Case N-847
Partial Excavation and Deposition of Weld Metal for Mitigation of Class 1 Items
Section XI, Division 1

Inquiry: As an alternative to the defect removal requirements of Article IWA-4000, is it permissible to perform a partial excavation from the outside surface followed by deposition of weld metal?

Reply: It is the opinion of the Committee that, in lieu of the defect removal requirements of Article IWA-4000, a defect in austenitic stainless steel or austenitic nickel alloy piping, components, or associated welds, may be reduced to a flaw of acceptable size as determined from IWB-3640 by 360 deg excavation and weld repair (EWR) or Partial Arc EWR, provided the following requirements are met.

1 GENERAL REQUIREMENTS

1.1 DEFINITIONS

(a) Type 1A EWR. An EWR that is applied over material with no inside-surface-connected flaw or subsurface defect. A pre-EWR examination is required for a Type 1A EWR. A Type 1A EWR meets the residual stress criteria of 2(c).

(b) Type 2A EWR. An EWR that is applied over material with no inside-surface-connected flaw or subsurface defect. A pre-EWR examination is required for a Type 2A EWR. A Type 2A EWR does not meet the residual stress criteria of 2(c), or a residual stress analysis is not performed.

(c) Type 1B EWR. An EWR that is applied over material with an inside-surface-connected flaw or subsurface defect, or when a pre-EWR examination is not performed. A Type 1B EWR meets the residual stress criteria of 2(c).

(d) Type 2B EWR. An EWR that is applied over material with an inside-surface-connected flaw or subsurface defect, or when a pre-EWR weld examination is not performed. A Type 2B EWR does not meet the residual stress criteria of 2(c) or a residual stress analysis is not performed.

(e) SCC-Susceptible Materials. For this Case, the materials considered susceptible to stress-corrosion-cracking (SCC) are UNS N06600, N06082, or W86182 in a Pressurized Water Reactor (PWR) environment; or UNS N06600, W86182, or sensitized austenitic stainless steels in a Boiling Water Reactor (BWR) environment.

(f) Full 360 deg EWR. An EWR that extends a full 360 deg circumferentially around the piping or component.

(g) Partial Arc EWR. An EWR that extends less than 360 deg around the piping or component.

(h) Analytical Evaluation Period of EWR. The time for a flaw or postulated flaw to grow to the flaw depth assumed in the design of the EWR as specified in 2(a).

(i) Pre-EWR Examination. Volumetric examination of the Class 1 item to be mitigated performed during the same refueling outage and prior to excavation for the EWR.

1.2 GENERAL EWR REQUIREMENTS

(a) This Case applies to EWRs on austenitic nickel alloy and austenitic stainless steel welds between the following:

1 P-No. 8 or P-No. 43 and P-Nos. 1 or 32
2 P-No. 8 and P-No. 43
3 P-No. 8 to P-No. 8
4 Any combination of P-Nos. 1 or 3 materials

The references in this Case are based on the 2015 Edition, except where references have specific edition or addenda specified. For use with other editions or addenda, refer to the Applicability Index for Section XI Cases, Table 1.

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 487 Grade 2Q were reassigned as P-No. 3, Group 3) may be welded using the temper bead rules of this Case.

The Committee’s function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and in-service inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the in-service inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations or other relevant documents.
(b) Weld filler metal shall be austenitic stainless steel or austenitic nickel alloy meeting the requirements of (e)(1) or (e)(2), respectively. The EWR weld metal shall be deposited with a groove weld Welding Procedure Specification (WPS) qualified in accordance with the Construction Code and Owner’s Requirements identified in the Repair/Replacement Plan.

(1) For ferritic base materials, the Construction Code postweld heat treatment (PWHT) exemptions permitted for circumferential butt welds may be applied to exempt the EWR from PWHT. The base material thickness for PWHT exemption is the thickness of the ferritic material where the EWR is applied.

(2) As an alternative to the PWHT requirements of the Construction Code and Owner’s Requirements, the provisions of Mandatory Appendix I, or IWA-4600, excluding IWA-4611, may be used for temper bead welding.

(c) Prior to deposition of the EWR, the surface to be welded shall be examined using the liquid penetrant method in accordance with IWA-2222 by personnel qualified in accordance with IWA-2300. Indications with major dimensions greater than \(\frac{1}{16}\) in. (1.5 mm) shall be removed, reduced to acceptable size, or sealed in accordance with the following requirements:

(1) One or more layers of weld metal may be applied to seal unacceptable indications in the EWR area to be welded with or without additional excavation. The thickness of the seal weld layers shall not be used in meeting EWR design thickness requirements. Peening the unacceptable indications prior to seal welding is permitted.

(2) If weld repair of indications identified in (c) is required, the area where the EWR is to be deposited, including any local weld repairs or seal weld layers, shall be examined using the liquid penetrant method in accordance with (c).

(d) To reduce the potential for hot cracking when applying nickel alloy filler metal over austenitic stainless steel, it is permissible to apply a layer or multiple layers of austenitic stainless steel filler metal over the austenitic stainless steel base metal or austenitic steel weld metal. The thickness shall be considered in the design analysis required by 2(b). Stainless steel filler metals shall meet the requirements of (e)(1) if considered as contributing to the EWR design.

(e) EWR weld deposits shall meet one of the following requirements, as applicable:

(1) An austenitic stainless steel EWR shall consist of at least two weld layers having as-deposited delta ferrite content of at least 7.5 FN. The carbon content of the stainless steel EWR shall not exceed 0.035% C. The first layer of weld metal with delta ferrite content of at least 7.5 FN shall constitute the first layer of the EWR that may be credited toward the required thickness. Alternatively, layers of at least 5 FN are acceptable, provided the C content of the deposited weld metal is determined by chemical analysis to be less than 0.02%. The C content of the first layer may be determined by chemical analysis of a production weld or of a representative coupon taken from a mockup prepared in accordance with the WPS for the production weld or a representative coupon taken from a mockup prepared in accordance with the WPS for the production weld.

(2) A full 360 deg EWR or Partial Arc EWR shall not be applied to correct flaw growth not bounded by the analysis of 2(a) in a previously-installed full 360 deg EWR that has been in service. A Partial Arc EWR is not permitted on a weldment previously repaired by a Partial Arc EWR. A full 360 deg EWR is permitted for repair of a weldment previously repaired by a Partial Arc EWR.

2 FLAW GROWTH AND DESIGN

(a) Flaw Growth Calculations of Flaws in the Original Weld or Base Metal. The size of all flaws detected or postulated in the original weld or base metal shall be used to define the analytical evaluation period of the EWR. Flaw growth due to both SCC and fatigue shall be included in the analytical evaluation. The SCC and fatigue crack growth curves shall be representative of the applicable Light Water Reactor (LWR) internal environment. Flaw growth shall be evaluated in accordance with Nonmandatory Appendix C of the 2010 Edition with the 2011 Addenda, or later, using the SCC and fatigue crack growth curves applicable to the materials affected by the remaining flaw. Analytical evaluation shall be based on the examination results or a postulated flaw, as described below. If the flaw is at or near the boundary of two different materials, evaluation of flaw growth in both materials is required. The flaw growth calculations shall include residual stresses determined in accordance with (c). If residual stress analysis is not performed, as permitted in (c) for a Type 2A or Type 2B EWR, yield-strength-level residual stresses shall be assumed over the entire cross section of the EWR and the underlying weld metal, for purposes of the flaw growth calculation.

(1) For a Type 1B or Type 2B EWR, the initial flaw size for flaw growth in the original weld or base metal shall be based on the as-found flaw from the pre-EWR Mandatory Appendix VIII, Supplement 10 or Supplement 2 ultrasonic examination, or a postulated flaw size in accordance with (2), if a pre-EWR examination was not performed.

(2) For a Type 1A or Type 2A EWR, or a Type 1B or Type 2B EWR when a pre-EWR examination was not performed, a postulated flaw shall be used. An axial flaw length of 1.5 in. (38 mm) or the combined width of the susceptible weld plus butting, when applicable, plus
any adjacent SCC-susceptible material, whichever is greater, shall be assumed. The circumferential flaw length shall be assumed to extend around the entire circumference. Flaw depths associated with these lengths are specified in (3), (4), and (5).

(3) If no inside-surface-connected planar flaws are detected by the pre-EWR Mandatory Appendix VIII, Supplement 10 or Supplement 2 examination, the EWR is considered to be a Type 1A or Type 2A EWR. For this case, postulated flaws originating from the inside surface of the weldment equal to 10% of the original wall thickness shall be assumed in both the axial and circumferential directions.

(4) For cast austenitic stainless steel (CASS) items, an inside-surface-connected through-wall flaw shall be assumed in the limiting direction in the CASS item, from the inside surface to the bottom of the EWR, regardless whether a pre-EWR examination is performed.

(5) When a pre-EWR examination is not performed, an inside-surface-connected through-wall flaw shall be assumed in the limiting direction in the weld from the inside surface to the bottom of the EWR.

(6) The detected or postulated flaw shall not grow into the EWR material to a depth that would violate the minimum EWR depth established in accordance with (b).

(b) Structural Design and Sizing of the EWR. The EWR shall be designed in accordance with the Construction Code or Section III such that, except for Partial Arc EWRs, the thickness of the newly-added weld metal meeting the requirements of 1.2(e) is capable of supporting all design basis loads at the EWR location, without credit for any of the original SCC-susceptible material.

(1) The minimum depth of the EWR excavation shall be determined by increasing the excavation depth of EWR material until the \(a/t\) ratio is no greater than 0.75, given the assumed flaw length and specific loading conditions for that joint. The minimum excavation depth is the minimum thickness of material that can support the design loading, plus an allowance for potential crack growth due to SCC and fatigue, as determined in (a).

(2) All applicable design basis loads, including load combinations, shall be used.

(3) The effects of any changes in applied loads, as a result of EWR weld shrinkage, on other items in the piping system (e.g., support loads and clearances, and nozzle loads) shall be evaluated. Existing flaws affected by weld shrinkage and previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640.

(c) Residual Stress Analysis of the EWR. To be classified a Type 1A or Type 1B EWR, a residual stress analysis shall be performed of the EWR and the underlying weld, meeting the following requirements.

(1) The residual stress analysis shall include the residual stresses that exist prior to application of the EWR. The analysis shall address residual stresses due to the as-welded condition plus any machining or weld repairs that might have previously occurred. A severe as-welded stress distribution for a 50%-through-wall 360 deg circumferential repair shall be assumed as the starting point for the analysis. If construction records or in-service records show more severe repairs, they shall be assumed in the analysis. The residual stress distribution may be modified considering the effects of PWHT, if applicable.

(2) The residual stress analysis shall address the effects of the EWR excavation, and welding to fill the excavation cavity.

(3) The EWR shall be shown to produce compressive residual stresses or tensile stresses no greater than 10 ksi (69 MPa) at operating temperature and pressure on the inside wetted surface of all SCC-susceptible materials defined in 1.1(e).

(4) If the residual stresses do not meet the requirements of (3), or if a residual stress analysis is not performed, the EWR shall be classified a Type 2A or Type 2B EWR.

(5) Residual stress analysis of a Partial Arc EWR shall be a three-dimensional analysis using finite element methods, to address the effects of the EWR on potential SCC initiation and growth in the SCC-susceptible material regions at the circumferential ends of the Partial Arc EWR.

(d) Additional Considerations

(1) EWRs applied to dissimilar metal welds between stainless steel and carbon or low alloy steel materials will contain dilution zones adjacent to these materials that might not meet the Cr requirements of 1.2(e)(2). Unless it is demonstrated by composition analysis on a mockup that these requirements are satisfied, the EWR cavity design shall include sufficient axial overlap (see Figure 1A) that this dilution zone does not create a continuous radial crack growth path of SCC-susceptible material. Analytical evaluation of this dilution region shall demonstrate that a flaw growing in the original SCC-susceptible material will arrest due to the change in flaw growth direction, without penetrating into the diluted EWR material zone.

(2) EWRs applied to similar or dissimilar metal welds where the SCC-susceptible region is in the austenitic base material heat affected zone (HAZ) shall be designed to ensure there is sufficient axial overlap (see Figure 1B) past the SCC-susceptible region. The EWR shall extend past the original weld as necessary to remove SCC-susceptible base material HAZ. Analytical evaluation shall demonstrate that a flaw growing in the original SCC-susceptible region will arrest due to the change in flaw growth direction, without penetrating into the adjacent SCC resistant base material or the EWR.

(3) Partial Arc EWRs require special attention to the SCC-susceptible material regions at the circumferential ends. The EWR cavity shall be designed with sufficient circumferential overlap (see Figure 2) beyond any observed flaws, such that growth of existing flaws or new flaws that might initiate due to unfavorable residual stress conditions are contained under the EWR overlap dimension for the design life of the EWR.
The Owner shall take measures as necessary to prevent pipe separation after excavation of the EWR.

3 EXAMINATIONS

(a) Pre-EWR Examination. Volumetric examinations performed prior to excavation and installation of the EWR shall be performed in accordance with the applicable supplements of Mandatory Appendix VIII.

(b) EWR Acceptance Examination. Nondestructive examination (NDE) methods shall be in accordance with IWA-2200, except as specified herein. NDE personnel shall be qualified in accordance with IWA-2300.

(1) Surface Finish. The EWR weld surface condition shall be either machined or ground smooth to an RMS finish of approximately 250 μin. (6.3 μm) RMS and shall be free of irregularities, loose material, or coatings, which may interfere with ultrasonic wave transmission. The weld crown shall be flush with the base material to allow for adequate scanning on top of the weld material. Flush is defined as no more than a \( \frac{1}{32} \) in. (1 mm) gap between the ultrasonic search unit and the examination surface for the entire scan area. Examples of conditions that could contribute to an unacceptable scan surface include weld shrinkage, tapers or transitions, or weld toes.

(2) Surface Examination. Examination surface A-B in Figure 3, which includes the EWR and adjacent base material for at least \( \frac{3}{4} \) in. (13 mm) on each side of the EWR, shall be examined using the liquid penetrant method. Additionally, for a Partial Arc EWR, the examination surface shall extend circumferentially \( \frac{1}{2} \) in. (13 mm) beyond each end of the EWR. The EWR shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NB-5300. The adjacent base material shall satisfy the surface examination acceptance criteria for base material of the Construction Code or NB-2500. If ambient temperature temper bead welding is performed, the liquid penetrant examination of the \( \frac{1}{2} \) in. (13 mm) of ferritic base material adjacent to the completed EWR shall be performed no sooner than 48 hr following completion of the three tempering layers over the ferritic steel.

(3) Volumetric Examination

(-a) Examination procedures, personnel, and equipment shall be qualified in accordance with Mandatory Appendix VIII, Supplement 11, with the following additional requirements.

(-1) A blind expansion demonstration shall be performed on representative EWR mock-ups containing typical fabrication flaws located in areas that would challenge the technique (e.g., bottom of cavity, along the bevel face). The minimum number of flaws included in the demonstration shall be five. 100% detection of all flaws is required, with no false calls.

(-2) Examination procedures, equipment, and personnel are qualified for length-sizing when the RMS error of the flaw length measurements, compared to the true flaw lengths, does not exceed 0.75 in. (19 mm).

(-3) Examination procedures, equipment, and personnel are qualified for depth sizing when the RMS error of the flaw depth measurements, compared to the true flaw depths, does not exceed 0.125 in. (3 mm).

(-4) The qualified procedures may be optimized to address the examination of the EWR configuration, but the changes to the qualified essential variables shall be limited to those required to adequately examine the EWR configuration (e.g., focal depth of search units).

(-b) The Examination Volume C-D-E-F in Figure 3 shall be ultrasonically examined to ensure adequate fusion (i.e., adequate bond) with the base material and to detect welding flaws, such as interbead lack of fusion, inclusions, or cracks.

(-c) Planar flaws detected in the EWR weld metal shall meet the preservice examination standards of IWB-3514 and shall not reduce coverage of the preservice Examination Volume C-D-E-F in Figure 5, or interfere with the sizing of existing flaws that may be present.

(-1) In applying the acceptance standards to planar indications, the thickness \( t_1 \) defined in Figure 4 shall be used as the nominal wall thickness in IWB-3514, provided the base material beneath the flaw (i.e., safe-end, nozzle, or piping) is resistant to SCC. For flaws above SCC-susceptible materials, the thickness \( t_2 \) defined in Figure 4 shall be used. If a flaw in the EWR crosses the boundary between SCC-susceptible material and SCC resistant material, \( t_2 \) shall be used.

(-2) Planar flaws at or near the EWR interface may be evaluated as subsurface flaws provided there was no through-wall leak in that area prior to installation of the EWR.

(-d) Laminar flaws detected in the EWR weldment shall meet the preservice examination standards of IWB-3514 and the following requirements.

(-1) The total laminar flaw area shall not exceed 10% of the weld surface area, and no linear dimension of the laminar flaw shall exceed the greater of 3 in. (76 mm) or 10% of the pipe circumference for a 360 deg EWR, or 10% of the EWR length for a Partial Arc EWR.

(-2) Reduction of preservice examination volume coverage due to laminar flaws shall be less than 10% of the required Examination Volume C-D-E-F in Figure 5, and shall not interfere with sizing of existing flaws.

(-3) Any uninspectable volume resulting from a laminar flaw shall be assumed to contain the largest radial planar flaw that could exist within that volume. This assumed flaw shall meet the preservice examination acceptance standards of IWB-3514, with nominal wall thickness as defined in (-c)(-1) for the planar flaw acceptance standard. Assumed flaws located at or near the EWR interface may be evaluated as subsurface flaws, provided there was no through-wall leak in that area prior to installation of the EWR. Alternatively, the assumed flaw shall meet the requirements of IWB-3640. Both axial and circumferential planar flaws shall be assumed.
(4) The flaw evaluations defined in (-1), (-2), and (-3) above shall be performed separately, using the actual values measured with qualified procedures, and do not require IWA-3360 proximity evaluation.

(c) After completion of all welding activities, a VT-3 visual examination shall be performed on all affected restraints, supports, and snubbers, to verify that the design tolerances are met.

(d) Preservice and Inservice Examination

(1) The required preservice and inservice EWR examination volume shown in Figure 5 shall be ultrasonically examined using procedures, personnel, and equipment qualified in accordance with Mandatory Appendix VIII, Supplement 10. The required inservice examination volume for regions outside the Partial Arc EWR shall be examined using equipment, procedures, and personnel qualified in accordance with the applicable Mandatory Appendix VIII supplement. The angle beam shall be directed perpendicular and parallel to the piping axis, with scanning performed in four directions. The purpose of this examination is to ensure that no additional flaws have initiated in the area of the EWR and that existing flaws have not propagated into the EWR material or grown circumferentially outside of the EWR region for a Partial Arc EWR.

(2) Flaws detected in the required examination volume shall be sized to determine the maximum through-wall dimension and length.

(3) The acceptance standards in Table 1 shall be used for EWRs installed in BWRs. The acceptance standards in Case N-770-5 (or later in accordance with 4 below) shall be used for EWRs installed in PWRs.

(4) The preservice examination shall be performed prior to placing the EWR in service.

(5) The method, extent, and frequency of inservice examinations shall be in accordance with Table 1 for BWRs or Case N-770-5 (or later in accordance with 4 below) for PWRs.

4 USE OF CASE N-770 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.

(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.
## Table 1

### Examination Categories

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<th>Inspection Item</th>
<th>Parts Examined</th>
<th>Examination Requirements</th>
<th>Examination Method</th>
<th>Acceptance Standard</th>
<th>Extent and Frequency of Examination [Note (1)]</th>
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<td>EWR-1A</td>
<td>Uncracked butt weld with full 360 deg Type 1A EWR of SCC-resistant material</td>
<td>Figure 5</td>
<td>Volumetric</td>
<td>IWB-3514</td>
<td>No sooner than the third refueling outage and no later than 10 yr following EWR application [Note (2)] Examination volumes that show no indication of cracking shall be examined in accordance with Category C [Note (1)]</td>
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<td>EWR-2A</td>
<td>Uncracked butt weld with full 360 deg Type 2A EWR of SCC-resistant material</td>
<td>Figure 5</td>
<td>Volumetric</td>
<td>IWB-3514</td>
<td>Once during the first or second refueling outage following EWR application [Note (2)] Examination volumes that show no indication of cracking shall be examined in accordance with Category C [Note (1)]</td>
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<td>Figure 5</td>
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<td>Once during the first or second refueling outage following EWR application [Note (2)] Examination volumes that show no indication of crack growth or new cracking shall be examined in accordance with Category E [Note (1)], [Note (3)]</td>
</tr>
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<td>Figure 5</td>
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<td>IWB-3514</td>
<td>Once during the first or second refueling outage following EWR application [Note (2)] Examination volumes that show no indication of crack growth or new cracking shall be examined in accordance with Category E [Note (1)], [Note (4)]</td>
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<tr>
<td>EWR-Partial Arc</td>
<td>Cracked butt weld with Partial Arc EWR of SCC-resistant material</td>
<td>Figure 5</td>
<td>Volumetric</td>
<td>IWB-3514</td>
<td>Volumetric examination shall be in accordance with Category F [Note (1)] Surface examination is required at the same frequency as the volumetric examination When the remaining analytical evaluation period is less than one refueling cycle, the Partial Arc EWR shall be examined prior to the end of the analytical evaluation period</td>
</tr>
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</table>

### NOTES:

1. The Category (e.g., Category C, E, or F) examination frequency, and scope expansion shall be in accordance with the Owner’s inspection program following NRC Generic Letter 88-01, or alternative (e.g., BWRVIP-075-A).
2. For any EWR with an analytical evaluation period of less than 10 yr, the inspection interval shall be less than or equal to the analytical evaluation period.
3. Requirements of Category E “Cracked – Reinforced by Weld Overlay” shall apply for EWR-1B.
4. Requirements of Category E “Cracked – Mitigated by Stress Improvement” shall apply for EWR-2B.
Figure 1A
Cross Section of Typical Dissimilar Metal EWR

Figure 1B
Cross Section of Typical Similar-Metal EWR
Figure 2
Illustration of Typical Partial Arc EWR

- Partial arc EWR
- Circumferential flaw
- Circumferential overlap

Figure 3
Extent of Surface and Volumetric Acceptance Examination for Full 360 deg EWR and Partial Arc EWR

- ½ in. (13 mm) Extent of EWR
- Profile of valve body, vessel nozzle, or pump connection
- Original weld
- As-found flaw
- Butter weld (as applied)

GENERAL NOTE: For a Partial Arc EWR, the examination volume shall extend at least 1/4 in. (6 mm) past the circumferential ends of the EWR, and the examination surface shall extend at least ½ in. (13 mm) past the circumferential ends of the EWR.
Figure 4
Thickness $t_1$ and $t_2$ for Application of IWB-3514 Acceptance Standards

Figure 5
Preservice and Inservice Examination Surface and Examination Volume

GENERAL NOTES:
(a) Volumetric examination shall include as-found flaws that extend outside Examination Volume C-D-E-F.
(b) For a Partial Arc EWR, the examination volume shall extend at least $\frac{1}{4}$ in. (6 mm) past the circumferential ends of the EWR, and the examination surface shall extend at least $\frac{1}{2}$ in. (13 mm) past the circumferential ends of the EWR.
MANDATORY APPENDIX I
AMBIENT-TEMPERATURE TEMPER BEAD WELDING

I-1 GENERAL REQUIREMENTS

(a) This Mandatory Appendix applies to dissimilar austenitic filler metal welds between P-Nos. 1 or 3 materials and their associated welds and welds joining P-No. 8 or 43 materials to P-Nos. 1 or 3 materials with the following limitation. This Appendix shall not be used to repair SA-302 Grade B material unless the material has been modified to include from 0.4% to 1.0% nickel, quenching, tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld based on the finished surface over the ferritic base material shall be 500 in.² (325 000 mm²).

(c) Repair/replacement activities on a dissimilar-metal weld in accordance with this Appendix are 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.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Appendix, provided the depth of repair in the base material does not exceed 1/8 in. (10 mm)

(e) 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 50°F (10°C).

(f) Welding materials shall meet the Owner’s Requirements and the Construction Code and Cases specified in the Repair/Replacement Plan. Welding materials shall be controlled so that they are identified as acceptable until consumed.

(g) Weld metal and heat affected zones may be peened to control distortion. Peening shall not be used on the final weld surface.

I-2 WELDING QUALIFICATIONS

(a) The welding procedures and the welding operators shall be qualified in accordance with QW-290 and the requirements of I-2.1 and I-2.2.

(b) Existing welding procedure and welding operator qualifications performed in accordance with another ambient-temperature temper bead Case, or applicable appendix to the Case, may be used with this Appendix without requalification.

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 nor 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 maximum interpass temperature for the first three layers of the test assembly shall be 150°F (66°C).

(c) The following are procedure qualification requirements:

1. The test assembly 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 as specified in (d) below, but shall be in the base metal. Impact testing of austenitic (nickel-based P-No. 4X and stainless steel P-No. 8) materials is not required.

2. As an alternative to the test temperature requirements of (1) above, the Charpy V-notch test temperature for procedure qualification may be determined by (-a), (-b), or (-c) below. Select a Charpy V-notch test temperature in the transition temperature range for the test assembly ferritic base metal.

   - (a) Determine the test temperature for the test assembly base metal from the full transition temperature curve in the Certified Material Test Report.

   - (b) Determine the test temperature by developing a full transition temperature curve for the test assembly base metal by Charpy V-notch testing.

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2 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 rules of this Case.
(c) Determine the test temperature 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.

(d) Charpy V-notch tests of the ferritic heat-affected zone (HAZ) shall be performed at the same temperature as the base metal. 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.

(2) If 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.

(3) 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.

(4) The Charpy V-notch test shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Figure 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.

(e) 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 the 2010 Edition with the 2011 Addenda, or later. 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.

I-3 WELDING PROCEDURE REQUIREMENTS

The welding procedure shall include the following requirements:

(a) The weld metal shall be deposited by the automatic or machine GTAW process.

(b) Dissimilar metal welds shall be made using A-No. 8 weld metal (Table QW-442) for P-No. 8 to P-No. 1 or 3 weld joints or F-No. 43 weld metal (Table QW-432) for P-No. 8 or 43 to P-No. 1 or 3 weld joints.

(c) 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) EWR 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 at the toe of the EWR 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.

(d) 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.

(e) The interpass temperature shall be determined as follows:

(1) Temperature measurement (e.g., pyrometers, temperature-indicating crayons, and thermocouples) during welding. If direct measurement is impractical, interpass temperature shall be determined in accordance with (2) or (3).

(2) 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) time per weld pass and delay time between each pass

(f) time to complete the weld

(3) 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 welding the test coupon.

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 metals, and shielding gas shall be suitably controlled.