April 17, 2006

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 2 (ANO-2) - RE: REQUEST FOR RELIEF FROM THE REQUIREMENTS OF THE ASME CODE (TAC NO. MC6408)

Dear Mr. Forbes:

By letter dated March 16, 2005, as supplemented by letters dated March 18 and 24, 2005, Entergy Operations, Inc. (EOI) submitted relief request number ANO2-R&R-003 for the use of alternatives to certain American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI requirements at ANO-2.

The Nuclear Regulatory Commission staff has completed its review and evaluation of the relief request and has determined that the alternative provides an acceptable level of quality and safety. Therefore, relief request number ANO2-R&R-003 is authorized pursuant to 10 CFR 50.55a(a)(3)(i) for outage number 17 at ANO-2, which commenced on March 9, 2005. Our review and acceptance of this relief request is authorized for the third 10-year ISI interval through the end of the refueling outage scheduled for the spring of 2005. EOI has commited to replace the pressurizer during ANO-2's fall 2006 refueling outage. Due to the immediate need of this relief, verbal authorization was granted on March 30, 2005.

The staff's safety evaluation is enclosed.

Sincerely,

/RA/

David Terao, Chief
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-368

Enclosure:
Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF REQUEST NO. ANO2-R&R-003

ENTERGY OPERATIONS INC.

ARKANSAS NUCLEAR ONE, UNIT 2

DOCKET NO. 50-368

1.0 INTRODUCTION

By letter dated March 16, 2005, as supplemented by letters dated March 18 and 24, 2005, Entergy Operations, Inc. (Entergy or the licensee) requested relief from the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI. The licensee found it necessary to perform an alternative repair to the temper bead welding requirements of the ASME Code. Due to immediate need of this relief, verbal authorization was given on March 30, 2005.

2.0 BACKGROUND

The licensee proposed an alternative to the temper bead welding requirements of the ASME Code, Section XI, IWA-4500 and IWA-4530. Due to a request for additional information (RAI) from the Nuclear Regulatory Commission (NRC) staff, the licensee provided supporting technical information for the request in a letter dated March 18, 2005, Agencywide Documents Access and Management System (ADAMS) Accession No. ML050890321. The licensee also resubmitted the entire request for the alternative and additional responses to the RAI in a letter dated March 24, 2005, ADAMS Accession No. ML050870448. In these letters, the licensee requested relief from the ASME Code, Section XI, 1992 Edition, which requires elevated temperature preheat and post-weld soak. As an alternative, the licensee proposed a repair using a remotely operated, gas tungsten-arc welding (GTAW) process. The GTAW process utilizes an ambient temperature temper bead method with a 50 EF minimum preheat temperature and no post-weld heat treatment (PWHT).

3.0 REGULATORY EVALUATION

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. Paragraph IWA-4170(b) of ASME Section XI requires that repairs and installation of replacement items shall be performed in accordance with the owner's Design Specification and the original Code of Construction of the component or system. Later editions and addenda of the Construction Code or of Section III may be used either in their entirety or portions thereof, and Code Cases may be used as well. If repair welding cannot be performed in accordance with these requirements, the applicable requirements of IWA-4200, IWA-4400 or IWA-4500 may be used. The Code of record the for Arkansas Nuclear One, Unit 2 (ANO-2), third 10-year inservice inspection (ISI) interval is the 1992 Edition of ASME Code, Section XI. The original Code of Construction for ANO-2 is ASME Code, Section III, 1968 Edition with the Addenda through summer 1970. The applicable edition of ASME Code, Section III for the third 10-year interval at ANO-2 is the 1989 Edition.

As stated in 10 CFR 50.55a(a)(3), alternatives to the requirements of paragraph (g) of this section 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.

4.0 TECHNICAL EVALUATION

Components for which Relief is Requested:

Pressurizer Heater Sleeve Repairs

Background

The ANO-2 pressurizer lower head was manufactured from SA-533, Grade B, Class 1 low alloy steel (P-Number 3, Group 3 material). Ninety-six (96) heater sleeves are welded to the pressurizer lower head. The heater sleeves were originally manufactured from nickel-based Alloy 600 material, which has a demonstrated sensitivity to primary water stress corrosion cracking (PWSCC).

During refueling outages in 1987 and 1988, heater sleeve “X1” was modified and plugged due to PWSCC. The modification to the X1 heater sleeve included a weld repair of pressurizer base material in the immediate vicinity of the X1 sleeve. The modification was performed using Alloy 600 materials and 082/182 weld materials. This repair was performed to repair the original, cracked heater sleeves and to restore pressurizer base material that had experienced boric acid corrosion as a result of the PWSCC leak. This repair was essentially a "half-nozzle" repair design which moved the pressure boundary weld between the pressurizer shell and heater sleeve to the exterior of the pressurizer shell.

Refueling Outage 17 at ANO-2 commenced on March 9, 2005. While performing bare metal visual inspections, leakage from the heater sleeve X1 attachment weld, i.e. the pressurizer to heater sleeve weld, was identified. The cause of leakage is believed to be PWSCC. As a repair, Entergy plans to perform a mid-wall half-nozzle repair using the Ambient Temperature Machine GTAW Temper Bead Technique.

Code Requirements for which Relief is Requested

The 1992 Edition of ASME Code, 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 requirements of IWA-4200 and IWA-4400 or IWA-4500 may be used."

IWA-4500 of ASME Code, Section XI, establishes alternative repair welding methods for performing temper bead welding. According to IWA-4500(a), "Repairs to base materials and welds identified in IWA-4510, IWA-4520, and IWA-4530 may be made by welding without the specified postweld heat treatment requirements of the Construction Code or Section III, provided the requirements of IWA-4500(a) through (e) and IWA-4510, IWA-4520, or IWA-4530, as applicable, are met."

Licensee's Proposed Alternative

"Pursuant to 10 CFR 50.55a(a)(3)(i), Entergy proposes alternatives to the machine GTAW temper bead process requirements of IWA-4500 and IWA-4530 of ASME Code, Section XI.

"Specifically, Entergy proposes to perform ambient temperature temper bead welding in accordance with Attachment 1 [to its March 24, 2005, supplemental letter], "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique." Entergy will use this proposed alternative for performing a mid-wall repair of the pressurizer heater sleeve X1. Entergy has reviewed the proposed ambient temperature temper bead welding techniques against the GTAW machine temper bead welding requirements of IWA-4500 and IWA-4530. Based upon this review, Entergy proposes alternatives to the following ASME Code, Section XI requirements of IWA-4500 and IWA-4530:

1. IWA-4500(a) specifies that repairs to base materials and welds identified in IWA-4530 may be performed without the specified [PWHT] of the Construction Code or ASME Code, Section III, provided the requirements of IWA-4500 and IWA-4530 are met. IWA-4530 includes temper bead requirements applicable to the shielded metal arc welding (SMAW) and the machine or automatic GTAW processes. As an alternative, Entergy proposes to perform temper bead weld repairs using the ambient temperature temperbead technique described [in their March 24, 2005, supplement]. Only the machine or automatic GTAW process can be used when performing ambient temperature temper bead welding in accordance with [the licensee's March 24, 2005, supplement].

2. IWA-4500(d)(2) specifies that if repair welding is to be performed where physical obstructions impair the welder's ability to perform, the welder shall also demonstrate the ability to deposit sound weld metal in the positions, using the same parameters and simulated physical obstructions, as are involved in the repair. This limited accessibility demonstration applies when manual temper bead welding is performed using the SMAW process. It does not apply to "welding operators'' who perform machine or automatic GTAW from a remote location. This distinction is clearly made in IWA-4500 and IWA-4530. Because the proposed ambient temperature temper bead technique described in [the licensee's March 24, 2005, supplement] utilizes a machine GTAW process, limited access demonstrations of "welding operators" are not required. Therefore, the requirement of IWA-4500(d)(2) does not apply.

3. IWA-4500(e)(2) specifies that the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 300 EF for the GTAW process during welding; maximum interpass temperature shall be 450 EF. As an alternative, Entergy proposes that the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 50 EF for the GTAW process during welding. The maximum interpass temperature shall be 350 EF regardless of the interpass temperature during qualification.

4. IWA-4500(e)(2) specifies that thermocouples and recording instruments shall be used to monitor process temperatures. Entergy cannot use thermocouples and recording instruments to monitor process temperatures during the performance of the pressurizer heater sleeve mid-wall repair. Because the inside diameter of the new sleeve is only 1.30 inches and welding is being performed internally, there is insufficient space and accessibility along the inside diameter of the heater sleeve to use thermocouples. As an alternative, Entergy will verify the preheat temperature with a pyrometer or temperature indicating crayon prior to welding. With respect to interpass temperature, Entergy will implement a five (5) minute hold time between passes to ensure that the interpass temperature will not approach 350 EF. Mock-up testing and supporting engineering analysis have been performed to demonstrate that the 350 EF interpass temperature limitation of the code case will not be exceeded.

5. IWA-4500(e)(2) specifies that thermocouple attachment and removal shall be performed in accordance with ASME Code, Section III. Because Entergy will not use thermocouples, the thermocouple attachment and removal requirements of IWA-4500(e)(2) do not apply.

6. IWA-4532.1 establishes procedure technique requirements that apply when using the SMAW process. Because the proposed ambient temperature temper bead technique [in the licensee's March 24, 2005, supplement] utilizes the machine or automatic GTAW welding process, the SMAW temper bead technique requirements of paragraph IWA-4532.1 do not apply.

7. IWA-4532.2(c) specifies that the repair cavity shall be buttered with six layers of weld metal in which the heat input of each layer is controlled to within +/-10% of that used in the procedure qualification test, and heat input control for subsequent layers shall be deposited with a heat input equal to or less than that used for layers beyond the sixth in the procedure qualification. As an alternative, Entergy proposes to deposit the weld area with a minimum of three layers of weld metal to obtain a minimum thickness of 1/8-inch. The heat input of each weld layer in the 1/8-inch thick section shall be controlled to within +/-10% of that used in the procedure qualification test. The heat input for subsequent weld layers shall not exceed the heat input used for layers beyond the 1/8-inch thick buttered section (first three weld layers) in the procedure qualification.

8. IWA-4532.2(c) specifies that the completed weld shall have at least one layer of weld reinforcement deposited. Once the weld is completed, this reinforcement shall be removed by mechanical means. As an alternative, Entergy's proposed ambient temperature temper bead technique does not include a reinforcement layer.

9. IWA-4532.2(d) specifies that, after at least 3/16-inch of weld metal has been deposited, the weld area shall be maintained at a temperature of 450 EF to 550 EF for a minimum of four (4) hours (for P-No. 3 materials). As an alternative, Entergy's proposed ambient temperature temper bead technique does not include a postweld soak.

10. IWA-4532.2(e) specifies that after depositing at least 3/16-inch of weld metal and performing a postweld soak 450 EF to 550 EF, the balance of welding may be performed at an interpass temperature of 350 EF. As an alternative, Entergy proposes that an interpass temperature of 350 EF may be used throughout the welding process without a postweld soak.

11. IWA-4533 specifies the following examinations shall be performed after the completed repair weld has been at ambient temperature for at least 48 hours: (a) the repair weld and preheated band shall be examined by the liquid penetrant method; (b) the repaired region shall be volumetrically examined by the radiographic method, and if practical, by the ultrasonic method. As an alternative to IWA-4533, Entergy proposes to perform the following examinations of the new mid-wall repair weld after the completed repair weld has been at ambient temperature for at least 48 hours:

    a. A liquid penetrant examination of the completed repair weld shall be performed in accordance with NB-5000 of ASME Code, Section III, 1989 Edition. Acceptance criteria shall comply with NB-5350.

    b. The completed repair weld shall be ultrasonically examined in accordance with NB-5000 of ASME Code, Section III, 1989 Edition. Acceptance criteria shall comply with NB-5330."

<u>Licensee's Basis for Relief</u>

"The pressurizer lower head is P-No. 3, Group 3 low alloy steel. If the repair were to be performed in accordance with ASME Code, Section III, Entergy would have two options:

1. Perform a weld repair that includes a [PWHT] at 1,100 EF to 1,250 EF in accordance with NB-4622.1:

   [PWHT, in accordance with NB-4600, is required to be performed at 1,100 EF to 1,250 EF]. PWHT of the pressurizer head is impractical. PWHT could cause ovalization and misalignment of heater sleeves, which would permanently damage the head, including the heater support assembly.

2. Perform a temper bead repair using the SMAW process in accordance with NB-4622.11:

   [Temper bead rules for repair welding dissimilar materials using SMAW] are provided in NB-4622.11. Because NB-4622.11 does not include temper bead rules for the machine or automatic GTAW process, a manual SMAW temper bead process must be used. However, a manual SMAW temper bead repair is not a desirable option due to radiological considerations. First, resistance heating blankets, thermocouples, and insulation must be installed. Secondly, the manual SMAW temper bead process is a time and dose intensive process. Each weld layer is manually deposited in a high dose and high temperature (350 EF) environment. The manual SMAW process also requires the weld crown of the first weld layer to be mechanically removed by grinding. Upon completing repair welding, the resistance heating blankets, thermocouples, and insulation must be removed. Thermocouples and heating blanket-mounting pins must be removed by grinding. The ground areas must be subsequently examined by either magnetic particle or liquid penetrant examination techniques.

"Entergy is not requesting an alternative to NB-4600; rather this request proposes an alternative to IWA-4500 and IWA-4530. Owners are allowed by ASME Code, Section XI, IWA-4170(b) and IWA-4500(a) to perform temper bead repairs of dissimilar materials. IWA-4170(b) and IWA-4500(a) provide requirements and controls for performing such repairs. For clarification, Entergy will meet applicable requirements of IWA-4000 except as otherwise approved by the NRC in accordance with this request.

"IWA-4500 and IWA-4530 of ASME Code, Section XI establish requirements for performing temper bead welding of "dissimilar materials." According to IWA-4530, either the automatic or machine GTAW process or SMAW process may be used. When using the machine GTAW process, a minimum preheat temperature of 300 EF must be established and maintained throughout the welding process while the interpass temperature is limited to 450 EF. Upon completion of welding, a postweld soak is performed at 450 EF to 550 EF for a minimum of 4 hours.

"The IWA-4500 and IWA-4530 temper bead welding process is a time and dose intensive process. Resistance heating blankets are attached to the pressurizer base material; typically a capacitor discharge stud welding process is used. Thermocouples must also be attached to the pressurizer base material using a capacitor discharge welding process to monitor preheat, interpass, and postweld soak temperatures. Prior to heatup, thermal insulation is also installed. Upon completion of repair welding (including the postweld soak), the insulation, heating blankets, studs, and thermocouples must be removed from the pressurizer base material. Thermocouples and stud welds are removed by grinding. Ground removal areas are subsequently examined by the liquid penetrant or magnetic particle method. A significant reduction in dose could be realized by utilizing an ambient temperature temper bead process. Therefore, Entergy proposes an alternative welding technique based on the methodology of ASME Code Case N-638.

"Research by the Electric Power Research Institute (EPRI) and other organizations on the use of an ambient temperature temper bead operation using the machine GTAW process is documented in EPRI Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temperbead Applications." According to the EPRI report, repair welds performed with an ambient temperature temper bead procedure utilizing the machine GTAW process exhibit mechanical properties equivalent to or better than those of the surrounding base material. Laboratory testing, analysis, successful procedure qualifications, and successful repairs have all demonstrated the effectiveness of this process. The effects of the ambient temperature temper bead welding process of [the licensee's March 24, 2005, supplement] on mechanical properties of repair welds, hydrogen cracking, and restraint cracking are addressed below.

1. Mechanical Properties: The principal reasons to preheat a component prior to repair welding is to minimize the potential for cold cracking. The two cold cracking mechanisms are hydrogen cracking and restraint cracking. Both of these mechanisms

occur at ambient temperature. Preheating slows down the cooling rate resulting in a ductile, less brittle microstructure, thereby lowering susceptibility to cold cracking. Preheat also increases the diffusion rate of monatomic hydrogen that may have been trapped in the weld during solidification. As an alternative to preheat, the ambient temperature temper bead welding process utilizes the tempering action of the welding procedure to produce tough and ductile microstructures. Because precision bead placement and heat input control is characteristic of the machine GTAW process, effective tempering of weld heat affected zones is possible without the application of preheat. According to Section 2-1 of EPRI Report GC-111050, "the temper bead process is carefully designed and controlled such that successive weld beads supply the appropriate quantity of heat to the untempered heat affected zone such that the desired degree of carbide precipitation (tempering) is achieved. The resulting microstructure is very tough and ductile."

The IWA-4530 temper bead process also includes a postweld soak requirement. Performed at 450 EF to 550 EF for 4 hours (P-No. 3 base materials), this postweld soak assists diffusion of any remaining hydrogen from the repair weld. As such, the postweld soak is a hydrogen bake-out and not a [PWHT] as defined by the ASME Code. At 450 EF to 550 EF, the postweld soak does not stress relieve, temper, or alter the mechanical properties of the weldment in any manner. Section 2.1 of [the licensee's March 24, 2005, supplement] establishes detailed welding procedure qualification requirements for base materials, filler metals, restrain, impact properties, and other procedure variables. The qualification requirements of Section 2.1 provide assurance that the mechanical properties of repair welds will be equivalent to or superior to those of the surrounding base material.

2. Hydrogen Cracking: Hydrogen cracking is a form of cold cracking. It is produced by the action of internal tensile stresses acting on low toughness heat affected zones. The internal stresses are produced from localized build-ups of monatomic hydrogen. Monatomic hydrogen forms when moisture or hydrocarbons interact with the welding arc and molten weld pool. The monatomic hydrogen can be entrapped during weld solidification and tends to migrate to transformation boundaries or other microstructure defect locations. As concentrations build, the monatomic hydrogen will recombine to form molecular hydrogen, thus generating localized internal stresses at these internal defect locations. If these stresses exceed the fracture toughness of the material, hydrogen induced cracking will occur. This form of cracking requires the presence of hydrogen and low toughness materials. It is manifested by intergranular cracking of susceptible materials and normally occurs within 48 hours of welding.

   IWA-4500 establishes elevated preheat and postweld soak requirements. The elevated preheat temperature of 300 EF increases the diffusion rate of hydrogen from the weld. The postweld soak at 450 EF to 550 EF was also established to bake-out or facilitate diffusion of any remaining hydrogen from the weldment. However, while hydrogen cracking is a concern for SMAW, which uses flux covered electrodes, the potential for hydrogen cracking is significantly reduced when using the machine GTAW welding.

   The machine GTAW process is inherently free of hydrogen. Unlike the SMAW process, GTAW filler metals do not rely on flux coverings that may be susceptible to moisture absorption from the environment. Conversely, the GTAW process utilizes dry inert shielding gases that cover the molten weld pool from oxidizing atmospheres. Any moisture on the surface of the component being welded will be vaporized ahead of the welding torch. The vapor is prevented from being mixed with the molten weld pool by the inert shielding gas that blows the vapor away before it can be mixed. Furthermore, modern filler metal manufacturers produce wires having very low residual hydrogen. This is important because filler metals and base materials are the most realistic sources of hydrogen for the automatic or machine GTAW temper bead welding. Therefore, the potential for hydrogen-induced cracking is greatly reduced by using the machine GTAW process.

3. Cold Restraint Cracking: Cold restraint cracking generally occurs during cooling at temperatures approaching ambient temperature. As stresses build under a high degree of restraint, cracking may occur at defect locations. Brittle microstructures with low ductility are subject to cold restraint cracking. However, the ambient temperature temper bead process is designed to provide a sufficient heat inventory so as to produce the desired tempering for high toughness. Because the machine GTAW temper bead process provides precision bead placement and control of heat, the toughness and ductility of the heat affected zone will typically be superior to the base material. Therefore, the resulting structure will be appropriately tempered to exhibit toughness sufficient to resist cold cracking.

"In conclusion, no elevated preheat or postweld soak above ambient temperature is required to achieve sound and tough repair welds when performing ambient temperature temper bead welding using the machine GTAW [gas tungsten arc] process. This conclusion is based upon strong evidence that hydrogen cracking will not occur with the GTAW process. In addition, automatic or machine temper bead welding procedures without preheat will produce satisfactory toughness and ductility properties both in the weld and weld heat affected zones. The results of previous industry qualifications and repairs further support this conclusion. The use of an ambient temperature temper bead welding procedure will improve the feasibility of performing localized weld repairs with a significant reduction in radiological exposure."

Licensee's Evaluation of Proposed Alternatives to IWA-4500 and IWA-4530:

"1. According to IWA-4500(a), repairs may be performed to dissimilar base materials and welds without the specified PWHT of ASME Code, Section III, provided the requirements of IWA-4500 and IWA-4530 are met. The temper bead rules of IWA-4500 and IWA-4530 apply to dissimilar materials such as P-No. 43 to P-No. 3 base materials welded with F-No. 43 filler metals. When using the GTAW-machine process, the IWA-4500 and IWA-4530 temper bead process is based fundamentally on an elevated preheat temperature of 300 EF, a maximum interpass temperature of 450 EF, and a postweld soak of 450 EF to 550 EF. The proposed alternative of [the licensee's March 24, 2005, supplement] also establishes requirements to perform temper bead welding on dissimilar material welds that join P-No. 43 to P-No. 3 base materials using F-No. 43 filler metals. However, the temper bead process of [the licensee's March 24, 2005, supplement] is an ambient temperature technique that only utilizes the GTAW-machine or GTAW-automatic process. The suitability of the proposed ambient temperature temper bead technique is evaluated above. The results of this evaluation demonstrate that the proposed ambient temperature temper bead technique provides an acceptable level of quality and safety.

2. According to IWA-4500(e)(2), the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 300 EF for the GTAW process while the maximum interpass temperature is limited to 450 EF. The ambient temperature temper bead technique of [the licensee's March 24, 2005, supplement] also establishes a preheat band of at least 1½ times the component thickness or 5 inches, whichever is less. However, the ambient temperature temper bead technique requires a minimum preheat temperature of 50 EF and a maximum interpass temperature of 350 EF. The suitability of an ambient temperature temper bead technique with reduced preheat and interpass temperatures is addressed [above].

3. According to IWA-4500(e)(2), thermocouples and recording instruments shall be used to monitor process temperatures. As explained [above], Entergy cannot use thermocouples and recording instruments to monitor process temperatures during the performance of the heater sleeve mid-wall repair. Because the inside diameter of the new sleeve is only 1.30 inches and welding is being performed internally, there is insufficient space and accessibility along the inside diameter of the heater sleeve to use thermocouples. As an alternative, Entergy will verify the preheat temperature with a pyrometer or temperature indicating crayon prior to welding. This method will provide an accurate measure of preheat temperature and is extensively used in non-temper bead welding applications. With respect to interpass temperature, Entergy will implement a five (5) minute hold time between passes to ensure that the interpass temperature will not approach 350 EF. Because of the large heat sink of the pressurizer shell and the five minute hold time between passes, the 350 EF interpass limitation of the welding procedure will not be exceeded. Mock-up testing and supporting engineering analysis have been performed by Welding Services, Inc. and Structural Integrity Associates to support this position. This alternative approach for controlling interpass temperature has been approved by the NRC for performing mid-wall repairs of reactor pressure vessel head nozzles at Arkansas Nuclear One, Unit 1; Calvert Cliffs Nuclear Power Plant, Units 1 and 2; Millstone Nuclear Power Station, Unit 2; Oconee Nuclear Station, Units 1 and 2; Palisades Plant; and Point Beach Nuclear Plant, Units 1 and 2.

4. According to IWA-4532.2(c), the repair cavity shall be buttered with six layers of weld metal in which the heat input of each layer is controlled to within +/-10% of that used in the procedure qualification test, and heat input control for subsequent layers shall be deposited with a heat input equal to or less than that used for layers beyond the sixth in the procedure qualification. As an alternative to IWA-4532.2, Entergy proposes to butter the ferritic base material with at least three layers of weld metal to obtain a minimum butter thickness of 1/8-inch. The heat input of each layer in the 1/8-inch thick buttered section shall be controlled to within +/-10% of that used in the procedure qualification test. The heat input for subsequent weld layers shall not exceed the heat input used for layers beyond the 1/8-inch thick buttered section (first three weld layers) in the procedure qualification. When using the ambient temperature temper bead technique of [the licensee's March 24, 2005, supplement], the machine GTAW process is used. Machine GTAW is a low heat input process that produces consistent small volume heat affected zones. Subsequent GTAW weld layers introduce heat into the heat affected zone produced by the initial weld layer. The heat penetration of subsequent weld layers is carefully applied to produce overlapping thermal profiles that develop a correct degree of tempering in the underlying heat affected zone. When welding dissimilar materials

with nonferritic weld metal, the area requiring tempering is limited to the weld heat affected zone of the ferritic base material along the ferritic fusion line. After welding the ferritic base material to Alloy 690 with at least 1/8-inch of weld metal (first 3 weld layers), subsequent weld layers should not provide any additional tempering to the weld heat affected zone in the ferritic base material. Therefore, less restrictive heat input controls are adequate after depositing the 1/8-inch thick weld section.

5. According to IWA-4532.2(c), at least one layer of weld reinforcement shall be deposited on the completed weld and with this reinforcement being subsequently removed by mechanical means. In the proposed alternative [of the licensee's March 24, 2005, supplement], the deposition and removal of a reinforcement layer is not required. A reinforcement layer is required when a weld repair is performed to a ferritic base material or ferritic weld using a ferritic weld metal. On ferritic materials, the weld reinforcement layer is deposited to temper the last layer of untempered weld metal of the completed repair weld. Because the weld reinforcement layer is untempered (and unnecessary), it is removed. However, when repairs are performed to dissimilar materials using nonferritic weld metal, a weld reinforcement layer is not required because nonferritic weld metal does not require tempering. When performing a dissimilar material weld with a nonferritic filler metal, the only location requiring tempering is the weld heat affected zone in the ferritic base material along the weld fusion line. However, the three weld layers of the 1/8-inch thick weld section are designed to provide the required tempering to the weld heat affected zone in the ferritic base material. Therefore, a weld reinforcement layer is not required. While Entergy recognizes that IWA-4532.2(c) does require the deposition and removal of a reinforcement layer on repair welds in dissimilar materials, Entergy does not believe that it is necessary for repair using a nonferritic filler material. This position is supported by the fact that ASME Code Case N-638 only requires the deposition and removal of a reinforcement layer of a similar filler material (ferritic) when performing repair welds on similar (ferritic) materials. Repair welds on dissimilar materials using nonferritic filler materials are exempt from this requirement in Code Case N-638.

6. According to IWA-4532.2(d), the weld area shall be maintained at a temperature of 450 EF to 550 EF for a minimum of 4 hours (for P-No. 3 materials) after at least 3/16-inch of weld metal has been deposited. In the proposed alternative [of the licensee's March 24, 2005, supplement], a postweld soak is not required. The suitability of an ambient temperature temper bead technique without a postweld soak is addressed [above].

7. [Under this paragraph in the relief request the licensee states,] "According to IWA-4532.2(e), after depositing at least 3/16-inch of weld metal and performing a postweld soak at <u>300 EF</u>, the balance of welding may be performed at an interpass temperature of 350 EF." [In preceding paragraphs in the relief request, the licensee states, "IWA-4532.2(e) specifies that after depositing at least 3/16-inch of weld metal and performing a postweld soak at <u>450 EF to 550 EF</u>, the balance of welding may be performed at an interpass temperature of 350 EF." This second statement is the correct statement of the ASME Code, Section XI requirements. The essential element of this item is that the balance of the welding will be performed with an interpass temperature of 350 EF and this is what is accepted by staff as the correct statement].

[As an alternative to the proposal that the balance of the welding will be performed with an interpass temperature of 350 EF after performing a postweld soak at 450 EF to 550 EF], Entergy proposes that an interpass temperature of 350 EF may be used throughout the welding process without a postweld soak. The proposed ambient temperature temper bead process [in the licensee's March 24, 2005, supplement] is carefully designed and controlled such that successive weld beads supply the appropriate quantity of heat to the untempered heat affected zone such that the desired degree of carbide precipitation (tempering) is achieved. The resulting microstructure is very tough and ductile. This point is validated during weld procedure qualification. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in the weld heat affected zone will be demonstrated to be equal to or better than those of the unaffected base material. The suitability of an ambient temperature temper bead technique without a postweld soak is [also addressed above].

8. IWA-4533 specifies that (a) the repair weld and preheated band shall be examined by the liquid penetrant method, and (b) the repaired region shall be volumetrically examined by the radiographic method, and if practical, by the ultrasonic method. As an alternative to IWA-4533, Entergy proposes to perform the following examinations after the completed repair weld has been at ambient temperature for at least 48 hours:

   a. Liquid penetrant examination shall be performed in accordance with NB-5000 of ASME Code, Section III, 1989 Edition. Acceptance criteria shall comply with NB-5350.

      Suitability: When using an ambient temperature temper bead technique, an elevated preheat temperature is not used. As a result, there is no preheated band. Therefore, the proposed alternative to only examine the new mid-wall repair weld (including weld heat affected zones) is acceptable.

   b. The completed repair weld shall be ultrasonically examined in accordance with NB-5000 of ASME Code, Section III, 1989 Edition. Acceptance criteria shall comply with NB-5330.

      Suitability: Radiographic examination is impractical since the pressurizer vessel inside diameter is inaccessible for positioning the gamma source. As an alternative to radiographic examination, an ultrasonic examination of the new mid-wall repair weld will be performed. Ultrasonic examination of temper bead repair welds is an acceptable option according to ASME Code, Section XI, IWA-4630 in the 1995 Edition, 1996 Addenda and later (approved by NRC through the 2001 Edition, 2003 Addenda). Ultrasonic examination of repair welds is also required in Code Case N-638. The proposed ultrasonic examination will be performed in accordance with ASME Code, Section III, NB-5000, which includes acceptance criteria that is appropriate for fabrication type flaws."

"Entergy believes that compliance with the repair rules, as stated in ASME Code, Section XI, and as described in the request, would result in unwarranted damage to the pressurizer head assembly. Additionally, the work required to meet the current Code repair method, automatic or machine GTAW temper bead with 300 EF minimum preheat and 450 EF to 550 EF postweld hydrogen bake-out, would be extremely difficult, and personnel radiation exposure resulting from set-up, monitoring, and removing the required equipment is not justified. Entergy also believes that the proposed alternative provides an acceptable level of quality and safety without exposing the pressurizer to potential distortion of the sleeves and heater support structure, as discussed above. Therefore, Entergy requests that the NRC staff authorize the proposed alternative in accordance with 10 CFR 50.55a(a)(3)(i)."

Staff Evaluation

According to IWA-4500(a), repairs may be performed to dissimilar base materials and welds without the specified PWHT of ASME Code, Section III, provided the requirements of IWA-4500 and IWA-4530 are met. The temper bead rules of IWA-4500 and IWA-4530 apply to dissimilar materials such as P-No. 43 to P-No. 3 base materials welded with F-No. 43 filler metals. When using the GTAW-machine process, the IWA-4500 and IWA-4530 temper bead process is based fundamentally on an elevated preheat temperature of 300 EF, a maximum interpass temperature of 450 EF, and a postweld soak of 450-550 EF. The proposed alternative in the licensee's March 24, 2005, supplemental letter also establishes requirements to perform temper bead welding on dissimilar metal welds that join P-No. 43 to P-No. 3 base metals using F-No. 43 filler metals. However, the temper bead process in the licensee's March 24, 2005, supplement is an ambient temperature technique that only utilizes the GTAW-machine or GTAW-automatic process.

According to IWA-4500(e)(2), the weld area plus a band around the repair area of at least 1½ times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 300 EF for the GTAW process during welding while the maximum interpass temperature is limited to 450 EF. The ambient temperature temper bead technique in the licensee's March 24, 2005, supplement also establishes a preheat band of at least 1½ times the component thickness or 5 inches, whichever is less. However, the proposed ambient temperature temper bead technique requires a minimum preheat temperature of 50 EF, a maximum interpass temperature of 150 EF for the first three layers, and a maximum interpass temperature of 350 EF for the balance of welding. This is suitable because the heat penetration of subsequent weld layers is carefully applied to produce overlapping thermal profiles that develop an acceptable degree of tempering in the underlying heat affected zone. This is further developed in EPRI report GC-111050, wherein repair welds performed with an ambient temperature temper bead procedure utilizing the machine GTAW process exhibit mechanical properties equivalent to or better than those of the surrounding base material. Laboratory testing, analysis, successful procedure qualifications, and successful repairs have all demonstrated the effectiveness of this process.

Also, according to IWA-4500(e)(2), thermocouples and recording instruments shall be used to monitor process temperatures. The licensee cannot use thermocouples and recording instruments to monitor process temperatures during the performance of the heater sleeve mid-wall repair because the inside diameter of the new sleeve is only 1.30 inches and welding is being performed internally, thus, there is insufficient space and accessibility along the inside diameter of the heater sleeve to use thermocouples. As an alternative, the licensee will verify the preheat temperature with a pyrometer or temperature indicating crayon prior to welding. This method will provide an accurate measure of preheat temperature. With respect to interpass temperature, Entergy will implement a five (5) minute hold time between passes to ensure that the interpass temperature will not approach 350 EF. The licensee states that because of the large heat sink of the pressurizer and the five minute hold time between passes, the 350 EF interpass limitation of the welding procedure will not be exceeded. It has performed mock-up testing and supporting engineering analysis to support this position. Therefore, this type of temperature control is acceptable.

According to IWA-4532.2(c), the repair cavity shall be buttered with six layers of weld metal in which the heat input of each layer is controlled to within +/-10% of that used in the procedure qualification test, and heat input control for subsequent layers shall be deposited with a heat input equal to or less than that used for layers beyond the sixth in the procedure qualification. As an alternative to IWA-4532.2, the licensee proposes to butter the repair cavity or weld area with at least three layers of weld metal to obtain a minimum butter thickness of 1/8-inch. The heat input of each layer in the 1/8-inch thick buttered section shall be controlled to within +/-10% of that used in the procedure qualification test. The heat input for subsequent weld layers shall not exceed the heat input used for layers beyond the 1/8-inch thick buttered section (first three weld layers) in the procedure qualification. When using the ambient temperature temper bead technique as discussed in the licensee’s March 24, 2005, supplement, the machine GTAW process is used. Machine GTAW is a low heat input process that produces consistent small volume heat affected zones. Subsequent GTAW weld layers introduce heat into the heat affected zone produced by the initial weld layer. The heat penetration of subsequent weld layers is carefully applied to produce overlapping thermal profiles that develop a correct degree of tempering in the underlying heat affected zone. When welding dissimilar materials with nonferritic weld metal, the area requiring tempering is limited to the weld heat affected zone of the ferritic base material along the ferritic fusion line. After buttering the ferritic base material with at least 1/8-inch of weld metal (first 3 weld layers), subsequent weld layers should not provide any additional tempering to the weld heat affected zone in the ferritic base material. Therefore, less restrictive heat input controls are adequate after depositing the 1/8-inch thick buttered section.

According to IWA-4532.2(c), at least one layer of weld reinforcement shall be deposited on the completed weld with this reinforcement being subsequently removed by mechanical means. In the proposed alternative discussed in the licensee’s March 24, 2005, supplement, the deposition and removal of a reinforcement layer is not required. A reinforcement layer is required when a weld repair is performed to a ferritic base material or ferritic weld using a ferritic weld metal. On ferritic materials, the weld reinforcement layer is deposited to temper the last layer of untempered weld metal of the completed repair weld. Because the weld reinforcement layer is untempered (and unnecessary), it is removed. However, when repairs are performed to dissimilar materials using nonferritic weld metal, a weld reinforcement layer is not required because nonferritic weld metal does not require tempering. When performing a dissimilar material weld with a nonferritic filler metal, the only location requiring tempering is the weld heat affected zone in the ferritic base material along the weld fusion line. However, the three weld layers of the 1/8-inch thick butter section are designed to provide the required tempering to the weld heat affected zone in the ferritic base material. Therefore, a weld reinforcement layer is not required. This position is supported by the fact that ASME Code Case N-638 only requires the deposition and removal of a reinforcement layer when performing repair welds on similar (ferritic) materials. Repair welds on dissimilar materials are exempt from this requirement. Non-ferritic filler metals, such as, the F-No. 43 filler metal do not undergo a phase change at elevated temperature and, therefore, do not require a PWHT. Since the last layer of weld metal is a non-ferritic metal being deposited over two previous non-ferritic weld filler metal layers, the need for a tempering layer is unnecessary and its removal is unnecessary. Therefore, deletion of this requirement is acceptable.

According to IWA-4532.2(d), the weld area shall be maintained at a temperature of 450 EF to 550 EF for a minimum of 4 hours (for P-No. 3 materials) after at least 3/16-inch of weld metal has been deposited. In the proposed alternative in the licensee's March 24, 2005, supplement, a postweld soak is not required. According to IWA-4532.2(e), after depositing at least 3/16-inch of weld metal and performing a postweld soak at 450 EF to 550 EF, the balance of welding may be performed at an interpass temperature of 350 EF. As an alternative, the licensee proposes that an interpass temperature of 350 EF may be used throughout the welding process without a postweld soak. The proposed ambient temperature temper bead process in the licensee's March 24, 2005, supplement is carefully designed and controlled such that successive weld beads supply the appropriate quantity of heat to the untempered heat affected zone such that the desired degree of carbide precipitation (tempering) is achieved. The resulting microstructure is tough and ductile. This point is validated during weld procedure qualification. Also, based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat affected zone will be demonstrated to be equal to or better than those of the unaffected base material. Therefore, the alternative temperature proposal is acceptable. The suitability of this proposal has also been explained above in the evaluation of IWA-4500(e)(2).

IWA-4533 specifies that the repair weld and preheated band shall be examined by the liquid penetrant method and the repaired region shall be volumetrically examined by the radiographic method and, if practical, by the ultrasonic method. As an alternative to IWA-4533, the licensee proposes to perform the following examinations after the completed repair weld has been at ambient temperature for at least 48 hours. Liquid penetrant examination shall be performed in accordance with NB-5000 of ASME Code, Section III, 1989 Edition. Acceptance criteria shall comply with NB-5350. The completed repair weld shall be ultrasonically examined in accordance with NB-5000 of ASME Code, Section III, 1989 Edition. Acceptance criteria shall comply with NB-5330. When using an ambient temperature temper bead technique, an elevated preheat temperature is not used. As a result, there is no preheat temperature band. Therefore, the proposed alternative to only examine the new mid-wall repair weld (including weld heat affected zones), when performing the liquid penetrant examination is acceptable. Radiographic examination is impractical since the pressurizer vessel inside diameter is inaccessible for positioning the gamma source. Also, the geometry of the pressurizer lower head and the orientation of the pressurizer to heater sleeve weld, make effective radiographic examination impractical. As an alternative to radiographic examination, an ultrasonic examination of the new mid-wall repair weld will be performed. Ultrasonic examination of temper bead repair welds is an acceptable option according to ASME Code, Section XI, IWA-4630 in the 1995 Edition, 1996 Addenda and later. Ultrasonic examination of repair welds is also required in Code Case N-638. The proposed ultrasonic examination will be performed in accordance with ASME Code, Section III, NB-5000, which includes acceptance criteria that is appropriate for fabrication type flaws.

The use of a GTAW temper bead 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 heat affected zone of the base material and preceding weld passes. The temper bead 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 and Welding Procedure Specifications 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 does the manual SMAW process. The very precise control over these factors afforded by the licensee's proposed alternative provides more effective tempering and will provide an acceptable level of quality and safety.

5.0 CONCLUSION

The staff concludes that the licensee's proposed alternative to use ambient temperature temper bead welding for repairing flaws in the pressurizer heater sleeve penetrations, as discussed in Relief Request No. ANO2-R&R-003, provides an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the staff authorizes the proposed alternative for use at ANO-2. The alternative is authorized for the third 10-year ISI interval through the end of the refueling outage scheduled for the spring of 2005.

All other requirements of the ASME Code, Sections 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.

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