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April 24, 2003

Subject: Request for Review and Approval of WCAP-16063, "Ambient Temper Bead Repair of Head Adapter Penetrations in PWR Reactor Vessel Upper Heads"

Westinghouse Electric Company LLC has developed services for repair of head adapter penetrations in the upper reactor vessel heads of pressurized water reactors. A machine Gas Tungsten Arc Welding (GTAW) temper bead repair technique at ambient temperature without the special process of a postbake or post weld heat treat requirement represents an alternate repair technique that requires NRC approval. WCAP-16063, "Ambient Temper Bead Repair of Head Adapter Penetrations in PWR Reactor Vessel Upper Heads" is provided to define and provide technical justification for the ambient temperature temper bead welding technique. The information provided in this report supports approval of the proposed alternative when requested by the licensees of nuclear power plants under the provisions of 10CFR50.55a(a)(3)(i).

It is requested that the NRC review and approve the technical justification for the temper bead repair technique at ambient temperature on a generic basis in support of plant specific requests under the provisions of 10CFR50.55a(a)(3)(i). The information in the enclosed report (WCAP-16063) is similar to that included in plant specific relief requests that have been approved by the NRC staff. Approved plant specific relief requests for the temper bead repair technique at ambient temperature include requests for Arkansas Nuclear One Units 1 & 2 and North Anna Unit 2. We also understand that review of a relief request based on the same information for the Indian Point units is in process. This request for review of WCAP-16063 supersedes our previous relief request (Westinghouse Letter LTR-NRC-02-6, dated February 18, 2002). The report includes information provided in a response (LTR-NRC-02-65, dated December 13, 2002) to an RAI request. Based on the NRC review of this subject already complete, we are requesting review and approval within three months.

Reactor pressure vessel (RPV) penetration nozzles throughout the pressurized water reactor vessel fleets have already experienced cracking due to susceptibility to Primary Water Stress Corrosion Cracking (PWSCC). Susceptibility rankings for the various plants have been reported to the NRC in response to NRC Bulletin 2001-01. Should repair welding of reactor pressure vessel head penetration nozzle J-welds encroach (within 1/8 inch) on the ferritic base material of the reactor pressure vessel head, temper bead weld repairs would be required.

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Differences between the American Society Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI requirements and the alternate repair process using ASME Code Cases (as a guideline) are outlined. The ASME Boiler and Pressure Vessel Code, Section XI permits temper bead weld repair techniques that include a heat treatment requirement. The machine GTAW temper bead welding technique at ambient temperature without the special process of a postbake or post weld heat treat requirement represents an alternate repair welding technique that requires NRC approval. An evaluation of the ambient temperature temper bead welding technique including a review of mechanical properties, hydrogen cracking, and cold restraint cracking is provided. An evaluation of test results demonstrates that the material properties of the weld and heat affected zone are acceptable. This report concludes that the proposed alternative would provide an acceptable level of quality and safety. The proposed alternative would also result in a reduction of radiological exposure to personnel.

Please contact D. A. Lindgren at 412-374-4956 if you have any questions concerning this transmittal.

Very truly yours,

H. A. Sepp, Manager
Regulatory Compliance and Plant Licensing

Enclosures

cc: D. Holland/NRR – 1 Enclosure
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Westinghouse Non-Proprietary Class 3

WCAP-16063 April 2003

Ambient Temper Bead Repair of Head Adapter Penetrations in PWR Vessel Upper Heads

Westinghouse

WESTINGHOUSE NON-PROPRIETARY CLASS 3

WCAP-16063

Ambient Temper Bead Repair of Head Adapter Penetrations in PWR Vessel Upper Heads

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April 2003

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ABSTRACT

Westinghouse Electric Co. LLC has developed services for repair of head adapter penetrations in the upper head of reactor vessels. A machine Gas Tungsten Arc Welding (GTAW) temper bead repair technique at ambient temperature without the special process of a postbake or post weld heat treat requirement, represents an alternate repair technique that requires NRC approval. This document is presented to define and provide technical justification for the ambient temperature temper bead welding technique. Differences between the American Society Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI requirements and the alternate repair process using ASME Code Cases (as a guideline) are outlined. An evaluation of the ambient temperature temper bead welding technique including a review of mechanical properties, hydrogen cracking, and cold restraint cracking is provided. An evaluation of test results demonstrates that the material properties of the weld and heat affected zone are acceptable. This report concludes that the proposed alternative would provide an acceptable level of quality and safety. The proposed alternative would also result in a reduction of radiological exposure to personnel. The information provided in this report supports approval of the proposed alternative when requested by the licensees of nuclear power plants under the provisions of 10CFR50.55a(a)(3)(i).

1 INTRODUCTION

Westinghouse Electric Co. LLC has developed services for repair of head adapter penetrations in the upper head of reactor vessels. Head adapter penetrations include those to which control rod drive mechanisms, instrument columns, and head vents are attached. One of the repair practices includes the ambient temperature temper bead welding technique applied with the machine gas tungsten arc welding (GTAW) process. The ASME Boiler and Pressure Vessel Code, Section XI, permits temper bead weld repair techniques that include a heat treatment requirement. The machine GTAW temper bead welding technique at ambient temperature without the special process of a postbake or post weld heat treat requirement, represents an alternate repair welding technique that requires NRC approval. This document is presented to define and provide technical justification for the ambient temperature temper bead welding technique. This document will support NRC approval of plant specific requests for the use of the ambient temperature temper bead welding technique methodology as an alternate to ASME Code Section XI requirements. Please note that this document uses the ASME Code, 1992 Edition as a basis for discussion but the repair concepts and technical justifications will apply to later editions as well. In the ASME Code, Section XI, starting with the 1995 Addenda, the information on temper bead weld repair was renumbered to IWA 4600. There was also some renumbering on the subsubarticle and paragraph level. The technical content and requirements did not change.

The components that are to be repaired using the ambient temperature temper bead technique are the head adapter penetrations on the upper reactor vessel head of pressurized water reactors (PWRs). The vessel head and the penetrations are ASME Code, Section III, Sub-Section NB (Code Class 1) components.

Reactor pressure vessel (RPV) penetration nozzles throughout the pressurized water reactor vessel fleets have already experienced cracking, due to susceptibility to Primary Water Stress Corrosion Cracking (PWSCC). Susceptibility rankings for the various plants have been reported to the NRC in response to NRC Bulletin 2001-01.

Should repair welding of reactor pressure vessel head penetration nozzle J-welds encroach (within 1/8 inch) on the ferritic base material of the reactor pressure vessel head, temper bead weld repairs would be required. See the following figures for additional details.

- Figure 1: Typical RPV Penetration Nozzle
- Figure 2: Example Repair of a Reactor Pressure Vessel Penetration Nozzle J-Weld

2 ASME CODE REQUIREMENTS

Subarticle IWA-4170 (b) of ASME 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 of system. Later Editions and Addenda of the Construction Code or of Section III either in their entirety or portions thereof, and Code Cases may be used. If repair welding cannot be performed in accordance with these requirements, the applicable alternative requirements of IWA-4200, 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 performed by welding without the specified postweld heat treatment of the Construction Code or ASME Section III, provided the requirements of IWA-4500 (a) through (e) and IWA-4510, IWS-4520 and IWA-4530 as applicable, are met.

IWA-4530 applies to dissimilar materials such as welds that join P-Number 43 (nickel alloys) to P-Number 3 (low alloy steels). According to IWA-4530, "Repairs to welds that join P-Number 8 or P-Number 43 material to P-Numbers 1, 3, 12A, 12B and 12C, 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 inch or less of non ferritic weld deposit exists above the fusion line after defect removal.

Temper bead repairs to reactor pressure vessel head penetration nozzles and 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 reactor pressure vessel head. When the Gas Tungsten Arc Welding (GTAW) process is used in accordance with IWA-4500 and IWQ-4530, then temper bead welding is performed as follows:

- Only the automatic or machine GTAW process using cold wire feed can be used. The manual GTAW process shall not be use.
- A minimum preheat temperature of 300°F is established and maintained throughout the welding process. Interpass temperature shall not exceed 450°F.
- The welding cavity is buttered with at least six (6) 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 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 post weld soak or hydrogen bake-out at 450°F - 550°F for a minimum of 4 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 EWA-4533 after the completed weld has been at ambient temperature for 48 hours.

3 ALTERNATIVE METHOD: AMBIENT TEMPERATURE TEMPER BEAD REPAIR

Westinghouse has developed an alternative to the GTAW-machine temper bead welding requirements of IWA-4500 and IWA-4530 of ASME Code, Section XI. The Westinghouse ambient temperature temper bead welding method is outlined in Attachment 1, "Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique."

Westinghouse has reviewed the proposed ambient temperature temper bead welding techniques of 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, Westinghouse 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 postweld heat treatment of the construction code or ASME 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, Westinghouse 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.

2. **IWA-4500(d)(2)** specifies that if repair welding is to be performed where physical obstructions impair the "welders" 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 Shielded Metal Arc Welding (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.

3. **IWA-4500(e)(2)** specifies that the weld area plus a band around the repair area of at least 1-1/2 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; maximum interpass temperature shall be 450°F. As an alternative, Westinghouse proposes that the weld area plus a band around the repair area of at least 1-1/2 times the component thickness or 5 inches, whichever is less, shall be preheated and maintained at a minimum temperature of 50°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.

4. **IWA-4500(e)(2)** specifies that thermocouples and recording instruments shall be used to monitor process temperatures. As an alternative, Westinghouse proposes to monitor preheat and interpass temperatures using an infrared thermometer as described in Section IV.B.3.

5. **IWA-4500(e)(2)** specifies that thermocouple attachment and removal shall be performed in accordance with ASME Section III. Because Westinghouse 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.

6. **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.

7. **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, Westinghouse 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.

8. **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. 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, Westinghouse 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.

9. **IWA-4532.2(c)** 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, Westinghouse's proposed ambient temperature temper bead technique does not include a reinforcement layer.

10. **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 - 550°F for a minimum of 4 hours (for P-No. 3 materials). As an alternative, Westinghouse's proposed ambient temperature temper bead technique does not include a postweld soak.

11. **IWA-4532.2(e)** specifies that after depositing at least 3/16 inch of weld metal and performing a postweld soak at 450°F - 550°F, the balance of welding may be performed at an interpass temperature of 350°F. As an alternative, Westinghouse's 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.

12. **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. Westinghouse will perform the liquid penetrant examination of the completed repair weld and preheated band as required by IWA-4533. As an alternative to the volumetric examination of IWA-4533, Westinghouse proposes the following examinations for repair welds in reactor pressure vessel penetration nozzle J-welds:

    - Repair welds will be progressively examined by the liquid penetrant method in accordance with NB-5245 of ASME Section III. The liquid penetrant examinations will be performed in accordance with NB-5000. Acceptance criteria shall be in accordance with NB-5350.

This request for an alternative repair method, is specific to localized weld repair of reactor pressure vessel head penetration nozzle J-welds where 1/8 inch or less of nickel-chromium-iron alloy weld metal, exists between the J-weld repair cavity and the ferritic base material of the reactor pressure vessel head. See Figures 1 and 2. Flaws in the J-weld will be removed prior to performing any temper bead repairs in accordance with this request.

4 BASIS FOR PROPOSED ALTERNATIVE

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°F must be established and maintained throughout the welding process while the interpass temperature is limited to 450°F. Upon completion of welding, a postweld soak is performed at 450°F - 550°F for a minimum of 4 hours.

The temper bead welding process permitted by IWA-4500 and IWA-4530 is a time and dose intensive process. Resistant heating blankets are attached to the reactor pressure vessel head; typically a capacitor discharge stud welding process is used. Thermocouples must also be attached to the reactor pressure vessel head using a capacitor discharge welding process to monitor preheats, 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 reactor pressure vessel head. 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. Because the ASME Code does not include rules for ambient temperature temper bead welding, Westinghouse proposes the alternative described above in Section III.

4.1 EVALUATION OF THE AMBIENT TEMPERATURE TEMPER BEAD TECHNIQUE

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 (Reference 1). 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 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 defined in Attachment 1 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 (Reference 1), "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 requirements for the temper bead process also include a postweld soak requirement. Performed at 450°F to 550°F for 4 hours (P-Number 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.

   Subsection 2.1 of Attachment 1 establishes detailed welding procedure qualification requirements. Simulating base materials, filler metals, restraint, impact properties, and procedure variables, the qualification requirements of Subsection 2.1 provide assurance that the mechanical properties of repair welds will be equivalent or superior to those of the surrounding base material. It should also be noted that the qualification requirements of Subsection 2.1 of Attachment 1 are identical to those in IWA-4530. Ambient temperature temper bead WPS 3-43/52-TB MC-GTAW-N638 (Reference 2) was qualified in accordance with Attachment 1. Based upon the procedure qualification test results, the impact properties of the base material heat affected zone were superior to those of the unaffected base material. The mechanical testing results for the procedure qualification are summarized in Subsection IV.C.

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°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 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 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 Section 4.0 of Attachment 1. Regarding this issue, EPRI Report GC-111050, Section 6.0 concluded the following:

> "No preheat temperature or postweld 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 postweld bake steps are necessary to remove hydrogen because the hydrogen is not present with the machine GTAW process."

3. Cold Restraint Cracking

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 as required in Section 4.0 of Attachment 1.

In conclusion, no elevated temperature 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 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. EPRI Report GC-111050, Section 6.0 concluded the following:

> "Repair of RPV components utilizing machine GTAW temper bead welding at ambient temperature produces mechanical properties that are commonly superior to those of the service-exposed substrate. The risk of 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."

4.2 EVALUATION OF PROPOSED ALTERNATIVES TO ASME CODE, SECTION XI, IWA-4500 AND IWA-4530

1. 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 - 550°F. The proposed alternative of Attachment 1 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 Attachment 1 is an ambient temperature technique which only utilizes the GTAW-machine or GTAW-automatic process. The suitability of the

proposed ambient temperature temper bead technique is evaluated in this section. 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°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. The suitability of an ambient temperature temper bead technique with reduced preheat and interpass temperatures is addressed in Section IV.A.

3. 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), Westinghouse 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. To determine the preheat and interpass temperatures during the welding operation, the infrared thermometer is pointed at a target location adjacent to the repair weld. A circle consisting of eight laser spots identifies the target location. A single laser spot in the center of the circle identifies the center of the measurement area. As the distance (D) from the object being measured increases, the diameter of the target location or "spot size" (S) also increases. The optics of the infrared thermometer sense emitted, reflected, and transmitted energy from the target location that is collected and focused onto a detector. The infrared thermometer's electronics translate the information into a temperature reading that is displayed on the unit. The infrared thermometer measures the maximum, minimum, differential, and average temperatures across the target location. This data can be stored and recalled until a new measurement is taken. Westinghouse plans to use an infrared thermometer such as the Raytek Rayngar ST80 (or equivalent). The Raytek Rayngar ST80 infrared thermometer measures temperatures from -25°F to 1400°F over the target location with the following accuracy: +/-3°F over the 0°F - 73°F temperature range and +/-1% of reading or 2°F, whichever is greater, above 73°F. Display resolution is 0.1°F. The distance (D) to "spot size" (S) is 50:1 for the Raytek Rayngar ST80 infrared thermometer. Since the "distance" (D) to the target location on the reactor pressure vessel penetration nozzle or J-weld is estimated to range from 3 feet to 6 feet, the "spot size" (S) will also range from 0.72 inch to 2.22 inches. The infrared thermometer will be appropriately calibrated prior to use.

4. **IWA-4532.2** establishes procedure technique requirements but do not address joint design access qualification of the repair cavity. As an alternative to IWA-4532.2, Westinghouse proposes to qualify the root width and included angle of the proposed repair cavity. Paragraph 2.1(c) of Attachment 1 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).

5. 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, Westinghouse 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 Specification (WPS) 3-43/52-TB MC-GTAW-N638 (Reference 2). Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat affected zone were superior to those of the unaffected base material. Therefore, the proposed heat input controls of Attachment 1 provide an appropriate level of tempering. Test results of the WPS qualification are provided in Subsection IV.C.

6. 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 Attachment 1, the deposition and removal of the 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. While Westinghouse recognizes that IWA-4532.2(c) does require the deposition and removal of a reinforcement layer on repair welds in dissimilar materials, Westinghouse does not believe that this reinforcement layer is necessary. This position is supported by the fact that ASME Code Case N-638 (Reference 3) 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.

7. According to **IWA-4532.2 (d)**, the weld area shall be maintained at a temperature of 450°F-550°F 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 Attachment 1, a postweld soak is not required. The suitability of an ambient temperature temper bead technique without a postweld soak is addressed below in Subsection IV.A.

8. According to **IWA-4532.2 (e)**, after depositing at least 3/16-inch of weld metal and performing a postweld soak at 450°F-550°F, the balance of welding may be performed at an interpass temperature of 350°F. As an alternative, Westinghouse's 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 process 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 such that the desired degree of carbide precipitation (tempering) is achieved. The resulting microstructure is very tough and ductile. This point is validated by the qualification of WPS 3-43/52-TB MC-GTAW-N638. Based on Charpy V-notch testing of the procedure qualification test coupon, impact properties in weld heat affected zone were superior to those of the unaffected base material. Test results of the WPS qualification are provided in Subsection IV.C. The suitability of an ambient temperature temper bead technique without a postweld soak is addressed in Section IV.A.

9. **IWA-4533** specifies that the repair weld shall be volumetrically examined by the radiographic method, and if practical, by the ultrasonic method after the completed repair weld has been at ambient temperature for at least 48 hours. As an alternative to the volumetric examinations of IWA-4533, Westinghouse proposes the examinations of repair welds in reactor pressure vessel penetration nozzle J-welds described below. The suitability of the alternative examinations is addressed in Section IV.D.

   - Repair welds will be progressively examined by the liquid penetrant method in accordance with NB-5245 of ASME Code, Section III. The liquid penetrant examinations will be performed in accordance with NB-5000. Acceptance criteria shall be in accordance with NB-5350.

4.3 MECHANICAL PROPERTIES OF WPS 3-43/52-TB MC-GTAW-N638

WPS 3-43/52-TB MC-GTAW-N638 (Reference 2) was qualified in accordance with Attachment 1. The welding procedure qualification test assembly was 3 inches thick and consisted of SA-533, Grade B, Class 1 (P-No. 3, Group 3) and SB-166, N06690 (P-No. 43) base materials. Prior to welding, the SA-533, Grade B, Class 1 portion of the test assembly was heat treated for 40 hours at 1,200°F. The repair cavity in the test assembly was 1.5 inches deep. The test assembly cavity was welded in the 3G (vertical) position using ERNiCrF3-7 (F-No. 43) filler metal. Results of the welding procedure qualification were documented on procedure qualification record PQR 707 (Reference 5). Results of mechanical testing – tensile testing, bend testing, Charpy V-notch testing, and drop weight testing – are summarized below. WPS 3-43/52-TB MC-GTAW-N638 will be used to perform the repair welding activities.

- Tensile test specimens exhibited a tensile strength that exceeded 80,000 psi and were acceptable per ASME Code, Section IX. The bend testing was also acceptable. Test results are as follows:

Tensile Test Results

Specimen No.	Tensile Specimen	Actual Tensile Strength	Failure
Test 1-1	0.505″ Turned Specimen	86,600 psi	Ductile/Base
Test 1-2	0.505″ Turned Specimen	84,500 psi	Ductile/Base
Test 2-3	0.505″ Turned Specimen	82,400 psi	Fusion Line
Test 2-4	0.505″ Turned Specimen	86,600 psi	Ductile/Weld Metal

Bend Test Results

Specimen Type and Figure No.	Result
Side Bend 1 QW-462.2	Acceptable
Side Bend 2 QW-462.2	Acceptable
Side Bend 3 QW-462.2	Acceptable
Side Bend 4 QW-462.2	Acceptable

- Drop weight and Charpy V-notch testing of the SA-533, Grade B, Class 1 unaffected base material was performed. Based upon drop weight testing of the SA-533, Grade B, Class 1 "unaffected" base material, a nil ductility transition temperature (T_{NDT}) of -50°F was established. Charpy V-notch testing was also performed at +10°F. All three Charpy V-notch specimens exhibited at least 35 mils and 50 ft-lbs. Based upon the above testing, an RT_{NDT} of -50°F was established for the SA-533, Grade B, Class 1 base material. Test results are as follows:

Drop Weight Test: Unaffected Base Material

Specimen ID	Specimen Type	Test Temperature	Drop Weight Break	T_{NDT}
DW1	P-3	-40°F	No	-50°F
DW2	P-3	-40°F	No	-50°F

Charpy V-Notch Tests: Unaffected Base Material

Specimen ID	Test Temperature	Absorbed Energy (ft-lbs)	Lateral Expansion(mils)	% Shear Fracture
1	+10°F	59.0	50.0	60.0
2	+10°F	51.0	43.0	50 0
3	+10°F	50.0	45.0	50.0
Average	+10°F	*53.3*	*46.0*	*53.3*

- Charpy V-notch testing of the SA-533, Grade B, Class 1 heat affected zone was also performed at +10°F. The absorbed energy, lateral expansion, and percent shear fracture of the heat affected zone test specimens were compared to the test values of the unaffected base material specimens. The average values of the three heat affected zone specimens were greater than those of the unaffected base material specimens. Based upon these results, it is clear that the proposed ambient temperature temper bead process improved the heat affected zone properties. Test results are as follows:

Charpy V-Notch Tests: Heat Affected Zone

Specimen ID	Test Temperature	Absorbed Energy (ft-lbs)	Lateral Expansion(mils)	% Shear Fracture
1	+10°F	85.0	65.0	90.0
2	+10°F	136.0	64.0	75.0
3	+10°F	124.0	49.0	30.0
Average	+10°F	*115.0*	*59.3.0*	*65.0*

- Supplemental microstructural evaluations were also performed on the test coupon weld of the procedure qualification. Microstructural evaluations consisted of micro-hardness testing (Vickers) and metallography. Vickers micro-hardness testing was performed at three different locations:

  1. 0.125 inch below the surface of the weld,
  2. 0.625 inch below the surface of the weld, and
  3. 0.125 inch above the root of the weld.

  Micro-hardness test values are provided in the table below.

  Metallography was performed at 100X and 500X magnifications. According to CONAM Laboratory Report #2333 (Reference 4), "There were a few colonies of tempered martensite observed near the root of the weld. These seem to be associated with the slight banding present in the base material. There was no indication of untempered martensite. The remaining areas of the heat affected zone consist of a mixed microstructure of by-products of high temperature pearlite degeneration, bainite and a small amount of ferrite." Regarding the presence of carbides, the CONAM report stated, "There was no evidence of massive carbides or carbide networks."

Vickers Micro-Hardness Tests Results

Weld Zone Location	0.125″ From Surface		0.625″ From Surface		0.125″ Above Weld Root	
	Filar	Vickers	Filar	Vickers	Filar	Vickers
Unaffected Base Material	182	224	184	219	182	224
	182	224	185	217	176	240
	183	222	186	214	174	245
	182	224	186	214	181	226
	184	219	182	224	178	234
	184	219	187	212	173	248
HAZ Grain Coarsened Region	167	266	162	283	150	330
	165	273	164	276	144	358
	165	273	169	260	144	358
HAZ Adjacent to Fusion Line	163	279	161	287	149	334
	161	287	161	287	147	343
	159	293	164	276	147	343
Weld Metal	183	222	187	212	190	205
	189	208	192	201	189	208
	184	219	185	217	186	214
	184	219	185	217	182	224
	189	208	183	222	182	224
	193	199	184	219	179	232

4.4 SUITABILITY OF ALTERNATIVE NONDESTRUCTIVE EXAMINATIONS (NDE)

IWA-4533 specifies that the repaired region shall be examined by the radiographic method, and if practical, by the ultrasonic method. The nondestructive examination requirements of IWA-4533 were established based upon a temper bead weld repair to butt welds. Figures IWA-4532.1-1 and IWA-4532.2-1 clearly indicate this. While the requirement to perform a radiographic examination, and if practical, an ultrasonic examination of a butt weld between a nozzle and pipe is appropriate, these examinations are not appropriate for weld repairs of reactor pressure vessel head penetration nozzle J-welds. See Figures 1 and 2.

1. Impracticality of Volumetric Examinations

Radiographic examination of weld repairs of reactor pressure vessel head penetration nozzle J-welds is not practical. Meaningful radiographic examination cannot be performed due to the weld configuration and access limitations. The weld configuration and geometry of the penetration in the head provide an obstruction for the radiography and interpretation would be very difficult. Ultrasonic examination of the J-weld would also be impractical.

2. Suitability of Proposed Alternative

As an alternative to radiographic and ultrasonic examinations, Westinghouse proposes to perform a progressive liquid penetrant of the J-weld repair weld in accordance with NB-5245 of ASME Code, Section III. It should be noted that ASME Code, Section III does not require volumetric examination of J-welds. According to 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." NB-4244 (d) establishes fabrication details for nozzles welded with partial penetration welds as shown in Figures NB-4244 (d)-1 and NB-4244 (d)-2.

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 partial penetration J-welds of the reactor pressure vessel head penetration nozzles were designed and fabricated in accordance with NB-3352.4 (d) and NB-4244 (d). Therefore, according to NB-3352.4 (d), the code required examination for these partial penetration J-welds is a progressive liquid penetrant examination performed in accordance with NB-5245. A volumetric examination is not required.

5 CONCLUSION

10CFR50.55a(a)(3)(i) states:

"Proposed alternatives to the requirements of (c), (d), (e), (f), (g), and (h) of this section or portions thereof may be used when authorized by the Director of the Office of Nuclear Reactor Regulation. The applicant shall demonstrate that:

(i) The proposed alternatives would provide an acceptable level of quality and safety, or

(ii) Compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety."

Westinghouse believes that compliance with the repair rules as stated in the ASME Code, Section XI, IWA-4500 and as described in Section III of this request would result in unwarranted radiological exposure. The proposed alternative would provide an acceptable level of quality and safety. The proposed alternative would also result in a reduction of radiological exposure to personnel. The information provided in this report supports approval of the proposed alternative when requested by the licensees of nuclear power plants under the provisions of 10CFR50.55a(a)(3)(i).

6 REFERENCES

1. EPRI Report GC-111050, Ambient Temperature Preheat for Machine GTAW Temperbead Applications, November 1998.

2. PCI Welding Procedure Specification WPS 3-43/52-TB MC-GTAW-N638, Revision 11, November 9, 2002.

3. ASME Code Case N-638, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, Section XI, Division 1," June 1998.

4. CONAM Laboratory Report #2333, Conam Test Report for PCI Procedure Qualification, July 23, 2002.

5. Procedure Qualification Record 707, Revision 5, October 2, 2002.

6. ASME Boiler and Pressure Vessel Code, Section III, 1989 Edition.

7. ASME Boiler and Pressure Vessel Code, Section XI, 1992 Edition with 1993 Addenda.

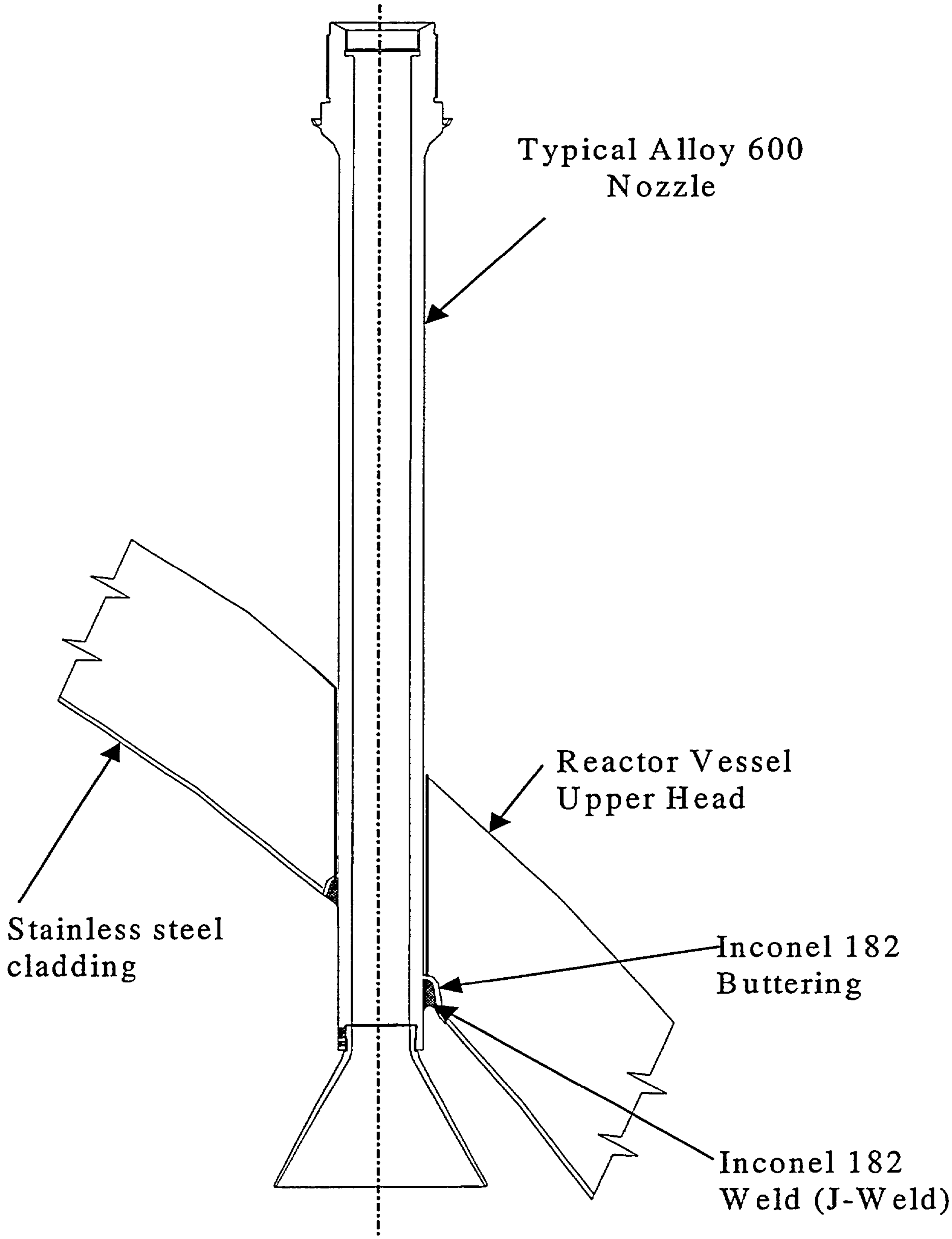


Figure 1
Typical RPV Penetration Nozzle

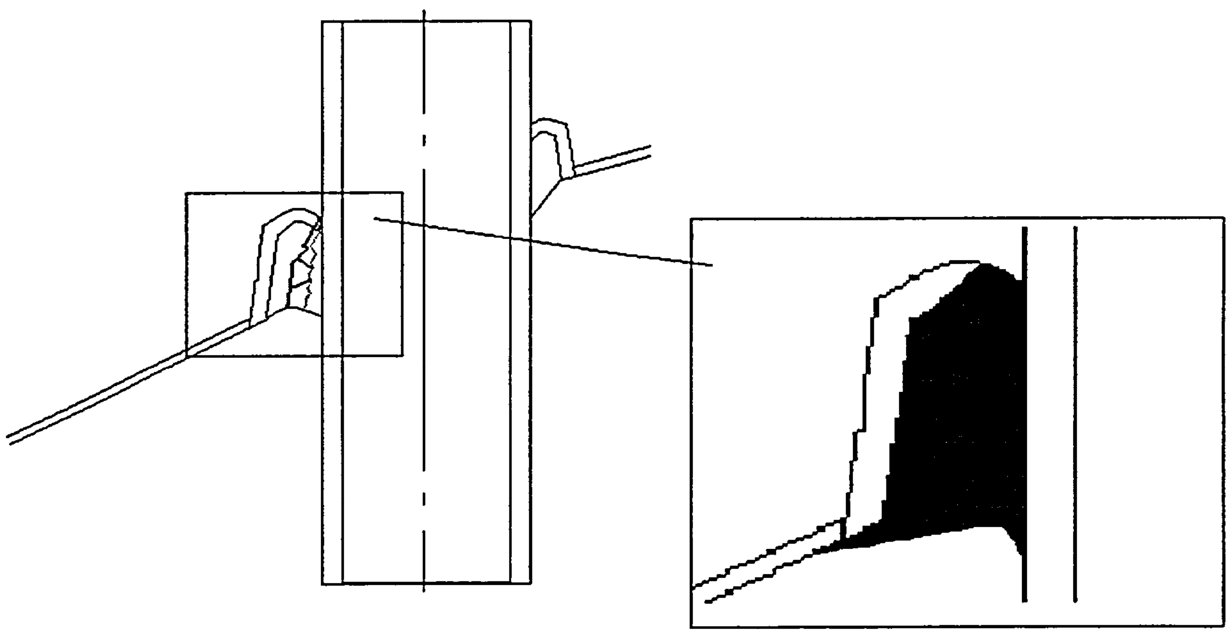


Figure 2
Example Repair of a Reactor Pressure Vessel Head Penetration Nozzle J-Weld

Attachment 1
Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Welding Technique

1.0 General Requirements

1. The maximum area of an individual weld based on the finished surface will be less than 100 square inches, and the depth of the weld will not be greater than one-half of the ferritic base metal thickness.

2. Repair/replacement activities on a dissimilar-metal weld are limited to those along the fusion line of a nonferritic weld to ferritic base material on which 1/8-inch or less of nonferritic weld deposit exists above the original fusion line. Repair/replacement activities on nonferritic base materials where the repair cavity is within 1/8-inch of a ferritic base material may also be performed.

3. If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed provided the depth of repair in the base material does not exceed 3/8-inch.

4. Prior to welding, the temperature of the area to be welded and a band around the area of at least 1½ times the component thickness (or 5 inches, whichever is less) will be at least 50°F.

5. Welding materials will meet the Owner's Requirements and the Construction Code and Cases specified in the repair/replacement plan. Welding materials will be controlled so that they are identified as acceptable until consumed.

6. The area prepared for welding shall be suitably prepared for welding in accordance with a written procedure.

2.0 Welding Qualifications

The welding procedures and the welding operators shall be qualified in accordance with Section IX and the requirements of paragraphs 2.1 and 2.2.

2.1 Procedure Qualification

1. The base materials for the welding procedure qualification will be the same P-Number and Group Number as the materials to be welded. The materials shall be post weld heat treated to at least the time and temperature that was applied to the material being welded.

2. Consideration will be given to the effects of irradiation on the properties of material, including weld material for applications in the core belt line region of the reactor vessel. Special material requirements in the Design Specification will also apply to the test assembly materials for these applications.

3. The root width and included angle of the cavity in the test assembly will be no greater than the minimum specified for the repair.

4. The maximum interpass temperature for the first three layers or as required to achieve the 1/8-inch butter thickness in the test assembly will be 150°F. For the balance of the welding, the maximum interpass temperature shall be 350°F.

5. The test assembly cavity depth will be at least one-half the depth of the weld to be installed during the repair/replacement activity, and at least 1 inch. The test assembly thickness will be at least twice the test assembly cavity depth. The test assembly will be large enough to permit removal of the required test specimens. The test assembly dimensions surrounding the cavity will be at least the test assembly thickness, and at least 6 inches. The qualification test plate will be prepared in accordance with Figure A-1.

6. Ferritic base material for the procedure qualification test will meet the impact test requirements of the Construction Code and Owner's Requirements. If such requirements are not in the Construction Code and Owner's Requirements, the impact properties shall be determined by Charpy V-notch impact tests of the procedure qualification base material at or below the lowest service temperature of the item to be repaired. The location and orientation of the test specimens shall be similar to those required in subparagraph (h) below, but shall be in the base metal.

7. Charpy V-notch tests of the ferritic weld metal of the procedure qualification shall meet the requirements as determined in subparagraph (f) above.

8. Charpy V-notch tests of the ferritic heat-affected zone (HAZ) will be performed at the same temperature as the base metal test of subparagraph (f) above. Number, location, and orientation of test specimens will be as follows:

    a. The specimens will be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The test coupons for HAZ impact specimens will be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimens will be cut approximately normal to the material surface in such a manner as to include as much HAZ as possible in the resulting fracture. When the material thickness permits, the axis of a specimen will be inclined to allow the root of the notch to be aligned parallel to the fusion line.

    b. If the test material is in the form of a plate or a forging, the axis of the weld will be oriented parallel to the principal direction of rolling or forging.

    c. The Charpy V-notch test will be performed in accordance with SA-370. Specimens will be in accordance with SA-370, Figure 11, Type A. The test will consist of a set of three full-size 10 mm x 10 mm specimens. The lateral expansion, percent shear, absorbed energy, test temperature, orientation and location of all test specimens will be reported in the Procedure Qualification Record.

9. The average values of the three HAZ impact tests will be equal to or greater than the average values of the three unaffected base metal tests.

2.2 Performance Qualification

Welding operators will be qualified in accordance with ASME Code, Section IX.

3.0 Welding Procedure Requirements

The welding procedure shall include the following requirements:

1. The weld metal shall be deposited by the automatic or machine GTAW process using cold wire feed.

2. Dissimilar metal welds shall be made using F-No. 43 weld metal (QW-432) for P-No. 43 to P-No. 3 weld joints.

3. The area to be welded will be buttered with a deposit of at least three layers to achieve at least 1/8-inch butter thickness as shown in Figure A-2, steps 1 through 3, with the heat input for each layer controlled to within ± 10% of that used in the procedure qualification test. Particular care will be taken in placement of the weld layers at the weld toe area of the ferritic base material to ensure that the HAZ is tempered. Subsequent layers will be deposited with a heat input not exceeding that used for layers beyond the third layer (or as required to achieve the 1/8-inch butter thickness) in the procedure qualification.

4. The maximum interpass temperature field applications will be 350°F regardless of the interpass temperature during qualification.

5. Preheat and interpass temperatures will be continuously monitored using an infrared thermometer. 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 temperature 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.

6. Particular care will be given to ensure that the weld region is free of all potential sources of hydrogen. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

4.0 Examination

1. Prior to welding, a surface examination will be performed on the area to be welded.

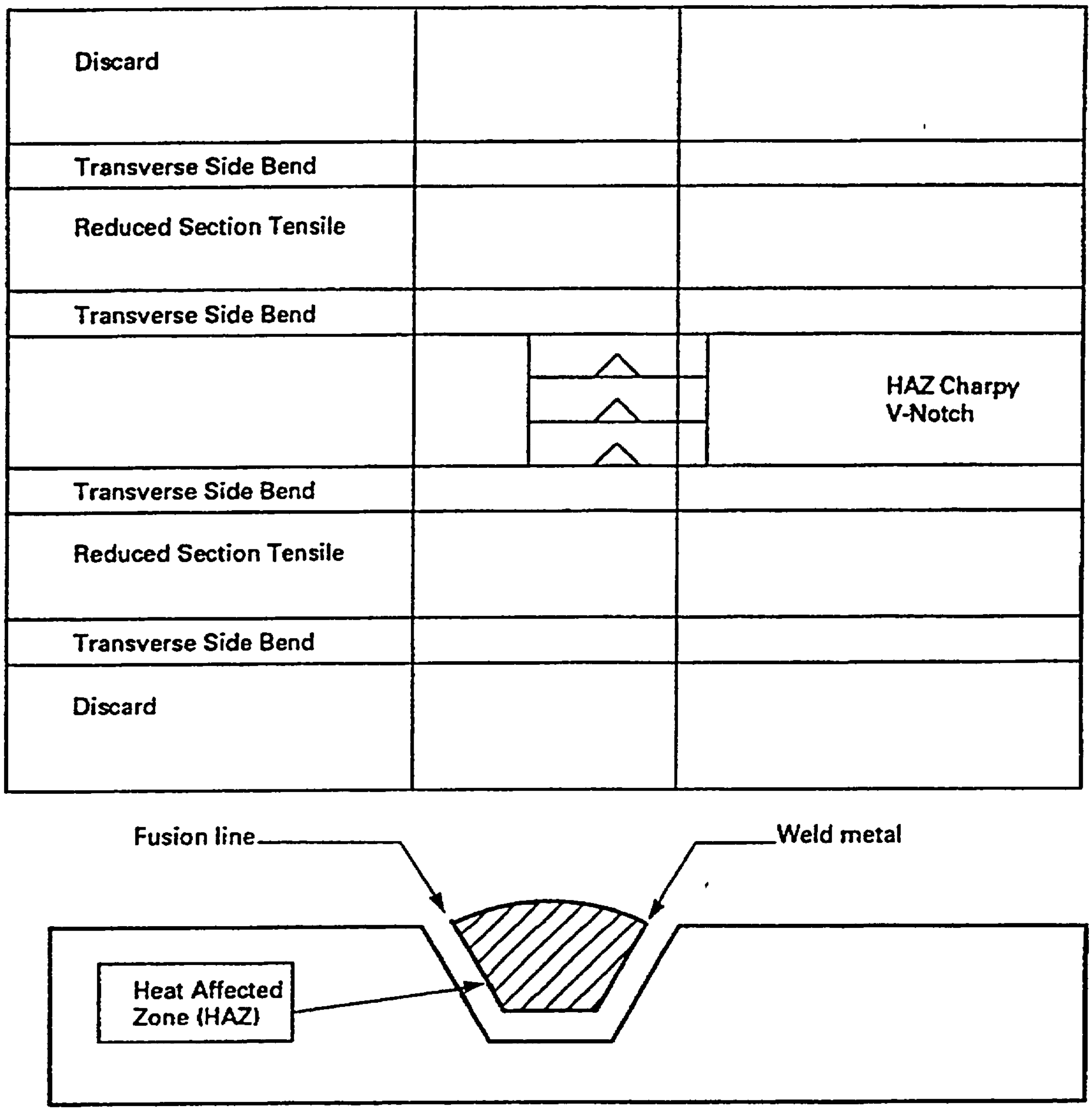
2. Repair welds in reactor pressure vessel penetration nozzle J-welds shall be examined as follows:

3. Repair welds will be progressively examined by the liquid penetrant method in accordance with NB-5245 of ASME Code, Section III. After the completed repair weld has been at ambient temperature for at least 48 hours, repair welds including the preheat band (1.5 times the component thickness or 5 inches, whichever is less) around the repair weld shall be examined by the liquid penetrant method. The liquid penetrant examinations will be performed in accordance with ASME Code, Section III, NB-5000. Acceptance criteria shall be in accordance with NB 5350.

4. NDE personnel performing liquid penetrant examination will be qualified and certified in accordance with NB-5500.

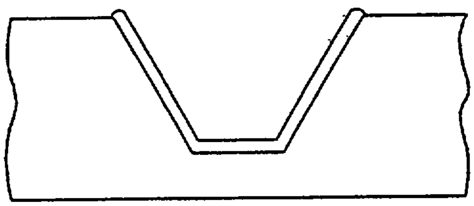
5.0 Documentation

Use of the ambient temper bead method described in WCAP-116063 shall be documented on NIS-2. Alternatively, repairs may be documented on Form NIS-2A as described in Code Case N-532 if prior approval is obtained from the NRC.

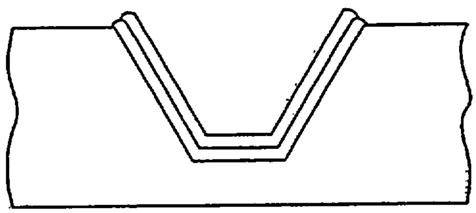


GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a similar-metal weld.

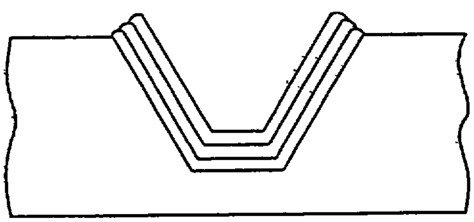
Figure A-1
Qualification Test Plate



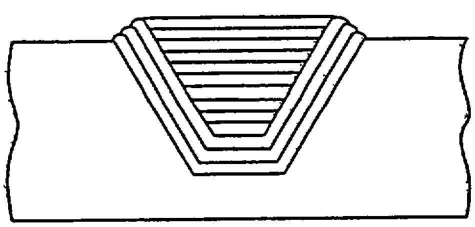
Step 1: Deposit layer one with first layer weld parameters used in qualification.



Step 2: Deposit layer two with second layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the second layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.



Step 3: Deposit layer three with third layer weld parameters used in qualification. NOTE: Particular care shall be taken in application of the third layer at the weld toe to ensure that the weld metal and HAZ of the base metal are tempered.



Step 4: Subsequent layers to be deposited as qualified, with heat input less than or equal to that qualified in the test assembly. NOTE: Particular care shall be taken in application of the fill layers to preserve the temper of the weld metal and HAZ.

GENERAL NOTE: The illustration above is for similar-metal welding using a ferritic filler material. For dissimilar-metal welding, only the ferritic base metal is required to be welded using steps 1 through 3 of the temperbead welding technique.

Figure A-2
Automatic or Machine GTAW Temper Bead Welding