensee proposes to use an analytical evaluation on flaws that would otherwise be prohibited by NB-5330(b). For IWA-4310, the licensee proposes that, defects not removed from the original J-groove weldment would be analytically evaluated for acceptability using a postulated worst-case scenario.

2.0 REGULATORY EVALUATION

The Inservice Inspection (ISI) of the ASME 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 50.55a(g) of Title 10 of the *Code of Federal Regulations* (10 CFR), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). The regulation at 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) twelve months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein. The ISI Code of record for ANO-1 third 10-year ISI interval is the 1992 Edition of ASME Section XI. The original code of construction for ANO-1 is ASME Section III, 1965 Edition with the Addenda through summer 1967. The applicable edition of ASME Section III for the third 10-year interval at ANO-1 is the 1989 Edition.

3.0 TECHNICAL EVALUATION: RELIEF REQUEST NO. ANO1-R&R-005, REVISION 0, REACTOR PRESSURE VESSEL HEAD NOZZLE TEMPER BEAD WELDING REPAIRS

3.1 System/Components for Which Relief is Requested

The proposed Relief Request No. ANO1-R&R-005 applies to all 69 RPV head nozzles. Specifically, this request pertains to ambient temperature temper bead welding repair of RPV head penetration nozzles by creating a new pressure boundary weld that is used to attach the nozzle to the RPV head.

The RPV head and RPV head nozzles are ASME Class 1 components. The ASME examination category, per ASME Section XI, is B-E, Pressure Retaining Partial Penetration Welds in Vessels, Item No. B4.12.

3.2 Code Requirements for which Relief is Requested

The 1992 Edition of ASME Section XI, paragraph IWA-4170(b) states:

> “Repairs and installation of replacement items shall be performed in accordance with the Owner's Design Specification and the original Construction Code of the component or system. Later editions and addenda of the construction code or of Section III, either in their entirety or portions thereof, and Code Cases may be used. If repair welding cannot be performed in accordance with these requirements, the applicable alternative requirements of IWA-4200 and IWA-4400 or IWA-4500 may be used.”

Because of the risk of damage to the RPV head material properties or dimensions, it is not feasible to apply the post weld heat treatment requirements of paragraph NB-4622 of the 1989 ASME Section III Code to the RPV head. The alternative temper bead methods (IWA-4500 and

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

3.3 Licensee's Proposed Alternative

Entergy will examine RPV head nozzles in accordance with NRC Order EA-03-009, *Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors*. [The NRC staff notes that *First Revised NRC Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors* was issued on February 20, 2004, and applies to all RPV nozzles inspections performed after its issue.] The use of any of the alternatives permitted by the applicable ASME Codes for repairs will result in increased radiation dose with no compensating increase in quality or safety. The post-weld heat treatment (PWHT) parameters required by NB-4622 would be difficult to achieve on a RPV head in containment and would pose significant risk of distortion to the geometry of the RPV head and RPV head nozzles. In addition, the existing J-groove welds would be exposed to PWHT for which they were not qualified. This request applies to any nozzle requiring repair by the methods described herein.

Entergy has determined that compliance with the specified requirements would result in unusual difficulty or hardship without a compensating increase in the level of quality. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), Entergy requests authorization to use an ambient temperature temper bead method of repair as an alternative to the requirements of the 1989 Edition of ASME Section III, NB-4622 as defined in Attachment 1 [of ANO1-R&R-005 dated February 23, 2004], "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." This alternative uses a remotely operated weld tool utilizing the machine gas tungsten-arc welding (GTAW) process and the ambient temperature temper bead method with 50°F minimum preheat temperature and no PWHT. The repairs will be conducted in accordance with the 1992 Edition of ASME XI (as applicable), the 1989 Edition of Section III (as applicable), and alternative requirements discussed below. A list of the most applicable articles, subarticles, paragraphs, and subparagraphs of ASME Section III and Section XI is given below.

NB-4331 establishes the requirement that all welding procedure qualification tests be in accordance with the requirements of ASME Section IX as supplemented or modified by the requirements of NB-4331. The welding procedure has been qualified in accordance with the requirements of paragraphs 2.0 and 2.1 of Attachment 1 [of ANO1-R&R-005 dated February 23, 2004]. These two paragraphs are modeled on ASME Code Case N-638 and include the additional requirements of ASME Section III Paragraph NB-4335.2. No alternative to the requirements of NB-4331 is needed or proposed.

NB-4622.1 establishes the requirement for PWHT of welds including repair welds. In lieu of the requirements of this subparagraph, Entergy proposes to utilize a temper bead 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 this subparagraph will not apply because the proposed alternative does not involve PWHT.

NB-4622.3 discusses the definition of nominal thickness as it pertains to time-at-temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.4 establishes the holding times at temperature for PWHT. The subparagraph is not applicable in this case because the proposed alternative involves no PWHT.

NB-4622.5 establishes PWHT requirements when different P-number materials are joined. This subparagraph is not applicable because the proposed alternative involves no PWHT.

NB-4622.6 establishes PWHT requirements for non-pressure-retaining parts. The subparagraph is not applicable in this case because the potential repairs in question will be to pressure retaining parts. Furthermore, the proposed alternative involves no PWHT.

NB-4622.7 established exemptions from mandatory PWHT requirements. 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. NB-4622.7(g) discusses exemptions to weld repairs to dissimilar metal welds if the requirements of NB-4622.11 are met. As described below, the ambient temperature temper bead repair is being proposed as an alternative to the requirements of NB-4622.11.

NB-4622.8 establishes exemptions from PWHT for nozzle-to-component welds and branch connection-to-run piping welds. 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, which will not exist for the welds in question. NB-4622.8(b) also does not apply because it discusses full penetration welds and the welds in question are partial penetration welds.

NB-4622.9 establishes requirements for temper bead repairs to P-No. 1 and P-No. 3 materials and A-Nos. 1, 2, 10, or 11 filler metals. The subparagraph does not apply in this case because the proposed repairs will involve F-No. 43 filler metals using GTAW instead of Shielded Metal Arc Welding (SMAW).

NB-4622.10 establishes requirements for repair welding to cladding after PWHT. The subparagraph does not apply in this case because the proposed repair alternative does not involve repairs to cladding.

NB-4622.11 discusses temper bead weld repair to dissimilar metal welds or buttering. The ambient temperature temper bead repair is being proposed as an alternative to the requirements of subparagraph NB-4622.11. As described below, elements of NB-4622.11 are incorporated into the proposed alternative.

- NB-4622.11(a) requires surface examination prior to repair in accordance with NB-5000. The proposed alternative will include surface examination prior to repair consistent with NB-5000.

- NB-4622.11(b) contains requirements for the maximum extent of repair including a requirement that the depth of excavation for defect removal not exceed 3/8 inch in the base metal. The proposed alternative includes the same limitations on the maximum extent of repair.

- NB-4622.11(c) discusses the repair welding procedure and requires procedure and welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy this requirement. In addition, NB-4622.11(c) requires that the Welding Procedure Specification (WPS) include the following requirements:

    - NB-4622.11(c)(1) requires the area to be welded be suitably prepared for welding in accordance with the written procedure to be used for the repair. The proposed alternative will satisfy this requirement.

    - NB-4622.11(c)(2) requires the use of the SMAW process with covered electrodes meeting either the A-No. 8 or F-No. 43 classifications. The proposed alternative utilizes GTAW with weld filler metals meeting F-No. 43 classifications.

    - NB-4622.11(c)(3) discusses requirements for covered electrodes pertaining to hermetically sealed containers or storage in heated ovens. These requirements do not apply because the proposed alternative uses weld filler metals that do not require storage in heated ovens since weld GTAW bare filler metals 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 weld filler metals, which do not require any special storage conditions to prevent the pick up of moisture from the atmosphere.

- ➢ NB-4622.11(c)(5) requires preheat to a minimum temperature of 350ºF prior to repair welding, a maximum interpass temperature of 450ºF and that thermocouples and recording instruments shall be used to monitor the metal temperature during welding. The proposed ambient temperature temper bead alternative does not require an elevated temperature preheat and interpass will be limited to 350°F. Because of the massive structure involved in the assembly, the absence of preheat and the complex configuration, thermocouples will not be used to monitor metal temperature.

- ➢ NB-4622.11(c)(6) establishes requirements for shielded metal arc electrode diameters for the first, second, and subsequent layers of the repair weld and requires removal of the weld bead crown before deposition of the second layer. Because the proposed alternative uses the machine GTAW process, the requirement to remove the weld crown of the first layer is unnecessary and the proposed alternative does not include the requirement.

- ➢ NB-4622.11(c)(7) requires the preheated area to be heated to 450°F to 660°F for four (4) hours after a minimum of 3/16 inch of weld metal has been deposited. The proposed alternative does not require this heat treatment because the use of the extremely low hydrogen GTAW temper bead procedure does not require the hydrogen bake-out.

- ➢ NB-4622.11(c)(8) requires welding subsequent to the hydrogen bake out of NB-4622.11(c)(7) be done with a minimum preheat of 100°F and maximum interpass temperature of 350°F. The proposed alternative limits the interpass temperature to a maximum of 350°F and requires the area to be welded be at least 50°F prior to welding. These limitations have been demonstrated to be adequate for the production of sound welds.

! NB-4622.11(d)(1) requires a liquid penetrant examination after the hydrogen bake-out described in NB-4622.11(c)(7). The proposed alternative does not require the hydrogen bake-out because it is unnecessary for the low hydrogen GTAW temper bead welding process.

! NB-4622.11(d)(2) requires liquid penetrant and radiographic examinations of the repair welds after a minimum time of 48 hours at ambient temperature. Ultrasonic inspection is required if practical. The proposed alternative includes the requirement to inspect after a minimum of 48 hours at ambient temperature. Because the proposed repair welds are of a configuration that cannot be radiographed, final inspection will be by liquid penetrant and ultrasonic inspection.

! NB-4622.11(d)(3) requires that all nondestructive examination be in accordance with NB-5000. The proposed alternative will comply with NB-5000 except that the progressive liquid penetrant inspection required by NB-5245 will not be done. In lieu of the progressive liquid penetrant examination, the proposed alternative will use liquid penetrant and ultrasonic examination of the final weld.

! NB-4622.11(e) establishes the requirements for documentation of the weld repairs in accordance with NB-4130. The weld repair will be documented in accordance with NB-4130.

! NB-4622.11(f) establishes requirements for the procedure qualification test plate relative to the P-No. and Group Number and the postweld heat treatment of the materials to be welded. The proposed alternative meets and exceeds 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).

! NB-4622.11(g) establishes requirements for welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs, which is particularly pertinent to the SMAW manual welding process. The proposed alternative involves a machine GTAW process and requires welding operators be qualified in accordance with ASME Section IX. The use of a machine process eliminates concern about obstructions, which might interfere with the welder's abilities since these obstructions will have to be eliminated to accommodate the welding machine.

NB-4453.4 of Section III requires examination of the repair weld in accordance with the requirements for the original weld. The welds being made per the proposed alternatives will be partial penetration welds as described by NB-4244(d) and will meet the weld design requirements of NB-3352.4(d). For these partial penetration welds, paragraph NB-5245 requires a progressive surface examination at the lesser of ½ the maximum weld thickness or ½ inch as well as a surface examination 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.

3.4 <u>Licensee’s Basis for Use of Proposed Alternative</u>

The proposed alternative requires the use of an automatic or machine GTAW temper bead technique without the specified preheat or post weld heat treatment of the Construction Code. The proposed alternative will include the requirements of paragraphs 1.0 through 5.0 of Attachment 1 to the February 23, 2004, relief request, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." The alternative will be used to make welds joining P-No. 3, RPV head material to P-No. 43 RPV head nozzle material using F-No. 43 filler material.

Results of procedure qualification work undertaken to date indicate that the process produces sound and tough welds. For instance, typical tensile tests have resulted in ductile breaks in the weld metal.

The NB-4622 temper bead procedure requires a 350°F preheat and a post weld soak at 450°F - 660°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 RPV head is able to produce martensite from the heating and cooling cycles associated with welding. However, the proposed alternative temper bead procedure utilizes a welding process that is inherently free of hydrogen. The GTAW process relies on bare welding filler metals 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 which typically produces porosity free welds. The gas would typically have no more than 1 part-per-million (ppm) of hydrogen (H_2) and no more than 1 ppm of water vapor (H_2O). A typical argon flow rate would be about 15 to 50 cubic feet per 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.

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 using thermocouples is unnecessary and would result in additional personnel dose associated with thermocouple placement and removal. Consequently, preheat temperature verification by use of a contact pyrometer on accessible areas of the closure head is sufficient. Also, in lieu of using thermocouples for interpass temperature measurements, calculations were performed to 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, when 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 heat affected zone. 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) the time to shift the starting location of the next weld bead circumferentially away from the end of the previous weld-bead, and 3) the time to shift the starting location of the next bead axially to insure a 50 percent weld bead overlap required to property execute the temper bead technique.

A welding mockup on the full size Midland RPV head, which is similar to the ANO-1 RPV head, was used to demonstrate the welding technique described herein. During the mockup, thermocouples were placed to monitor the temperature of the closure head during welding. Thermocouples were placed on the outside surface of the closure head within a 5-inch band surrounding the RPV head nozzle. Three other thermocouples were placed on the closure head inside surface. One of the three thermocouples was placed 1½ inches from the RPV head nozzle penetration, on the lower hillside. The other inside surface thermocouples were placed at the edge of the 5-inch band surrounding the RPV head nozzle, one on the lower hillside, the second on the upper hillside. During the mockup, all thermocouples fluctuated less than 150°F throughout the welding cycle. Based on past experience, it is believed that the temperature fluctuation was due more to the resistance heating temperature variations than the low heat input from the welding process. For the Midland RPV head mockup application, 300°F minimum preheat temperature was used. Therefore, for ambient temperature conditions used for this repair, maintenance of the 350°F maximum interpass temperature will not be a concern.

The licensee believes that based on the information that it provided, it may be concluded that using the proposed alternative temper bead weld technique described in its submittal, is an acceptable alternative to Code requirements and will produce sound, permanent weld repairs and an acceptable level of quality and safety.

3.5 Staff Evaluation

The 1989 Edition of ASME 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 the paragraphs NB-4622.11(a) through (g) are met.

The requirements of subarticles NB-4453 and 4622 of the 1989 Edition of ASME 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 "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique," (Attachment 1 to the relief request) will be used. Specifically, alternatives are being proposed for the following subparagraphs of ASME Section III, subarticle NB-4622:

NB-4622.1 through NB-4622.7 all establish various requirements for PWHT of welds. Since the repair welds will not be postweld heat treated these paragraphs do not apply to the proposed alternative repair method.

NB-4622.8 establishes exemptions from PWHT for nozzle to component welds and branch connection to run piping welds. 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 which will not exist for the welds in question. 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 temper bead repairs to P-No. 1 and P-No. 3 materials and A-Nos. 1, 2, 10, or 11 filler metals. The subparagraph does not apply in this case because the proposed repairs will involve F-No. 43 filler metals.

NB-4622.10 establishes requirements for repair welding to cladding after PWHT. The subparagraph does not apply in this case because the proposed repair alternative does not involve repairs to cladding.

NB-4622.11 discusses temper bead weld repair to dissimilar metal welds or buttering and would apply to the proposed repairs as follows:

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.

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.

Subparagraph NB-4622.11(c) discusses the repair welding procedure and welder qualification in accordance with ASME Section IX and the additional requirements of Article NB-4000. The proposed alternative will satisfy these requirements. In addition, subparagraph NB-4622.11(c) requires the WPS include the following requirements:

NB-4622.11(c)(1) requires the area to be welded be suitably prepared for welding in accordance with the written procedure to be used for the repair. The proposed alternative will satisfy this requirement.

NB-4622.11(c)(2) requires the use of the 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 the F-No. 43 classification. The use of a GTAW temper bead welding technique to avoid the need for postweld heat treatment is based on many acceptable procedure qualification records (PQRs) and WPSs which have been utilized to perform numerous successful repairs which indicate that the use of the ambient GTAW temper bead welding technique is an acceptable approach. From this data, it can be shown that adequate toughness can be achieved in base metal and heat affected zones with the use of a GTAW temper bead welding technique. The temper bead process has been shown effective by research, successful procedure qualifications, and many successful repairs performed since the technique was developed. Therefore, the alternative temperature proposal is acceptable.

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 temper bead alternative does not require elevated temperature preheat. Data from welding procedure qualification tests using the machine GTAW ambient temperature temper bead welding shows that quality temper bead welds can be performed with a 50°F minimum preheat and no post heat treatment. The licensee's use of a contact pyrometer to monitor the preheat temperature and calculations performed to show that the interpass temperature will not be exceeded during the welding process, precludes the need for temperature monitoring in the weld region using thermocouples.

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. 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). Also, the use of the ambient temperature automatic or machine GTAW temper bead process allows more precise control of heat input, bead placement, and bead size and contour than the manual SMAW process required by ASME Code, Sections III and XI. The very precise control over these factors afforded by the process provides more effective tempering and eliminates the need to grind or machine the first layer of the repair.

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 temper bead procedure does not require the hydrogen bake-out.

NB-4622.11(c)(8) requires welding subsequent to the hydrogen bake-out of 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 be at least 50°F prior to welding. These limitations are adequate since the F-43 filler metal is not subject to hydrogen embrittlement and subsequent weld layers are not being deposited over a ferritic metal layer.

NB-4622.11(d)(1) requires a liquid penetrant examination after the hydrogen bake-out described in subparagraph NB-4622.11(c)(7). The proposed alternative does not require the hydrogen bake-out because the very low hydrogen ambient GTAW temper bead welding process makes it unnecessary. A liquid penetrant examination will be performed as a post-weld examination.

NB-4622.11(d)(2) requires liquid penetrant examination and radiographic testing (RT) of repair welds after a minimum of 48 hours at ambient temperature. Ultrasonic testing (UT) is required, if practical. The proposed alternative includes the requirement to inspect after a minimum of 48 hours at ambient temperature. The licensee states that with the exception of the progressive liquid penetrant examination required by NB-5245, the proposed alternative will comply with NB-5000. The geometry of the RPV head and the orientation of the inner bore of the RPV head 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 geometric unsharpness condition, the NRC staff concludes RT is impractical for this type of repair. Therefore, examinations by the ultrasonic method will be used in lieu of examinations by the radiographic method defined by IWA-4533. The effectiveness of the UT was demonstrated by the licensee’s vendor on a mockup temper bead weld involving the same material as will be used for this repair. The staff finds that the use of UT in lieu of RT for the reactor vessel head examination is acceptable because UT provides reasonable assurance of structural integrity of the reactor vessel head.

NB-4622.11(d)(3) requires that all nondestructive examination be performed in accordance with NB-5000. In lieu of the progressive liquid penetrant examination required by NB-5245, the proposed alternative will use liquid penetrant and ultrasonic examination of the final weld which is a more robust examination than that required by Code.

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. These requirements are more conservative than the NB-4622.11(f) requirements. 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 welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs which is particularly pertinent to the SMAW manual welding process. The proposed alternative involves a machine GTAW process and requires welding operators be qualified in accordance with ASME Section IX. The use of a machine process eliminates concern about obstructions, which might interfere with the welder's abilities since these obstructions will have to be eliminated to accommodate the welding machine.

NB-4453.4 requires that the examination of repair welds be conducted in accordance with the requirements of the original welds. The proposed welds will be partial penetration welds as defined in 4244(d). The proposed partial penetration welds require examination in accordance with NB-5253 which specifies a progressive surface examination. The licensee's proposal to perform a surface examination of the completed weld along with a volumetric examination provides a more robust examination than the requirements of NB-5253 and is therefore acceptable.

The use of a GTAW temper bead welding technique to avoid the need for PWHT is based on research that has been performed by the Electric Power Research Institute (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 heat affected zone of the base material and preceding weld passes. Data presented in the report show the results of procedure qualifications performed with 300°F preheats and 500°F preheats, as well as with no preheat and postheat. From that data, it is clear that equivalent toughness is achieved in base metal and heat affected zones in both cases. The temper bead 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 for temper bead welding allows 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.

3.6 Conclusion

The NRC staff concludes that the licensee's proposed alternative to use ambient temperature temper bead welding for repairing flaws in the reactor vessel closure head nozzle penetration welds, and UT and liquid penetrant examination for inspection of the repair welds as discussed in Relief Request No. ANO1-R&R-005, Revision 0, provides 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 use at ANO-1. The alternative is authorized for the third 10-year ISI interval through the end of the refueling outage scheduled for the fall of 2005.

All other requirements of the ASME Code, Section III and XI for which relief has not been specifically requested and approved remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

4.0 TECHNICAL EVALUATION: RELIEF REQUEST NO. ANO1-R&R-006, REVISION 0, EVALUATION OF FLAWS IN THE J-GROOVE WELD AND ACCEPTANCE CRITERIA FOR NEW PRESSURE BOUNDARY WELD

4.1 System/Components for Which Relief is Requested

The proposed Relief Request No. ANO1-R&R-006 applies to all 69 RPV head nozzles. This request includes the six RPV head nozzles that were repaired using the approved alternative ANO1-R&R-004 during refueling outage 1R17. Specifically, this request applies to the remnant J-groove weld that is proposed to be left in place with postulated flaws and a flaw evaluation pertaining to the new pressure boundary weld that is used to attach the nozzle to the RPV head.

The RPV head and RPV head nozzles are ASME Class 1 components. The ASME examination category, per ASME Section XI, is B-E, Pressure Retaining Partial Penetration Welds in Vessels, Item No. B4.12.

4.2 Remnant J-Groove Weld

4.2.1 ASME Code Section XI Applicable to Remnant J-Groove Weld

The codes of record for the repairs described in ANO1-R&R-006 are the 1989 Edition of ASME Section III and the 1992 Edition of ASME Section XI. ASME Section XI provides specifications for inspection and testing of nuclear plant components. Subsection IWA of Section XI provides general requirements and subsection IWB of Section XI provides requirements for Class 1 Components. IWA-4310 requires in part that “Defects shall be removed or reduced in size in accordance with this Paragraph.” Furthermore, IWA-4310 allows that “...the defect removal and any remaining portion of the flaw may be evaluated and the component accepted in accordance with the appropriate flaw evaluation rules of Section XI.” The ASME Section XI, IWA-3300 rules require characterization of flaws detected by inservice examination.

IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300.

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 during the next three inspection periods.

IWB-3613 contains acceptance criteria for evaluating flaws in areas where bolt-up loads play a significant role (i.e., the RPV-to-head interface). IWB-3613(b) requires the use of a safety factor of $\sqrt{10}$ (3.16) to determine the stress intensity factor of a flaw during normal operating conditions.

4.2.2 Licensee's Proposed Alternative Pertaining to the J-Groove Weld Remnant

Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee requested relief from ASME Section XI IWB-3420/IWA-3300, IWB-3142.4 and IWB-3613(b) as they pertain to the remnant J-groove weld for the RPV head penetration nozzle. The alternative involves leaving a remnant of the J-groove weld in place following repair activities, and operating with safety factors of 3 for the primary stresses and 1.5 for the secondary stresses, which include residual stresses, on fracture mechanics parameters until the ANO-1 RPV head is replaced during the next refueling outage (1R19).

The proposed repair for the subject RPV head nozzles does not include removal of any cracks in the remaining J-groove welds. Therefore, per the requirements of IWA-4310, the cracks must be evaluated using the appropriate flaw evaluation rules of the ASME Code, Section XI. No additional inspections are planned to characterize the cracks due to the configuration of the nozzle and the weld. Thus, the actual dimensions of the flaw will not be fully determined as required by IWA-3300. The licensee proposes to accept these flaws by analysis of the worst case that might exist in the J-groove weld. Based on the worst case condition analysis, the licensee proposes that no future examinations be performed of the J-groove flaws. After boring and removing a nozzle end, the remaining J-groove weld material will be chamfered to reduce the stress intensity factor.

4.2.3 Licensee's Basis for Use of Proposed Alternative Pertaining to the J-Groove Weld Remnant

The licensee's position is that the original nozzle to RPV head weld configuration is extremely difficult to UT due to the compound curvature of the head and radius. These conditions preclude ultrasonic coupling and control of the sound beam in order to perform flaw sizing with reasonable confidence from the inner surface of the head. The licensee indicated that presently, the technology does not exist to characterize flaw geometries that may exist in the J-groove weld. Not only is the configuration not conducive to UT but the dissimilar metal interface between the Ni-Cr-Fe weld and the low alloy steel RPV head increases the difficulty of UT. Similarly, impediments to examination from the outer surface of the RPV head exist due to proximity of adjacent nozzle penetrations.

After boring and removing a nozzle end, the remaining J-groove weld material will be chamfered to reduce the stress intensity factor.

The licensee used worst-case assumptions to conservatively estimate the crack extent and orientation. The postulated crack extent and orientation were evaluated using linear elastic fracture mechanics and elastic plastic fracture mechanics methods. The licensee's evaluation, in conjunction with this request, justifies leaving the remnant J-groove weld in place without performing successive examinations in accordance with IWB-3142.4. The evaluation also determined that the results of the fracture mechanics analysis meet safety factors of 3 and 1.5 for primary and secondary stresses, respectively.

4.2.4 Staff Evaluation of the Remnant J-Groove Weld

The licensee's repair plan consists of partially machining out the control rod drive mechanism nozzle through the section of the J-groove weld which attaches the nozzle to the RPV head, up to approximately mid-wall. At mid-wall, the remaining portion of the nozzle is welded to the RPV head and acts as the pressure retaining boundary. This repair action changes the category of the remnant J-groove weld. After the repair is complete, the remnant J-groove weld no longer falls under Examination Category B-E Item B4.12 and becomes a non-pressure retaining weld, which is part of the base metal thickness. The newly deposited repair weld is now treated as the pressure retaining weld and is considered to fall under Examination Category B-E Item B4.12.

The NRC staff agrees with the licensee that ultrasonic examination of any flaws in the original J-groove weld region is ineffective and impractical due to the configuration of the RPV head. 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. If examination of the J-groove weld were to be attempted from the inner diameter of the head, the cladding provides an acoustic interface which severely limits a confident examination of the weld material. Radiography of the area is also ineffective due to orientation of circumferentially oriented flaws being perpendicular to gamma- and x-rays. In addition, surface examinations will not provide any useful volumetric information.

The licensee has performed several flaw evaluations for the remnant J-groove weld since 2002. In the 2002 submittal, the licensee used the linear elastic fracture mechanics method to analyze a postulated crack in the J-groove weld remnant as shown in its relief request No. ANO1-R&R-004 dated November 26, 2002. In the process of preparing the current submittal, the licensee found that its 2002 flaw evaluation did not consider appropriate weld residual stresses and that the stress intensity factor equation was not applicable for the crack configuration in the J-groove weld. In the current relief request ANO1-R&R-006, the licensee submitted a revised linear elastic fracture mechanics analysis and introduced an elastic-plastic fracture mechanics method to support its proposed alternatives to the ASME Code, Section XI as discussed above.

In its linear elastic fracture mechanics analysis, the licensee assumed a worst-case flaw in the J-groove weld remnant, i.e., the entire weld remnant is assumed to be cracked and the crack tip is located at the interface between the weld and reactor vessel head base metal. The licensee considered the following operating conditions for loading on the postulated crack: (1) normal steady state operation; (2) normal heat-up from ambient condition; (3) normal cool-down from steady state condition; (4) reactor trip from steady state condition; and, (5) rod withdrawal accident from steady state condition.

In addition, the licensee calculated residual stresses in the J-groove weld using the finite element method. The finite element analysis simulated the original installation of the RPV head penetration nozzle. The process includes the installation of the butter layer followed by a PWHT, J-groove welding of the nozzle followed by a Code hydro-test, and subsequent steady state operation. The licensee considered an appropriate chamfer design of the J-groove weld remnant that will result in an appropriate stress intensity factor at the interface between Inconel alloy 600 butter weld and the low alloy steel reactor vessel head. A bounding nozzle, which is the outermost nozzle penetration location (38.5°), was modeled in the finite element analysis. The licensee applied the weld residual stresses and operating stresses to the crack face. The licensee's linear elastic fracture mechanics result showed that the stress intensity factor at the postulated crack tip could not meet the safety margin specified in ASME Section XI, IWB-3613(b).

Subsequently, the licensee pursued an elastic-plastic fracture mechanics analysis using the guidance in Appendix K of ASME Section XI. However, the equations for the stress intensity factor determination in Appendix K were not used because they do not apply to the geometry of the postulated crack in the J-groove weld remnant. Instead, the licensee used the stress intensity factor from the linear elastic fracture mechanics analysis to perform the elastic plastic fracture mechanics analysis. The staff finds that the licensee's approach is acceptable because the stress intensity factor methodology in Appendix K is not applicable to the flaw geometry in the J-groove weld in the reactor vessel head. The stress intensity factor calculation in Appendix K is primarily used to evaluate the flaw in the reactor vessel beltline region. The reactor vessel beltline region and the reactor vessel head are two different structural components. Also, the licensee's stress intensity factor taken from the linear elastic fracture mechanics analysis is a more accurate representation of the flaw condition than the stress intensity factor obtained via the Appendix K method, because it was calculated based on a detailed finite element analysis.

The licensee also performed a fatigue crack growth calculation for two operating cycles using the expected transient conditions because the reactor vessel head is scheduled to be replaced in one operating cycle. The licensee's fatigue calculation shows that the extension of the postulated crack due to the anticipated fatigue cycles to be 0.005 inch per cycle. This crack growth is insignificant compared to the initial postulated crack size of 1.5 inches.

The licensee's elastic-plastic fracture mechanics analysis demonstrates that the J value for the reactor vessel head material to resist crack propagation is 4.4 in-kip/in^2, and the applied J value at the crack tip that would drive a crack to propagate is 0.853 in-kip/in^2. This result shows that the reactor vessel head material has sufficient resistance to crack propagation. The licensee concluded that its analysis demonstrates that the structural and leakage integrity of the ANO-1 RPV head is maintained for the remaining one additional operating cycle of the reactor vessel head.

The NRC staff evaluated four issues in the licensee's flaw evaluation and the staff's findings are discussed below.

The first issue is related to the licensee's linear elastic fracture mechanics analysis in which the safety factor of the postulated crack in the J-groove weld did not satisfy the safety factor of $\sqrt{10}$ as specified in IWB-3613 of the ASME Code, Section XI. The low safety factor is a result of the conservatism in the licensee's analysis. The NRC staff believes that the majority of licensee's conservatism stems from the magnitude and modeling of the weld residual stresses as a constant applied load on the crack face. The other conservatism stems from the use of linear elastic fracture mechanics. IWB-3600 methodology is based on linear elastic fracture mechanics which is inherently conservative for low alloy steel of the reactor vessel head because linear elastic fracture mechanics does not consider the ductility of the low alloy steel. The licensee's safety factor does not imply that the structural integrity of the reactor vessel head is compromised but rather, it is a reflection of the conservatism in the licensee's analytical approach and assumptions. The staff finds that the licensee's calculated safety factor, which is lower than the $\sqrt{10}$, is acceptable because the reactor vessel has sufficient ductility to resist crack propagation as shown in the elastic plastic fracture mechanics calculations as discussed below.

The second issue is related to the applicability of elastic-plastic fracture mechanics analysis to analyze the postulated crack in the J-groove weld propagating into vessel head base metal. The licensee used the screening criteria in Appendix H to the ASME Code, Section XI to show that use of elastic-plastic fracture mechanics analysis is applicable to this case. The screening criteria compare the ratio of the material toughness of the vessel head to the applied stresses of the postulated crack in the J-groove weld. The licensee calculated a ratio of about 0.35 which is within the range of the screening criteria of 0.2 to 1.8 to qualify for the elastic-plastic fracture mechanics application as specified in Appendix H to the ASME Code, Section XI. On the basis of the screening criteria, the NRC staff finds that use of elastic-plastic fracture mechanics analysis to analyze crack stability in the ANO-1 reactor vessel head is appropriate.

The third issue is whether the ANO-1 reactor vessel head has sufficient resistance to crack propagation. Resistance to crack propagation depends on the fracture toughness of a material which, in this case, is measured by the upper shelf Charpy energy of the reactor vessel head base metal. The licensee has no upper shelf Charpy energy data for the ANO-1 reactor vessel head base metal, which usually are obtained at high test temperature (e.g., >150 °F) in the Charpy V-notch tests. The available ANO-1 Charpy energy data were taken at a relatively low temperature (+10°F). However, the licensee has the complete Charpy energy versus temperature data from the Grand Gulf Nuclear Station (GGNS) reactor vessel material. The licensee stated that the materials of the ANO-1 and GGNS reactor vessel head are comparable. The plate materials for both plants are SA533 Grade B Class 1 and were supplied by the same steel company, Lukens Steel. The licensee superimposed the ANO-1 Charpy energy data on the GGNS Charpy energy graph and showed that the ANO-1 data fit the general trend of the GGNS Charpy energy data.

For the upper shelf Charpy energy for ANO-1, the licensee extrapolated a lower bound Charpy energy of 94 ft-lbs from the GGNS data.

The NRC staff performed an independent verification by reviewing surveillance capsule reports of reactor vessel material specimens and final safety analysis reports of various nuclear plants. The NRC staff found that the ANO-1 Charpy test data are consistent with the Charpy energy data from other Babcock and Wilcox reactor vessels with the same SA 533 plate material. The NRC staff also found in an EPRI report, TR-113596 (Reference 11) that the upper shelf Charpy energies of SA 533 plate materials fabricated by Lukens Steel between 1966 and 1974 ranged from 91 ft-lb to 177 ft-lb. The mean upper shelf energy is 127 ft-lb and one standard deviation is 15 ft-lb. The upper shelf energy at 2 standard deviations from the mean is 97 ft-lb, which represents the 95 percent confidence interval value. The lower the upper shelf energy used in the elastic-plastic fracture mechanics calculation the more conservative the results will be. That is, if a crack can be shown to be stabilized at a low upper shelf energy, the crack will certainly be stabilized at a higher upper shelf energy. Therefore, the NRC staff finds that an upper shelf energy of 94 ft-lb used by the licensee is acceptable because it is conservative as compared to the 95 percent confidence value of 97 ft-lb.

The fourth issue is related to the proposed safety factors which deviate from and are lower than the safety factor of $\sqrt{10}$ specified in IWB-3613 of the ASME Code, Section XI. IWB-3613(b) applies the same safety factor, $\sqrt{10}$, to the stress intensity factor derived from the primary stresses and secondary stresses. The licensee believes that this results in an overly conservative allowable stress intensity factor when the predominant loading mechanism in the J-groove weld is highly localized and due to residual stresses, which are considered as the secondary stresses. A safety factor of $\sqrt{10}$ would be over-conservative when applying elastic- plastic fracture mechanics methodology to this case (i.e., with the large postulated flaw and residual stresses).

As discussed in Enclosure 2 to the May 4, 2004, letter, the licensee stated that a more reasonable approach would be to use the philosophy of Appendix G to ASME Section XI and ASME Section III, i.e., different safety factors apply to primary stresses and secondary stresses. The licensee stated that the design rules for Section III of the ASME Code are specified for primary bending stress (P_b) and local primary membrane stress (P_L) to be lower than $1.5S_m$ (S_m = stress intensity), which is approximately equal to the material yield strength. Further, the stress range when considering secondary stresses is increased by an additional factor of 2 to $3S_m$. This increase for local primary stresses then results in a nominal safety factor of 2 with consideration of bending and local stress effects. The limit on secondary stresses was included to prevent gross distortion of Code components.

The licensee stated that in Appendix G to ASME Section XI, the distinction between primary and secondary stresses are recognized by using a safety factor of 2 on primary stresses and a safety factor of 1 on secondary stresses. Although this appendix is for “hypothetical flaw analysis” to ensure safety against non-ductile fracture, its applicability to the evaluation of flaws potentially left in the J-groove welds is appropriate. The licensee's evaluation assumes that the entire J-groove weld (including the butter) is cracked, which is analogous to postulating a worst-case hypothetical flaw.

Therefore, the licensee proposed a safety factor of 3 applied to the stress intensity factor calculated from the primary stresses, and a safety factor of 1.5 applied to the stress intensity factor calculated from the secondary stresses.

The regulation at 10 CFR 50.55a requires licensees to meet the requirements of the ASME Code; therefore, the requirements of IWB-3613 of the ASME Code, Section XI, must be satisfied. However, the NRC staff finds that the licensee proposed safety factors of 3 on primary stresses and 1.5 on secondary stresses are acceptable when compared to the safety factor of $\sqrt{10}$ required by IWB-3613 because (1) the J-integral value for the vessel head material is higher than the applied J-integral value at the crack tip, which indicates that the vessel head base metal has sufficient resistance to crack propagation; (2) the licensee's elastic-plastic fracture mechanics analysis showed that the safety factor for secondary stresses could actually be higher than the proposed 1.5, which implies that the proposed safety factors do not deviate significantly from that of IWB-3613; and (3) the licensee was conservative in modeling the weld residual stresses in its flaw evaluation.

The NRC staff concludes that ultrasonic examination of any flaws in the original J-groove weld region is ineffective and impractical due to the configuration of the RPV head. The NRC staff also concludes that the licensee's proposed alternatives to ASME Code, Section XI, IWA-3300, IWA-4310, IWB-3142.4, and IWB-3613 pertaining to the J-groove weld remnant are acceptable because (1) the licensee has demonstrated by fracture mechanics analyses that a worst-case flaw in the J-groove weld will not adversely affect the structural and leakage integrity of the RPV head and (2) the licensee's fracture mechanics analyses demonstrate that the postulated crack will not grow into the vessel head base metal significantly (i.e., 0.005 inch per cycle). As a result, the licensee's alternative provides reasonable assurance of structural integrity of the RPV head.

4.3 Acceptance Criteria for New Pressure Boundary Weld

4.3.1 ASME Code Section III Applicable to New Repair Weld

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

4.3.2 Licensee's Proposed Alternative Pertaining to New Pressure Boundary Weld

Pursuant to 10 CFR 50.55a(a)(3)(ii), the licensee requested relief from ASME Section III

NB-5330(b) as it pertains to the examination and evaluation of the repair weld for the RPV head penetration nozzle. The alternative involves acceptance criteria for analyzing weld flaws in accordance with ASME Section XI in lieu following the acceptance criteria in Section III.

The new pressure boundary repair weld that connects the remaining portion of the RPV head nozzles to the low alloy RPV head contains a material "triple point." The triple point is located at the root of the weld where the Alloy 600 nozzle will be welded with Alloy 690 (Alloy 52) filler material to the SA-533 Grade B, Class 1 Mn-Mo low alloy steel plate. Experience has shown that during solidification of the Alloy 52 filler material, a lack of fusion (otherwise known as a welding solidification anomaly) area may occur at the root of the partial penetration welds.

Entergy is requesting relief from the requirements of ASME Section III, NB-5330(b), regarding the potential lack of fusion at the root of the repair weld. If a weld triple point anomaly occurs in any of the repair welds, it will be evaluated in accordance with the appropriate flaw evaluation rules of ASME Section XI.

4.3.3 Licensee's Basis for Use of Alternative Acceptance Criteria for New Weld

The licensee indicates that unavoidable flaws commonly occur at the root of partial penetration welds involving Alloy 600 base materials and Alloy 52 filler metals. The licensee refers to these flaws as weld anomalies. These anomalies are typical for welds that involve a "lap joint" type interface, such as typical partial penetration weld geometries, in the weld joint design. According to the licensee, cross sections of nickel alloy welds made utilizing similar joint designs with Alloy 600 base materials and Alloy 82 filler metals have exhibited these phenomena consistently.

The licensee states that eliminating the weld triple point anomaly requires an entirely different process than that proposed for use at ANO-1. The only qualified method currently available would involve extensive manual welding that would result in radiation doses estimated to be in excess of 30 REM per nozzle as compared to the 5 REM estimated for each nozzle repaired by the proposed process. Compliance with the specified Code requirements would result in excessive radiation exposure.

IWA-4170 mandates that the repair design meets the original construction code or the adopted ASME Section III Code. The licensee has adopted the 1989 ASME Section III code for qualification of the described repairs. Subsection NB-5330(b) stipulates that no lack of fusion area be present in the weld. A fracture mechanics analysis was performed to demonstrate compliance with Section XI of the ASME Code, for operating with the postulated weld anomaly described above. The anomaly was modeled as a 0.1 inch "crack-like" defect, 360° around the circumference at the "triple point" location. Full-size mockups using coupons from the Midland RPV head were metallographically evaluated. Flaws were occasionally found as expected and were less than the analyzed maximum allowed of 0.100 inch.

The licensee states that based on the fact that this anomaly is predictable, the anomaly can be detected by UT within the prescribed acceptance criteria and evaluated for fatigue and flaw growth using applicable ASME Sections III and Xl methods. The licensee believes that the intent of the ASME Codes will be met. The ASME Section III analysis conservatively assumes a reduction in weld area (along the new weld-to-ferritic steel penetration fusion line) due to the anomaly and the ASME Section Xl analysis assumes the anomaly is a crack-like defect.

The licensee believes the proposed alternatives to the ASME Code requirements are justified. The licensee contends that the alternatives that it described in its submittal and supporting documentation provide an acceptable level of quality and safety, and requested NRC staff approval of its request pursuant to 10 CFR 50.55a(a)(3)(ii)

4.3.4 Staff Evaluation of Repair Weld Examination Acceptance Criteria

The licensee indicated that the repair weld could contain an indication referred to as a "weld anomaly." The licensee defines an anomaly as the unusual solidification patterns that result at the intersection of the low alloy steel of the vessel head base metal, the Alloy 600 RPV head nozzle, and Filler Metal 52 of the repair weld. The licensee concluded that its fracture mechanics analysis demonstrated that the postulated 0.10-inch weld anomaly is acceptable for a 25-year design life of the RPV head nozzle temper bead weld repair. The fracture toughness margins have been demonstrated for each of the two flaw propagation paths considered in the analysis. The margins on limit load for the normal/upset conditions and emergency/faulted conditions were also found to be acceptable.

The phenomenon that the licensee refers to as a weld anomaly is not uncommon in weld fabrication involving a partial penetration or lap joint type welds comprised of ferritic material, nickel alloys, and nickel alloy filler metal using the GTAW process. It is sometimes unavoidable under the best fabrication circumstances. In the case of the licensee's request, it plans to perform a UT examination that will detect any anomalies and evaluate them for acceptance under ASME Code Section XI. The licensee indicated that a 0.10-inch weld anomaly is acceptable for 25 years of operation. Considering the component and its configuration, the NRC staff finds that it would be impractical to hold the licensee to the weld acceptance standards of the construction code. The NRC staff finds the licensee's approach acceptable because its approach will provide reasonable assurance that the new pressure boundary will contain a sound weld that is free of any defects that will challenge pressure boundary integrity before the next refueling cycle, at which time the RPV head is scheduled to be replaced.

The licensee's flaw evaluation also determined the amount of time needed for a crack to grow 75 percent through-wall in the Alloy 600 nozzle material above the repair weld, which differs slightly from the alternative, Relief Request No. ANO1-R&R-004, approved by the NRC for the licensee's fall 2002 outage. The current submittal does not include water jet conditioning. The licensee's justification for not employing water jet conditioning is explained in detail in Entergy Engineering report M-EP-2004-002, Rev. 0, in its March 4, 2004, letter. The licensee indicated that for the initial conditions that it chose, it would take 4 years for a crack above the weld to grow 75 percent through-wall. Since the licensee will be replacing its RPV head in the fall of 2005 during the1R19 refueling outage, the NRC staff finds this acceptable.

The licensee volumetrically examined all six repaired welds installed during its last outage, 1R17, and during refueling outage 1R18 in May 2004. The licensee did not find signs of degradation in the repaired welds. One nozzle, No. 61, was repaired, during the licensee's 1R18 outage using the techniques described in ANO1-R&R-006. The lack of any defects in the licensee repair welds from the 1R17 and 1R18 outages provide further assurance that the structural integrity of the RPV head will be maintained.

The NRC staff concludes that requiring the licensee to comply with the construction code repair and nondestructive examination requirements is impractical. The licensee's request and supporting information on the impracticality of characterizing flaws in the remnant J-groove welds and analyses bounding postulated flaws provides assurance of structural integrity of the repair.

4.4 Conclusion

Based on the discussion above for Relief Request No. ANO1-R&R-006, Revision 0, the NRC staff has concluded that the proposal to leave cracks in the nonpressure boundary portion of the remaining J-groove partial penetration weld and to evaluate crack growth using the methodology described in the licensee's letter dated May 4, 2003, for a worst-case crack growth scenario is acceptable. Also, based on the above discussion, the NRC staff has concluded that flaws left in the J-groove penetration weld are impractical to examine. Further, based on the licensee's anticipated replacement of the RPV head in the fall of 2005, the actions of the licensee provides reasonable assurance of structural integrity for the RPV head repair. The NRC staff concludes that granting relief pursuant to 10 CFR 50.55a(g)(6)(i) 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.

With respect to the new pressure boundary weld, the NRC staff concludes that requiring the licensee to comply with the construction code nondestructive examination requirements and acceptance standards is impractical. Further, the NRC staff finds that the licensee's alternative acceptance criteria provides reasonable assurance of structural integrity for the RPV head repair. Therefore, relief is granted for the repair and examinations of RPV head nozzles with leaks or other unacceptable conditions that were identified during the refueling outage that began on April 20, 2004, and the 6 nozzles that were repaired during the previous refueling outage during fall 2002. The relief for the subject repaired nozzles is valid until the 1R19 refueling outage scheduled for the fall of 2005. The NRC staff concludes that granting relief pursuant to 10 CFR 50.55a(g)(6)(i) 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.

All other requirements of the ASME Code, Section III and XI for which relief has not been specifically requested and approved remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

5.0 CONCLUSION FOR RELIEF REQUESTS ANO1-R&R-005 AND ANO1-R&R-006

The NRC staff has completed its review as documented above. For relief request number ANO1-R&R-005, the NRC staff determined that the alternative provides an acceptable level of quality and safety. For relief request number ANO1-R&R-006, the NRC staff determined that complying with the Code requirement would be impractical and the proposed inspection provides reasonable assurance of structural integrity of the reactor vessel head. Therefore, relief request number ANO1-R&R-005 is authorized pursuant to 10 CFR 50.55a(a)(3)(i) and relief request number ANO1-R&R-006 is granted pursuant to 10 CFR 50.55a(g)(6)(i) for the third 10-year ISI interval through the fall 2005 refueling outage. The NRC staff determined that granting relief pursuant to 10 CFR 50.55a(g)(6)(i) 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.

6.0 REFERENCES

1. Letter dated June 6, 2003, M.A. Krupa (Entergy Operations, Inc., Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Relief Request ANO1-R&R-005 and ANO1-R&R-006. ML031631238

2. Letter dated November 25, 2003, U.S. Nuclear Regulatory Commission to J.S. Forbes (Entergy Operations, Inc. , Vice President, Operations ANO), Approval letter for Relief Request ANO1-R&R-003 and ANO1-R&R-004. ML033290597

3. Letter dated February 23, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing complete re-submittal of Relief Request ANO1-R&R-005 and ANO1-R&R-006. ML040620671

4. Letter dated March 4, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Request for Alternative ANO1-R&R-006-Proposed Alternative to ASME Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles. ML040750278

5. Letter dated April 8, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Request for

Alternative ANO1-R&R-006-Proposed Alternative to ASME Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles. ML041050668

6. Letter dated April 12, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Request for Alternatives ANO1-R&R-005 and ANO1-R&R-006-Proposed Alternatives to ASME Weld Repair and Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles. ML041110821

7. Letter dated May 4, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Request for Alternative ANO1-R&R-006-Proposed Alternative to ASME Weld Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles. ML041410519

8. Letter dated June 1, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Request for Alternatives ANO1-R&R-005 and ANO1-R&R-006-Proposed Alternatives to ASME Weld Repair and Examination Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles. ML041620398

9. I.S. Raju and J.C. Newman Jr., "Stress Intensity Factors for Internal and External Surface Cracks in Cylindrical Vessels," <u>Transactions of the ASME, Journal of Pressure Vessel Technology,</u> pp. 293-298, Vol.104, November 1982.

10. Letter dated November 26, 2002, M.A. Krupa (Entergy Operations, Inc., Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, Subject: Proposed Alternative to ASME Examination Requirement for Repairs Performed on Reactor Vessel Head Penetrations. ML040440450

11. Letter dated September 21, 1999, Carl Terry of Electric Power Research Institute, Subject: "BWR VIP Vessel and Internals Project, BWR Reactor Pressure Vessel Inspection and Flaw Evaluation Guidances (BWRVIP-74)," EPRI Report TR-113596, September 1999, page B-3.

12. Letter dated September 16, 2004, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Relief Request ANO1-R&R-005 Response to the NRC's Request for Additional Information.

13. Letter dated May 3, 2005, F.G. Burford (Entergy Operations, Inc., Acting Director, Nuclear Safety & Licensing) to U.S. Nuclear Regulatory Commission, containing Request for

Alternatives ANO1-R&R-005 - Proposed Alternatives to ASME Weld Repair Requirements for Repairs Performed on Reactor Vessel Head Penetration Nozzles. ML041330262

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