April 16, 2003

Mr. Michael Krupa
Director, Nuclear Safety & Licensing
Entergy Operations, Inc.
1340 Echelon Parkway
Jackson, MS 39213-8293

SUBJECT: ARKANSAS NUCLEAR ONE - UNIT 1 (ANO-1), ARKANSAS NUCLEAR ONE - UNIT 2 (ANO-2), AND WATERFORD STEAM ELECTRIC STATION, UNIT 3 (WATERFORD 3) - RE: REQUEST FOR RELIEF FROM THE REQUIREMENTS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME) BOILER AND PRESSURE VESSEL CODE (CODE) CONCERNING ALTERNATIVE TO TEMPER BEAD WELDING REQUIREMENTS FOR INSERVICE INSPECTION (ISI) PROGRAM (TAC NOS.: MB4288, MB4289, AND MB4286)

Dear Mr. Krupa:

By letter dated March 4, 2002, as supplemented by letters dated, March 29, August 2, and September 23, 2002, Entergy Operations Inc. (the licensee) requested relief from certain American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Section XI requirements at ANO-1, ANO-2, and Waterford 3.

The U. S. Nuclear Regulatory Commission staff concludes that the licensee's proposal to use Gas Tungsten Arc Welding (GTAW) ambient temperature temper bead welding for reactor pressure (RPV) vessel head penetration nozzle J-groove weld repairs as stated in relief request PWR-R&R-001 provides an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the staff authorizes the use of the proposed alternative to the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530 of ASME Code Section XI for the third 10-year ISI interval of ANO-1, which ends on May 31, 2007; for the third 10-year ISI interval of ANO-2, which ends on March 25, 2010; and the second 10-year ISI interval for Waterford 3, which ends on June 30, 2007.

The staff also concludes that compliance with the Code-required volumetric examinations of the repair weld would result in hardship without a compensating increase in the level of quality and safety, and that the licensee's proposed alternative to implement progressive liquid penetrant examination for RPV head penetration nozzle J-groove weld repairs provides reasonable assurance of structural integrity. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), the proposed alternative is authorized for the third 10-year ISI interval of ANO-1, which ends on May 31, 2007; for the third 10-year ISI interval of ANO-2, which ends on March 25, 2010; and the second 10-year ISI interval for Waterford 3, which ends on June 30, 2007.

The NRC staff's safety evaluation is enclosed.

Sincerely,

/RA/

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

Docket Nos. 50-313, 50-368, and 50-382

Enclosure: Safety Evaluation

cc w/encl: See next page

The NRC staff's safety evaluation is enclosed.

Sincerely,

/RA/

Robert A. Gramm, Chief, Section 1
Project Directorate IV
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cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

INSERVICE INSPECTION PROGRAM RELIEF REQUEST PWR-R&R-001

ENTERGY OPERATIONS, INC.

ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 (ANO-1 AND ANO-2) AND

WATERFORD STEAM ELECTRIC STATION UNIT 3 (WATERFORD 3)

DOCKET NUMBERS 50-313, 50-368 AND 50-382

1.0 INTRODUCTION

By letter dated March 4, 2002, as supplemented by letters dated, March 29, August 2, and September 23, 2002, Entergy Operations, Inc. (Entergy or the licensee) requested approval to utilize an alternative method to the temper bead welding requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, IWA-4500 and IWA-4530 for reactor pressure vessel (RPV) Head-to-Control Rod Drive Mechanisms (CRDM[1] or CEDM) welds.

2.0 BACKGROUND

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

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) will meet the requirements, except the design and access provisions and the preservice examination requirements, set forth in ASME Code, Section XI, 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

[1]In this Safety Evaluation, Control Rod Drive Mechanism (CRDM) and Control Element Drive Mechanism (CEDM) are used interchangeably.

120-month interval, subject to the limitations and modifications listed therein. The ISI code of record the third 10-year ISI interval, for ANO-1 and ANO-2, and the second 10-year ISI interval for Waterford 3 is the 1992 Edition of the ASME Code.

3.0 EVALUATION

Proposed Alternative to ASME Code Requirements for Weld Repairs

The Item for which Relief is Requested:

RPV Head penetration nozzles

Code Requirements for which Relief is Requested:

Subarticle IWA-4170(b) of ASME Code, Section XI, 1992 Edition 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, 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),

> "*All Materials*. 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."

IWA-4530 applies to dissimilar materials such as welds that join P-Number (No.) 43 nickel alloy to P-No. 3 low alloy steels. According to IWA-4530,

> "Repairs to welds that join P-No. 8 or P-No. 43 material to P-Nos. 1, 3, 12A, 12B, and 12C material may be made without the specified postweld heat treatment, provided the requirements of IWA-4530 through IWA-4533 are met. Repairs made to this paragraph are limited to those along the fusion line of a nonferritic weld to ferritic base material where 1/8-in. [inch] or less of nonferritic weld deposit exists above the original fusion line after defect removal."

Temper bead repairs of RPV head penetration nozzle J-welds are performed in accordance with IWA-4500 and IWA-4530 whenever the repair cavity is within 1/8-inch of the ferritic base materials of the RPV head. When the Gas Tungsten Arc Welding (GTAW) process is used in accordance with IWA-4500 and IWA-4530, then temper bead welding is performed as follows:

- Only the automatic or machine GTAW process using cold wire feed can be used. Manual GTAW cannot be used.

- A minimum preheat temperature of 300 °F is established and maintained throughout the welding process. Interpass temperature cannot exceed 450 °F.

- The weld cavity is buttered with at least six layers of weld metal.

- Heat input of the initial six layers is controlled to within +/-10% of that used for the first six layers during procedure qualification testing.

- After the first six weld layers, repair welding is completed with a heat input that is equal to or less than that used in the procedure qualification for weld layers seven and beyond.

- Upon completion of welding, a postweld soak or hydrogen bake-out at 450 °F to 550 °F for a minimum of four hours is required.

- Preheat, interpass, and postweld soak temperatures are monitored using thermocouples and recording instruments.

- The repair weld and preheated band are examined in accordance with IWA-4533 after the completed weld has been at ambient temperature for 48 hours.

<u>Licensee’s Proposed Alternative to Code</u>:

Pursuant to 10 CFR 50.55a(a)(3)(i), Entergy proposes alternatives to the GTAW-machine temper bead welding 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 Relief Request PWR-R&R-001, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique."

Entergy has reviewed the proposed ambient temperature temper bead welding techniques proposed in Attachment 1 against the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530. This review was performed to identify differences between Attachment 1 and IWA-4500 and IWA-4530. Based upon this review, Entergy proposes alternatives to ASME Code, Section XI requirements of IWA-4500 and IWA-4530 as follows:

IWA-4500(a) specifies that repairs to base materials and welds identified in IWA-4530 may be performed without the specified postweld heat treatment 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 temper bead technique described in Attachment 1. Only the machine or automatic GTAW process can be used when performing ambient temperature temper bead welding in accordance with Attachment 1.

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 demonstrate the ability to deposit sound weld metal in the required 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 welding 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 Attachment 1 utilizes a machine GTAW welding process, limited access demonstrations of "welding operators" are not required. Therefore, the requirement of IWA-4500(d)(2) does not apply.

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 in., whichever is less, shall be preheated and maintained at a minimum temperature of 350 °F for the SMAW process and 300 °F for the GTAW process during welding. The maximum interpass temperature shall be 450 °F." 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 55 °F for the GTAW process during welding; maximum interpass temperature shall be 150 °F for the 1/8-inch butter thickness (first three weld layers as a minimum) and 350 °F for the balance of welding.

IWA-4500(e)(2) further specifies that "Thermocouples and recording instruments shall be used to monitor process temperatures." As an alternative, Entergy proposes to monitor preheat and interpass temperatures using an infrared thermometer.

IWA-4500(e)(2) also specifies that "Their [thermocouples] attachment and removal shall be performed in accordance with [ASME Code] Section III." Because Entergy will use an infrared thermometer to monitor preheat and interpass temperatures, thermocouples will not be used. Therefore, the thermocouple attachment and removal requirements of IWA-4500(e)(2) do not apply.

IWA-4532.1 establishes procedure technique requirements that apply when using the SMAW process. Because the proposed ambient temperature temper bead technique of Attachment 1 utilizes the machine or automatic GTAW welding process, the SMAW temper bead technique requirements of paragraph IWA-4532.1 do not apply.

IWA-4532.2 establishes procedure technique requirements that apply when using the GTAW process but do not address joint design qualification of the repair cavity. As an alternative, Entergy proposes to qualify the joint design of the proposed repair cavity by requiring that the root width and included angle of the repair cavity in the test assembly be no greater than the minimum specified for the repair.

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 butter the weld area with a minimum of three layers of weld metal to obtain a minimum butter thickness of 1/8-inch. The heat input of each weld 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.

IWA-4532.2(c) further specifies that "The completed weld shall have at least one layer of weld reinforcement deposited and then 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.

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 °F to 550 °F for a minimum of four hours (for P-No. 3 materials). As an alternative, Entergy's proposed ambient temperature temper bead technique does not include a postweld soak.

IWA-4532.2(e) specifies that after depositing at least 3/16-inch of weld metal and performing a postweld soak at 450 °F to 550 °F, the balance of welding may be performed at an interpass temperature of 350 °F. As an alternative, Entergy proposes that an interpass temperature of 350 °F may be used after depositing at least 1/8-inch of weld metal without a postweld soak.

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 (PT) method; and (b) the repaired region shall be volumetrically examined by the radiographic (RT) method, and, if practical, by the ultrasonic (UT) method. Entergy will perform the PT examination of the completed repair weld and preheated band, as required by IWA-4533. As an alternative to the volumetric examination of IWA-4533, Entergy proposes the following examinations for repair welds in RPV penetration nozzle J-welds. Repair welds will be progressively examined by the PT method in accordance with NB-5245 of ASME Code, Section III. The PT examinations will be performed in accordance with NB-5000. Acceptance criteria shall be in accordance with NB-5350.

This request for alternative is specific to localized weld repair of RPV head penetration nozzle J-welds where 1/8-inch or less of Inconel weld metal exists between the J-weld repair cavity and the ferritic base material of the RPV head. Flaws in the J-weld will be removed prior to performing any temper bead repairs in accordance with this relief request.

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

The IWA-4500 and IWA-4530 temper bead welding process is a time- and dose-intensive process. Resistance heating blankets are attached to the RPV head and typically, a capacitor discharge stud welding process is used. Thermocouples must also be attached to the RPV head using a capacitor discharge welding process to monitor preheat, interpass, and postweld soak temperatures. Prior to heat-up, 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 RPV head. Thermocouples and stud welds are removed by grinding. Ground removal areas are subsequently examined by the PT or magnetic particle (MT) method. A significant reduction in dose could be realized by utilizing an ambient temperature temper bead process. Because the ASME Code does not presently include rules for ambient temperature temper bead welding, Entergy proposes the alternative described above.

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

Temper Bead Applications." According to the EPRI report, repair welds performed with an ambient temperature temper bead procedure utilizing the machine GTAW welding 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 principal reason 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 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 are characteristics of the machine GTAW process, effective tempering of weld heat-affected zones is possible without the application of preheat. According to 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."

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 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 °F increases the diffusion rate of hydrogen from the weld. The postweld soak at 450 °F 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 welding process is inherently free of hydrogen. Unlike the SMAW process, GTAW welding filler metals do not rely on flux coverings that are susceptible to moisture absorption from the environment. Conversely, the GTAW process utilizes dry, inert shielding gases that protect 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 that have very low residual hydrogen. This is important because filler metals and base materials are the most realistic sources of hydrogen for automatic or machine GTAW temper bead welding.

As explained above, the potential for hydrogen-induced cracking is greatly reduced by using machine GTAW process. However, should it occur, cracks would be detected by the final nondestructive examinations (NDE) performed after the completed repair weld has been at ambient temperature for at least 48 hours as required in Attachment 1. Regarding this issue, EPRI Report GC-111050, concluded the following:

> "No preheat temperature or post-weld bake above ambient temperature is required to achieve sound machine GTAW temper bead repairs that have high toughness and ductility. This conclusion is based on the fact that the GTAW process is an inherently low hydrogen process regardless of the welding environment. Insufficient hydrogen is available to be entrapped in solidifying weld material to support hydrogen delayed cracking. Therefore, no preheat nor post-weld bake steps are necessary to remove hydrogen because the hydrogen is not present with the machine GTAW process."

The IWA-4530 temper bead process also includes a postweld soak requirement. Performed at 450 °F to 550 °F for four 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 postweld heat treatment as defined by the ASME Code. At 450 °F to 550 °F, the postweld soak does not stress relieve, temper, or alter the mechanical properties of the weldment in any manner.

Cold 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. Additionally, even if cold cracking were to occur, it would be detected by the final NDE which is performed after the completed repair weld has been at ambient temperature for at least 48 hours.

Attachment 1 to PWR-R&R-001 establishes detailed welding procedure qualification requirements. Simulating base materials, filler metals, restraint, impact properties, and procedure variables, these qualification requirements provide assurance that the mechanical properties of repair welds will be equivalent to or superior to those of the surrounding base material. It should also be noted that these qualification requirements are identical to those in IWA-4530. Based upon ambient temperature temper bead procedure qualification test results, the impact properties of the base material heat-affected zone were greater than those of the unaffected base material.

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 process. This conclusion is based upon 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. EPRI Report GC-111050 concluded the following:

> "Repair of RPV components utilizing machine GTA temper bead welding at ambient temperature produces mechanical properties that are commonly superior to those of the service-exposed substrate. The risk for hydrogen delayed cracking is minimal using the GTAW process. Cold stress cracking is resisted by the excellent toughness and ductility developed in the weld HAZ [heat affected zone]. Process design and geometry largely control restraint considerations, and these factors are demonstrated during weld procedure qualification."

Evaluation:

According to IWA-4500(a), repairs may be performed to dissimilar base materials and welds without the specified postweld heat treatment 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 °F, a maximum interpass temperature of 450 °F, and a postweld soak of 450 °F to 550 °F. The proposed alternative of Attachment 1 to PWR-R&R-001 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 of Attachment 1 is an ambient temperature technique which only utilizes the GTAW-machine or GTAW-automatic process.

The requirement of IWA-4500(d)(2), which discusses the ability of the welder to deposit sound weld metal in the required positions, does not apply to welding operators who perform machine or automatic GTAW welding from a remote location. Therefore, the requirement of IWA-4500(d)(2) does not apply.

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 °F for the GTAW process during welding, while the maximum interpass temperature is limited to 450 °F. The ambient temperature temper bead technique of Attachment 1 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 °F, a maximum interpass temperature of 150 °F for the first three layers, and a maximum interpass temperature of 350 °F 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 welding 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. As an alternative to IWA-4500(e)(2), Entergy proposes to monitor preheat and interpass temperatures using an infrared thermometer. Infrared thermometers are hand-held devices that can be used to monitor process temperature from a remote location. The preheat temperature will be verified to be 55 °F (minimum) prior to depositing the first weld layer. Prior to depositing the second and third weld layers, the interpass temperatures will be verified to be at least 55 °F but less than 150 °F. The interpass temperature of each remaining layer will be verified to be at least 55 °F but less than 350 °F prior to depositing the subsequent weld layers. The initial preheat temperature and the interpass temperatures for each weld layer will be recorded in the weld documentation of the repair traveler for each repair weld. The weld documentation of the repair traveler will be maintained as a permanent plant record. The preheat temperature required for this welding is 55 °F. This temperature is to be maintained on a weldment inside a building which normally is above this temperature. Therefore, preheat measurement by this alternate method is acceptable. The maximum interpass temperatures required for this welding (150 °F for the first three layers, and a maximum interpass temperature of 350 °F for the balance of welding) also can easily be measured with this type of device; however, procedure qualifications performed for this welding showed that these temperatures were not exceeded or even approached when these tests where performed on similar materials, thicknesses, and welding processes. Thus it is unlikely that these welds will ever exceed these temperatures and, with the alternate temperature measurement methods, a close control will be maintained on these temperatures. Therefore, this type of temperature measurement is acceptable.

IWA-4532.2 establishes procedure technique requirements but does not address joint design access qualification of the repair cavity. As an alternative to IWA-4532.2, Entergy proposes to qualify the root width and included angle of the proposed repair cavity. Attachment 1 to PWR-R&R-001 requires that the root width and included angle of the repair cavity in the test assembly be no greater than the minimum specified for the repair. This requirement ensures that the welding procedure is only used in repair cavity configurations where it has demonstrated capability (i.e., sufficient access to deposit root passes, tie-in to the beveled or tapered walls of the repair cavity, provide appropriate tempering, and ensure complete weld fusion). The alternate exceeds Code requirements and 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(c), Entergy 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 of Attachment 1, 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. It should also be noted that IWA-4530 does not require temper bead welding except "where 1/8-inch or less of nonferritic weld deposit exists above the original fusion line after defect removal." The proposed heat input techniques of Attachment 1 were utilized in the qualification of Welding Procedure Specifications to be used for this repair. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat-affected zone were greater than those of the unaffected base material. Therefore, the proposed heat input controls of Attachment 1 provide an appropriate level of tempering and the proposed alternate is acceptable.

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 of Attachment 1 to PWR-R&R-001, 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 temperatures and, therefore, do not require a postweld heat treatment. 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 °F to 550 °F for a minimum of four hours (for P-No. 3 materials) after at least 3/16-inch of weld metal has been deposited. According to IWA-4532.2(e), after depositing at least 3/16-inch of weld metal and performing a postweld soak at 450 °F to 550 °F, the balance of welding may be performed at an interpass temperature of 350 °F. In the proposed alternative of Attachment 1, a postweld soak is not required and Entergy also proposes that an interpass temperature of 350 °F may be used after depositing at least 1/8-inch of weld metal without a postweld soak. The proposed ambient temperature temper bead welding technique of Attachment 1 is carefully designed and controlled such that successive weld beads supply the appropriate quantity of heat to the untempered heat-affected zone and the desired degree of tempering is achieved. Use of the automatic or machine GTAW process utilized for temper bead welding allows for precise control of heat input, bead placement, and bead size and contour. The resulting microstructure is tough and ductile. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in the weld heat-affected zone were greater than those of the unaffected base material. Therefore, the proposed heat input controls of Attachment 1 provide an appropriate level of tempering. The use of a GTAW temper bead welding technique to avoid the need for postweld heat treatment is based on research that has been performed by EPRI and other organizations. The research demonstrates that carefully controlled heat input and bead placement allows subsequent welding passes to relieve stress and temper the HAZ of the base material and preceding weld passes. Data presented in the EPRI report show the results of acceptable procedure qualifications performed with 300 ^{o}F preheats and 500 ^{o}F preheats, as well as with no preheat and postheat. Many acceptable Procedure Qualification Records and Welding Procedure Specifications presently exist and have been utilized to perform numerous successful repairs, which indicates 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.

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 PT method; and (b) the repaired region shall be volumetrically examined by the RT method, and, if practical, the UT method. The licensee's NDE alternative is to progressively examine the repair welds by PT in accordance with paragraph NB-5245 of ASME Code, Section III. The PT examinations will be performed in accordance with subsection NB-5000 with acceptance criteria in accordance with paragraph NB-5350.

Pursuant to 10 CFR 50.55a(a)(3)(i), the licensee stated that alternative progressive PT examination of the repair weld provides an acceptable level of quality and safety. The licensee stated that RT of the weld repairs of the J-groove welds is not practical due to the weld configuration and access limitations. The weld configuration and geometry of the penetration in the head provide an obstruction for the RT and limiting interpretation of the film. They also indicated that UT was impractical for the J-groove weld but did not provide a basis for the impracticality of performing the UT examination. The licensee stated that ASME Code, Section III does not require volumetric examination of J-groove welds. According to sub-subparagraph NB-3352.4(d)(1): "partial penetration welds used to connect nozzles as permitted in NB-3337.3 shall meet the fabrication requirements of NB-4244(d) and shall be capable of being examined in accordance with NB-5245." According to NB-5245, "Partial penetration welds, as permitted in NB-3352.4(d), and as shown in Figures NB-4244(d)-1 and NB-4244(d)-2, shall be examined progressively using either the magnetic particle or liquid penetrant method. The increments of examination shall be the lesser of one-half of the maximum weld dimension measured parallel to the centerline of the connection or ½ inch. The surface of the finished weld shall also be examined by either method."

The staff concurs that the access limitations of the CRDM penetrations prevent meaningful RT of the repair welds. Placement of the film and maintaining radioactive source alignment due to the near proximity of adjoining nozzles prevents the accomplishment of a meaningful RT. Though not stated by the licensee, industry experience with UT examination of austenitic weld materials such as the J-groove weld does not provide meaningful results due to the attenuative properties of the weld metal. Secondly, the licensee proposes to perform the progressive PT of the repair weld as required by ASME Code, Section III. Subsection IWA-4000 of ASME Code, Section XI allows repair in accordance with the Construction Code or later Editions of ASME Code, Section III. Based on the above discussion, the staff concludes that the licensee's alternative to perform progressive PT of the J-groove weld repairs is a suitable alternative that provides reasonable assurance that structurally sound welds are deposited.

4.0 CONCLUSION

The staff concludes that the licensee's proposed alternative to use GTAW ambient temperature temper bead welding for RPV head penetration nozzle J-groove weld repairs as stated in relief request PWR-R&R-001 provides an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the staff authorizes the proposed alternative to the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530 of ASME Code, Section XI at ANO-1, ANO-2, and Waterford 3.

The staff also concludes that compliance with the Code-required volumetric examinations of the repair weld would result in hardship without a compensating increase in the level of quality and safety, and that the licensee's proposed alternative to implement progressive PT for RPV head penetration nozzle J-groove weld repairs provides reasonable assurance of structural integrity. Therefore, pursuant to 10 CFR 50.55a(a)(3)(ii), the proposed alternative is authorized for the third 10-year ISI interval for ANO-1 and ANO-2, and the second 10-year ISI interval for Waterford 3.

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

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