Case N-766-3
Nickel Alloy Reactor Coolant Inlay and Onlay for Mitigation of PWR Full Penetration Circumferential Nickel Alloy Dissimilar Metal Welds in Class 1 Items
Section XI, Division 1

Inquiry: As an alternative to the provisions of IWA-2200, IWA-4400, and IWA-4530, is it permissible to mitigate flaws or the potential for flaws, by application of a corrosion resistant inlay or onlay on the inside surface of full penetration circumferential austenitic nickel alloy dissimilar metal welds (DMW) in Class 1 vessel nozzles and piping in PWRs?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-2200, IWA-4400, and IWA-4530, an austenitic nickel alloy inlay or onlay may be deposited to mitigate flaws or the potential for flaws on the inside surface of Class 1 full penetration circumferential austenitic nickel alloy DMW in PWR vessel nozzles and piping in accordance with the provisions of this Case.

1 GENERAL

(a) Definitions of Terms

inlay: a corrosion resistant barrier applied on the inside surface of the component between the stress-corrosion-cracking (SCC) susceptible material and the reactor coolant, requiring excavation of some portion of the SCC susceptible material. See Figure 1.

onlay: a corrosion-resistant barrier applied on the inside surface between the SCC susceptible material and the reactor coolant, not requiring (nor prohibiting) excavation of some portion of the SCC susceptible material. See Figure 2.

mitigation: an activity performed to reduce or eliminate the susceptibility of Alloy 82/1821 weld filler material or Alloy 600 materials to crack initiation or crack propagation. Mitigation can be preemptive, i.e., performed before crack initiation, or repair, i.e., performed after crack initiation is discovered.

(b) This Case shall apply to inlay or onlay for DMW and adjacent vessel nozzles, cladding, piping, and associated austenitic stainless steel welds, if applicable, consisting of the following base materials or combinations thereof:

1. P-No. 8 and P-No. 43
2. P-No. 8 or 43 and P-No. 1 and 3
3. Prior to installation of the inlay or onlay, the DMW and area to be welded shall be examined in accordance with 3(b). Any detected flaws shall meet the following requirements.
   (1) Indications detected in the examination of 3(b)(1) that exceed the acceptance standards of IWB-3514 shall be corrected in accordance with the defect removal requirements of Article IWA-4000. Alternatively, indications that do not meet the acceptance standards of IWB-3514 may be accepted by analytical evaluation in accordance with IWB-3600.
   (2) Surface indications with major dimensions greater than $\frac{1}{16}$ in. (1.5 mm) shall be removed or reduced in size, or shall be weld repaired in accordance with the following requirements.

1. Alloy 82 and Alloy 182 are common abbreviations used by industry, the regulatory authority, and research organizations for UNS N06082 (SFA-5.14, ERNiCr-3) and UNS W68182 (SFA-5.11, ENiCrFe-3), respectively.
2. Alloy 600 is a common abbreviation used by industry, the regulatory authority, and research organizations for UNS N06600.
3. P-No. 1 and 3 materials include some materials previously assigned P-No. 12A, 12B, or 12C designations by Section IX between 1967 and 1973. The old P-No. 12A, 12B, and 12C materials reassigned as P-No. 1 or P-No. 3 (SA-352 Grade LCB was reassigned as P-No. 1 Group 1; SA-508 Class 1 and SA-541 Class 1 were reassigned as P-No. 1 Group 2; SA-537 Grade B was reassigned as P-No. 1 Group 3; SA-352 Grade LC1 was reassigned as P-No. 3 Group 1; SA-508 Class 2, SA-508 Class 3, SA-533 Class 1 Grade A, SA-533 Class 1 Grade B, SA-533 Class 1 Grade C, SA-541 Class 2, SA-541 Class 3, SA-533 Class 2 Grade A, SA-533 Class 2 Grade B, SA-533 Class 2 Grade C, and SA-487 Grade 2Q were reassigned as P-No. 3 Group 3) may be welded using the temper bead requirements of IWA-4600.
to the thickness of the inlay or onlay as specified in 2. However, the thickness of the layers shall be included in the analysis of 2(b).

(3) If weld repair of indications identified in (c) is required, the area where the weld inlay or onlay is to be deposited, including any local weld repairs, shall be examined using the liquid penetrant or eddy current method. The area shall be free of surface indications with major dimensions greater than $\frac{1}{16}$ in. (1.5 mm) prior to installation of the inlay or onlay.

(d) To reduce the potential for hot cracking when applying an austenitic nickel alloy over P-No. 8 base metal, cladding, or adjacent weld, it is permissible to apply austenitic filler material over the austenitic stainless steel or ferritic steel materials. The thickness of these layers shall be included in the analysis in 2(b).

(e) The location of the DMW fusion zones shall be identified. The accuracy of the locating technique shall be demonstrated on representative mockups and documented.

(f) Inlays or onlays shall be deposited using a Welding Procedure Specification (WPS) qualified for groove welding in accordance with the Construction Code and Owner’s Requirements identified in the Repair/Replacement Plan.

(g) Welders and welding operators shall be qualified in accordance with the Construction Code and Owner’s Requirements identified in the Repair/Replacement Plan.

(h) The preheat and postweld heat treatment requirements of the Construction Code and Owner’s Requirements identified in the Repair/Replacement Plan shall be met if welding on ferritic base materials or if $\frac{1}{8}$ in. (3 mm) or less of nonferritic weld deposit exists above the fusion line of the ferritic steel base material. As an alternative, a temper bead welding may be performed in accordance with Mandatory Appendix I.

(i) Weld filler metal for the inlay or onlay shall be nickel alloy with chromium content of at least 28%. Repairs to the DMW may be made with nickel alloy weld filler material having a chromium content of at least 28% or ERNiCr-3.

(j) The inlay or onlay shall consist of at least two layers after final surface preparation and shall comply with the thickness requirements of 2(a). All inlay or onlay layers credited toward the minimum thickness shall contain at least 24% chromium.

(k) 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 inlay or onlay will be deposited using the applicable production weld parameters and the same production weld metal classification. The weld filler metal used for the mockup shall have chromium content no greater than that to be used for the inlay or onlay. Alternatively, if the chromium content of the mockup filler metal is greater than that used for the inlay or onlay, the mockup coupon may be accepted provided the following criteria are met.

$$Cr_1 - (Cr_2 - Cr_m) \geq 24\%$$

where

$$Cr_1 = Cr \text{ content (%) of filler metal to be used for inlay or onlay as reported on the CMTR}$$

$$Cr_2 = Cr \text{ content (%) of filler metal used in the mockup coupon as reported on the CMTR}$$

$$Cr_m = Cr \text{ content (%) of the mockup coupon weld deposit as determined by chemical analysis}$$

(l) For onlays, metal removal associated with surface preparation for welding is permitted, provided it does not encroach on the minimum design thickness.

(m) A new inlay or onlay shall not be installed over an existing inlay or onlay that has been in service.

2 DESIGN AND ANALYSIS REQUIREMENTS

(a) The thickness of the inlay or onlay shall comply with the following:

(1) The thickness shall be at least $\frac{1}{8}$ in. (3 mm).

(2) The minimum thickness shall cover the DMW and extend beyond the DMW and butter fusion zones by at least $\frac{1}{8}$ in. (3 mm). The inlay or onlay design may be considered exempt from evaluation of the primary plus secondary stress intensity (NB-3222.2) and analysis for cyclic operation (NB-3222.4).

(b) A new inlay or onlay may be installed over an existing inlay or onlay that has been in service, Case N-888 or later, as specified in 4, or IWA-4600. The inlay/onlay examinations shall be performed in accordance with Case N-299.

(c) The inlay or onlay shall not grow by fatigue through the full thickness of the interface between the DMW or butter and the inlay or onlay. The fatigue crack growth evaluation shall be performed in accordance with IWB-3640, for the applicable service life, considering all loads subject to Level A and B Service Limits. Both axial and circumferential planar flaws shall be evaluated using the following criteria as applicable.

(1) Flaws With Depths of 10% or Less of DMW Thickness. Axial and circumferential flaw depths shall be assumed to be 10% of the original DMW thickness if the embedded flaw depths do not exceed 10% of the original DMW thickness, or if there are no embedded flaws. The length of the assumed circumferential flaw shall be the full circumference of the weld (360 deg). The length of

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4 IWB-3640 or IWB-3650 in 2001 Edition or earlier.
the assumed axial flaw shall be the entire width of the DMW and butter plus any adjacent SCC-susceptible material.

(2) Flaws With Depths Greater Than 10% of DMW Thickness

(-a) For axial and circumferential flaws whose depths exceed 10% of the original DMW thickness, the actual flaw depths and lengths shall be used in the IWB-3640 evaluation.

(-b) In addition to the evaluation of 2(c)(2)(-a), postulated axial and circumferential flaws with depths equal to 10% of the DMW thickness shall be evaluated. The length of the assumed circumferential flaw shall be 360 deg. The length of the assumed axial flaw shall be the entire width of the DMW and butter plus any adjacent SCC-susceptible material.

(d) Postulated planar flaws in the inlay or onlay shall be evaluated for fatigue crack growth through the inlay or onlay in accordance with IWB-3640 for the service life. Both circumferential and axial surface connected flaws of \( \frac{1}{16} \text{in.} \) (1.5 mm) depth shall be postulated. A postulated circumferential flaw shall be 360 deg around the circumference. The postulated axial flaw length shall be \( \frac{3}{8} \text{in.} \) (9.5 mm). The fatigue crack growth evaluation shall demonstrate that a surface-connected flaw will not grow through the full thickness of the inlay or onlay, considering all applicable loads subject to Level A and B Service Limits.

(e) If the inlay or onlay deposited in accordance with this Case is thicker than \( \frac{7}{8}t \), where \( t \) is the original nominal DMW thickness, the effects of any change in applied loads, as a result of weld shrinkage from the entire inlay or onlay, on other items in the piping system (e.g., support loads and clearances, nozzle loads, and changes in system flexibility and weight due to the inlay or onlay) shall be evaluated. Existing flaws previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640.

3 EXAMINATION

(a) General

(1) The examination requirements of this Case shall be met in lieu of all other examination requirements.

(2) Nondestructive examination methods shall meet the requirement of IWA-2200, except as specified in (-a) and (-b) below.

(-a) Eddy current examination shall be performed in accordance with IWA-2223, except that the length of the Appendix IV, Supplement 2 qualification cracks or notches shall not exceed \( \frac{1}{16} \text{in.} \) (1.5 mm).

(-b) Volumetric acceptance examinations shall comply with (c)(2) and (d).

(3) Nondestructive examination personnel shall be qualified in accordance with IWA-2300.

(b) Examination Prior to Application of the Inlay or Onlay

(1) Volumetric examination of the applicable DMW and butter shall be performed in accordance with Case N-770-1 or later, as specified in 4, during the same outage as the repair/replacement activity.

(2) Surface examination shall be performed using the liquid penetrant or eddy current method on the area to be welded.

(3) Prior to installation of the inlay or onlay, all indications shall meet the requirements of 1(c).

(c) Acceptance Examination of the Inlay or Onlay

(1) The inlay or onlay surface, including at least \( \frac{7}{8} \) in. (13 mm) of adjacent material, shall be examined using eddy current examination method. Indications with major dimension greater than \( \frac{1}{16} \) in. (1.5 mm) are not permitted. The adjacent material, including existing cladding, may alternatively be examined using the liquid-penetrant method and evaluated using the surface examination acceptance criteria for base material of Section III, NB-2500.

(2) The inlay or onlay volume, including the fusion zone, and ferritic steel heat-affected zone, when temper bead welding is used, shall be ultrasonically examined in accordance with Section V, Article 4, using Cladding Technique One. Calibration blocks shall be in accordance with Figure T-434.4.2.2. Imperfections producing a response greater than 20% of the reference level are unacceptable regardless of length. If temper bead welding is used, the examination shall be conducted no sooner than 48 hr after the completion of the third temper bead layer over the ferritic steel base material.

(d) Acceptance Examination of the Weld Repair (if applicable)

(1) If weld repair is required for indications identified in 1(c)(1), the weld repair volume shall be examined ultrasonically in accordance with Section V, Article 4. The acceptance criteria of Section III, NB-5330 shall be met. If temper bead welding is used, the examination shall be conducted no sooner than 48 hr after the completion of the third temper bead layer over the ferritic steel base material.

(e) Preservice and Inservice Examination

(1) Preservice and inservice examinations shall be performed in accordance with Case N-770-1 or later, as specified in 4.

4 USE OF CASE N-770-1 OR LATER

(a) The revision of Case N-770 used shall be applicable, as indicated in the Applicability Index for Section XI Cases found in the Code Cases: Nuclear Components book, to the Edition and Addenda specified for the repair/replacement activity.

5 All Section V references are to the 2001 Edition with the 2002 Addenda or later.
(b) The revision of Case N-770 used is subject to acceptance by the regulatory and enforcement authorities having jurisdiction at the plant site.

(c) The revision of Case N-770 used shall be in effect at the time of the repair/replacement activity, except as provided in (d).

(d) A revision of Case N-770 that is superseded at the time of the repair/replacement activity, but acceptable to the regulatory and enforcement authorities having jurisdiction at the plant site, may be used.
Figure 2
Typical Onlay

Onlay: 2 layers (min.), each layer 24% Cr (min.)

1/8 in. (3 mm) min.

1/4 in. (6 mm) or twice the demonstration accuracy of locating technique, whichever is greater (typ.)

Existing cladding

Austenitic safe end of piping

Alloy 82/182 DMW

Ferritic nozzle

Alloy 82/182 Butter
Mandatory Appendix I
Ambient-Temperature Temper Bead Welding

I-1 General Requirements

(a) The maximum area of an individual inlay or onlay based on the finished surface over the ferritic base material shall be 500 in.$^2$ (325 000 mm$^2$).

(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 $\frac{1}{6}$ 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 $\frac{3}{2}$ times the component thickness or 5 in. (130 mm), whichever is less, shall be at least 50°F (10°C).

I-2 Welding Qualifications

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

I-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. Prior simulated postweld heat treatment on the procedure qualification test assembly is neither required not prohibited. However, if used, the simulated postweld heat treatment shall not exceed the time or temperature already applied to the base material 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 weld.

(c) The maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(d) The weld procedure 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 Figure I-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. For all qualification tests, the location and orientation of the test specimens shall be similar to those required in (g), but shall be in the base metal.

(f) As an alternative to the test temperature requirements of (e), the Charpy V-notch test temperature for procedure qualification may be determined in accordance with (1), (2), or (3) below. The Charpy V-notch test temperature shall be in the transition temperature range for the test assembly ferritic base metal.

(1) The test temperature for the test assembly base metal shall be derived from the full transition temperature curve in the Certified Material Test Report.

(2) A full transition temperature curve for the test assembly base metal shall be developed using Charpy V-notch testing.

(3) The test temperature shall be in the range where one or more Charpy V-notch tests in the test assembly base metal exhibit 35 mils to 50 mils (0.89 mm to 1.3 mm) lateral expansion.

(g) 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). Number, location, and orientation of test specimens shall be as follows:

(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 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 × 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.

(h) 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 the 2002 Addenda or later. The RTNDT 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.

I-2.2 Performance Qualification. Welding operators shall be qualified in accordance with Section IX.

I-3 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 \( \frac{1}{8} \) in. (3 mm) weld thickness with the heat input for each layer controlled to within ±10% of that used in the procedure qualification test. The heat input of the first three layers shall not exceed 45 kJ/in. (1.8 kJ/mm) under any conditions. Particular care shall be taken in the placement of the weld layers of the austenitic weld filler material at the toe of the 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 350°F (180°C) 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 at least the variables listed below:
   (-a) welding heat input
   (-b) initial base material temperature
   (-c) configuration, thickness, and mass of the item being welded
   (-d) thermal conductivity and diffusivity of the materials being welded
   (-e) arc time per weld pass and delay time between each pass
   (-f) arc time to complete the weld

(2) Measurement of the maximum interpass temperature on a test coupon that is no thicker than 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 from all potential sources of hydrogen. The surfaces to be welded, filler metals, and shielding gas shall be suitably controlled.
Figure I-1
Qualification Test Plate

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<th>discard</th>
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<th>Transverse side bend</th>
<th>Reduced section tensile</th>
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<tr>
<td></td>
<td>HAZ Charpy V-notch</td>
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<td>Transverse side bend</td>
<td>Reduced section tensile</td>
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<td>discard</td>
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GENERAL NOTE: Base metal Charpy impact specimens are not shown. This figure illustrates a dissimilar-metal weld.