

Case N-XXX (07-1682) Nickel Alloy Reactor Coolant Barrier Weld for Mitigation of PWR Full Penetration Circumferential Nickel Alloy Welds in Class 1 Items

Section XI, Division 1 DRAFT Rev B

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Inquiry: As an alternative to the provisions of IWA-4000, is it permissible to mitigate the potential for occurrence of defects, by application of a corrosion resistant barrier weld on the inside surface of full penetration circumferential austenitic nickel alloy welds associated with component nozzles and piping in PWRs?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4000, for full penetration circumferential austenitic nickel alloy dissimilar metal welds in PWRs, an austenitic nickel alloy barrier weld may be deposited on the inside surface of full penetration circumferential austenitic nickel alloy welds associated with component nozzles and piping in accordance with the requirements specified herein. IWA-4000 shall be applicable for all activities not specifically addressed herein.

1.0 GENERAL

(a) Definitions

(1) DMW: full penetration circumferential austenitic nickel alloy dissimilar metal weld (F-No. 43), including associated buttering when applicable, associated with component nozzles and piping in PWRs.

(2) Barrier Weld:

(i) A corrosion resistant barrier (weld inlay) applied between the DMW and the reactor coolant requiring excavation using mechanical methods of some portion of the DMW thickness and associated cladding and/or base material thickness for the full circumference, prior to welding.

(ii) A corrosion resistant barrier (corrosion resistant cladding onlay) applied between the DMW and the reactor coolant that does not require excavation other than mechanical removal of surface contaminants to shiny bright metal prior to welding.

(3) Sulfur Mitigation Layer: a single layer of ER309L filler material applied over austenitic stainless steel base material and ERNiCr-3 (Alloy 82) filler material when applied over the interface of the base material and DMW. The purpose of the layer is to mitigate the adverse effects of high sulfur [or other element(s)] content on ERNiCrFe-7/7A (Alloy 52/52M) weldability. When used, the sulfur mitigation layer shall be considered pressure boundary.

(b) This Case shall apply to barrier welds for DMWs and adjacent component nozzles, cladding, piping and their austenitic stainless steel welds, if applicable, consisting of the following materials and combinations thereof:

(1) P-No. 8, A-No. 8, F-No. 43 and P-No. 43.

(2) P-No.8 or 43 and P-No.1, 3, 12A, 12B, or 12C¹

(c) The DMW shall not contain volumetric pre-existing flaws exceeding the in-service examination acceptance standards of Table IWB-3514-2 and IWB-3514-3.

Deleted: The welds are classified as Examination Category B-F, Item No. B5.10 as specified in Table IWB-2500-1.

¹ P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified in a later Edition of Section IX.

- (d) If 1/8 in. (3 mm) or less of nonferritic weld deposit remains between the barrier weld fusion line and the ferritic steel base material, ambient temperature temper bead welding shall be required and performed in accordance with Appendix 1. Measurement methods to determine the distance between the surface to be welded and the ferritic steel base material boundary shall be provided and demonstrated. Alternatively, if measurement accuracy cannot be demonstrated, temper bead welding shall be performed in accordance with Appendix 1.
- (e) This Case shall be limited to applications predicted not to have exceeded a thermal neutron fluence of 1×10^{17} ($E < 0.5$ eV) neutrons per cm^2 on the material prior to barrier welding.
- (f) The governing Code for these applications shall be IWA-4000, ASME Section XI, 2007 Edition, no Addenda.
- (g) The minimum final thickness of the barrier weld over the exposed portion of the original DMW shall be the excavation depth or 1/8 in. (3 mm), whichever is greater. This minimum final thickness portion of the barrier weld shall extend across the exposed inner surface of the DMW and extend 1/4 in. (6 mm) minimum distance beyond both edges of the DMW as specified in 2.0(b).
- (h) The maximum final thickness of the barrier weld shall be 3/8 in. (10 mm) or 10% of the DMW thickness, whichever is less.

2.0 WELDING

- (a) The location of the DMW fusion zones shall be determined. Demonstration of the location technique on representative mockups shall be performed and documented.
- (b) The full thickness portion of the barrier weld shall extend across the inner exposed surfaces of the DMW and past the fusion zone at each edge of the DMW by at least twice the demonstrated accuracy of the locating technique or 1/4 in. (6 mm), whichever is greater.
- (c) Sulfur Mitigation Layer: A single layer of austenitic stainless steel filler material (SFA-5.9, ER309L) may be applied over austenitic stainless steel (P-No. 8) base material prior to barrier welding thereon. A single layer of SFA-5.14, ERNiCr-3, may be used at the interface between the P-No. 8 base material and the DMW, when the ER309L layer is used.
- (d) The barrier weld shall consist of at least two (2) layers after final surface preparation. The machine gas tungsten arc welding (GTAW) process shall be used.
- (e) When the preheat and post weld heat treatment requirements of the Construction Code and Owner's Requirements are applicable but are impractical, the ambient temperature temper bead welding provisions of Appendix 1 shall be used.
- (f) The barrier weld filler metal shall be austenitic nickel alloy SFA-5.14, ERNiCrFe-7/7A or equivalent filler metal. The minimum chromium content shall be at least 28% for the equivalent filler metal.
- (g) The barrier weld final surface shall contain at least 24% chromium.
- (h) The chromium content of the deposited weld metal shall be determined by chemical analysis of a coupon from a mockup representative of the materials on which the barrier weld will be deposited using the applicable production weld parameters and the same production weld metal classification. The weld filler used for the mockup shall have chromium content no greater than that to be used for the barrier weld. The results shall be documented.

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<#>DESIGN AND STRESS ANALYSIS ¶
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¶ FLAW GROWTH EVALUATION¶

¶ Flaw growth evaluations shall be performed in accordance with IWB-3640.¶

The postulated planar flaw in the barrier weld shall be based on the limiting case of (1) or (2) below:¶

Circumferential 1/16 in. deep flaw for the entire circumference.¶

Axial 1/16 in. deep flaw for the full thickness length. ¶

Flaw growth in the barrier weld shall be evaluated as an extension of the maximum size flaw permitted by the inservice examination acceptance standards of Table IWB-3514-2.¶

(d) Flaw growth through the barrier weld thickness within the remaining service life due to fatigue under all anticipated loadings shall not be acceptable.¶

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3.0 EXAMINATION

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The examination requirements of this Case shall be applicable in lieu of all other examination requirements.

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(a) Qualification

- (1) Liquid penetrant surface examination personnel and procedures for barrier weld [acceptance](#) examination shall be in accordance with NB-5000.
- (2) Eddy current surface examination personnel and procedures [for barrier weld acceptance examination](#) shall be in accordance with IWA-2200 and IWA-2300.
- (3) Barrier weld volume ultrasonic examination personnel [for barrier weld acceptance examination](#) shall be qualified in accordance with the provisions of NB-5000.

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The ultrasonic examination procedures shall be in accordance with Section V, Article 4, using Cladding Technique One. Calibration blocks shall be in accordance with Fig. T-434.4.2.2. If it is demonstrated that the preservice examination techniques can adequately examine the barrier weld, then the preservice examination and inservice examination [as specified in Case N-XXX](#) may take credit for barrier weld volumetric acceptance examination and replace the Section V, Article 4 examination for the barrier weld.

- (4) Preservice and inservice examination personnel and procedures shall be in accordance with [Case N-XXX](#).

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(b) Demonstration

- (1) The volumetric examination detection, length sizing and through-wall sizing capabilities and coverage achieved on the DMW shall not be adversely affected by the barrier weld. Demonstration of this verification shall be performed on representative mockups and the results shall be documented. The procedures shall be in accordance with the requirements specified in [3.0\(a\)\(4\)](#).
- (2) The representative mockups shall be DMW weld samples including the barrier weld. The demonstration specimen(s) shall contain cracks between 10% and 20% of the original DMW thickness. This demonstration shall verify that the provisions of [3.0\(b\)\(1\)](#) are attained and the results shall be documented.

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(c) Examination Prior to Application of the Barrier Weld

- (1) Volumetric examination of the applicable DMW volume specified in [Case N-XXX](#) shall be performed prior to any modification activities. The examination shall be in accordance with [3.0\(a\)\(4\)](#). If flaws are detected, exceeding the inservice examination acceptance standards of IWB-3514, and are not removed during the modification activity, this Case shall not apply [see 1.0(c)].

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- (2) Surface examination shall be performed on the area to be welded plus 1/2 in. (13 mm) on each side of the area. Section III, NB-5352 acceptance criteria shall be applicable. If this acceptance criterion cannot be met, this Case shall not apply.

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(d) Acceptance Examination of the Barrier Weld

- (1) The barrier weld surface, including at least 1/2 in. (13 mm) from each edge thereof, shall be examined using the liquid penetrant or eddy current examination method. Acceptance criteria shall be in accordance with Section III, NB-5352 except rounded indications with major dimension greater than 1/16 in. (1.5 mm) shall not be permitted. If temper bead welding is used, the surface examinations shall be conducted at least 48 hours after the completion of the third temper bead layer over the ferritic steel base material.

(2) The barrier weld volume including the fusion zone (and ferritic steel heat-affected zone, when temper bead welding is used) shall be ultrasonically examined per 3.0(a)(3). The acceptance criteria of Section III, NB-5330 shall apply. If temper bead welding is used, the examination shall be conducted at least 48 hours after the completion of the third temper bead layer over the ferritic steel base material.

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(3) Volumetric examination of the applicable DMW volume specified in Case N-XXX shall be performed. The examination shall be in accordance with 3.0(a)(4). The examination detection, length sizing and through-wall sizing capabilities and coverage achieved during this examination shall be equivalent to the examinations performed as specified in 3.0(c)(1)

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(e) Preservice Examination

Preservice examination shall be in accordance with Case N-XXX.

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(f) Inservice Examination

Inservice examination shall be in accordance with Case N-XXX.

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4.0 PRESSURE TESTING

A system pressure or leakage test shall not be required.

5.0 DOCUMENTATION

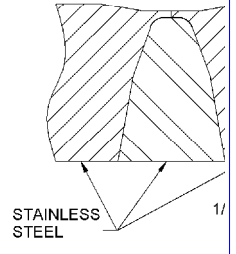
Use of this Case shall be documented on Form NIS-2.

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Deleted: volume in Figures 1 and 2 shall be examined at the frequency specified in Table IWB-2500-1, Examination Category B-F or within the design life of the DMW, whichever is less. ¶
Flaws shall not exceed the inservice examination acceptance standards of IWB-3514. ¶
Any flaws detected in the barrier weld and/or DMW shall require DMW removal and replacement in accordance with the repair/replacement requirements of IWA-4000. ¶
Additional Examination¶
When examination results are as shown in 5.0(f)(3) all other locations where barrier welds have been applied shall be examined during the current outage. The examination shall be in accordance with 5.0(a)(4).¶
Any unacceptable flaws detected in the barrier weld and/or DMW shall require DMW removal and replacement in accordance with the repair/replacement requirements of IWA-4000.¶
If no flaws are detected in the barrier weld and/or DMW the examination shall be repeated again at the first or second refuel outage, then the examination schedule shall revert back to that specified in 5.0(f)(1).

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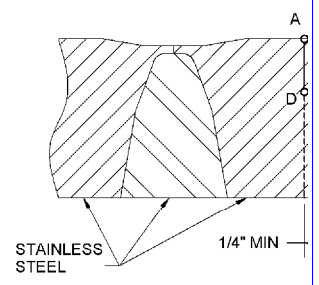
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Examination Volume A-B-C-D in
DMW with Barrier Weld
Figure 1



ONLAY
 SEE NOTE



NOTE 1. CRC ONLAY INCLUD
Examination Volume A-B-C-D in
DMW with Barrier Weld
Figure 2

APPENDIX 1

Ambient Temperature Temper Bead Welding

1.0 GENERAL REQUIREMENTS

- (a) The maximum area of an individual barrier weld based on the finished surface over the ferritic base material shall be 500 sq. in. (325,000 sq. mm).
- (b) Repair/replacement activities on a DMW in accordance with this Appendix shall be limited to those along the fusion line of a nonferritic weld to ferritic base material on which 1/8 in. (3 mm) or less of nonferritic weld deposit exists above the original fusion line.
- (c) Prior to welding the area to be welded and a band around the area of at least 1-1/2 times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50F (10C).

2.0 WELDING QUALIFICATIONS

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

2.1 Procedure Qualification

- (a) The base materials for the welding procedure qualification shall be of the same P-Number and Group Number, as the materials to be welded. The materials shall be postweld heat treated to at least the time and temperature that was applied to the materials to be welded.
- (b) The root width and included angle of the cavity in the test assembly shall be no greater than the minimum specified for the barrier weld.
- (c) The maximum interpass temperature for the first three layers of the test assembly shall be 150F (66C).
- (d) The barrier weld shall be qualified using a groove weld coupon. The test assembly cavity depth shall be at least 1 in. (25 mm). The test assembly thickness shall be at least twice the test assembly cavity groove depth. The test assembly shall be large enough to permit removal of the required test specimens. The test assembly dimensions on either side of the cavity groove shall be at least 6 in. (150 mm). The qualification test plate shall be prepared in accordance with Fig. 1-1.
- (e) Ferritic base material for the procedure qualification test shall 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 (f) below, but shall be in the base metal.
- (f) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal test of (e) above. Number, location, and orientation of test specimens shall be as follows:

Deleted: The maximum interpass temperature shall be 350F (180C) for the balance of the weld.

- (1) The specimens shall be removed from a location as near as practical to a depth of one-half the thickness of the deposited weld metal. The coupons for HAZ impact specimens shall be taken transverse to the axis of the weld and etched to define the HAZ. The notch of the Charpy V-notch specimen shall 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 shall be inclined to allow the root of the notch to be aligned parallel to the fusion line.
 - (2) If the test material is in the form of a plate or a forging, the axis of the weld shall be oriented parallel to the principal direction of rolling or forging.
 - (3) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. The test shall 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 shall be reported in the Procedure Qualification Record.
- (g) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be equal to or greater than the average lateral expansion value of the three unaffected base metal specimens. However, if the average lateral expansion value of the HAZ Charpy V-notch specimens is less than the average value for the unaffected base metal specimens and the procedure qualification meets all other requirements of this appendix, either of the following shall be performed:
- (1) The welding procedure shall be requalified.
 - (2) An *Adjustment Temperature* for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of Section III, 2001 Edition with 2002 Addenda. The RT_{NDT} or lowest service temperature of the materials for which the welding procedure will be used shall be increased by a temperature equivalent to that of the Adjustment Temperature.

2.2 Performance Qualification

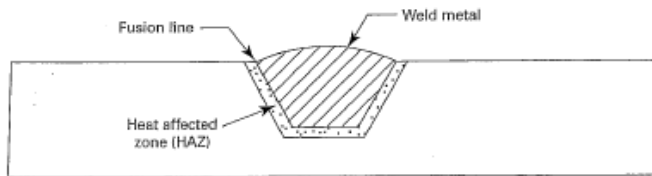
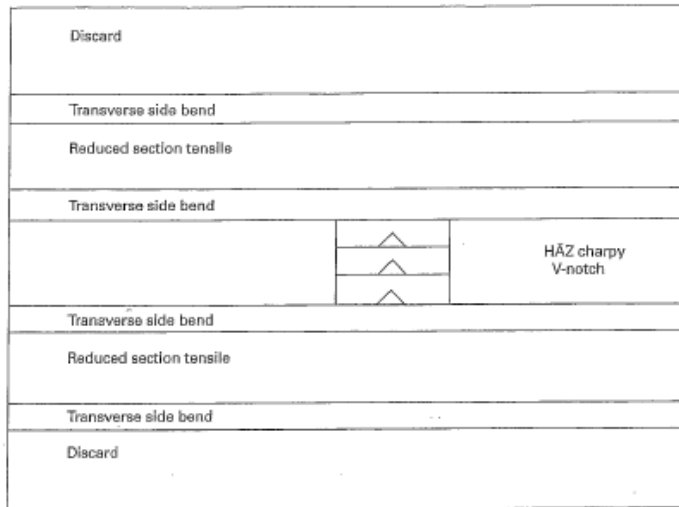
Welding operators shall be qualified in accordance with Section IX.

3.0 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements.

- (a) The area to be welded shall be buttered with a deposit of at least three layers to achieve at least 1/8 in. (3mm) barrier weld thickness with the heat input for each layer controlled to within $\pm 10\%$ of that used in the procedure qualification test. The heat input of the first three layers shall not exceed 45,000 J/in. (1,800 J/mm) under any conditions. Particular care shall be taken in the placement of the weld layers of the austenitic barrier weld filler material at the toe of the barrier weld to ensure that the HAZ and ferritic base metal are tempered. Subsequent layers shall be deposited with a heat input not exceeding that used for layers beyond the third layer in the procedure qualification.

- (b) The maximum interpass temperature for field applications shall be 350F (180C) for all weld layers regardless of the interpass temperature used during qualification. The interpass temperature limitation of QW-406.3 need not be applied.
- (c) The interpass temperature shall be determined by one of the following methods:
 - (1) Heat flow calculations using the variables listed below as a minimum:
 - (i) welding heat input
 - (ii) initial base material temperature
 - (iii) configuration, thickness, and mass of the item being welded
 - (iv) thermal conductivity and diffusivity of the materials being welded
 - (v) arc time per weld pass and delay time between each pass
 - (vi) arc time to complete the weld
 - (2) Measurement of the maximum interpass temperature on a test coupon that is equal to or less than the thickness of the item to be welded. The maximum heat input of the welding procedure shall be used in the welding of the test coupon.
- (d) Particular care shall 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.



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

Fig. 1-1 QUALIFICATION TEST PLATE

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