NONMANDATORY APPENDIX Q
WELD OVERLAY REPAIR OF CLASSES 1, 2, AND 3 AUSTENITIC STAINLESS STEEL PIPING WELDMENTS

ARTICLE Q-1000
SCOPE

This Nonmandatory Appendix provides an alternative to the requirements of IWA-4420, IWA-4520, IWA-4530, and IWA-4600 for making repairs to, and subsequent examination of Class 1, 2, and 3 austenitic stainless steel pipe weldments by deposition of weld reinforcement (weld overlay) on the outside surface of the pipe. If used, all provisions of this Nonmandatory Appendix are mandatory. After a weld overlay has been installed in accordance with this Nonmandatory Appendix, the in-service examinations identified in Q-4300 shall be performed as long as the repair remains part of the pressure boundary.
ARTICLE Q-2000
PREREQUISITES

(a) Reinforcement weld metal shall be low carbon (0.035% max.) austenitic stainless steel applied 360 deg around the circumference of the pipe, and shall be deposited using a Welding Procedure Specification for groove welding, qualified in accordance with the Construction Code and Owner's Requirements and identified in the Repair/Replacement Plan.

(b) Prior to deposition of the weld reinforcement, the surface to be repaired shall be examined by the liquid penetrant method. Indications greater than 1/16 in. (1.5 mm) shall be removed, reduced in size, or corrected in accordance with the following requirements, prior to application of weld reinforcement. One or more layers of weld metal shall be applied to seal unacceptable indications in the area to be repaired with or without excavation. The thickness of these layers shall not be used in meeting weld reinforcement design thickness requirements. Peening the unacceptable indication prior to welding is permitted.

(c) If correction of indications in (b) is required, the area where the weld reinforcement is to be deposited, including any local repairs or initial weld overlay layers, shall be examined by the liquid penetrant method. The area shall contain no indications greater than 1/16 in. (1.5 mm) prior to the application of the structural layers of the weld overlay.

(d) For BWR applications, the weld reinforcement shall consist of at least two weld layers having as-deposited delta ferrite content of at least 7.5 FN. The first layer of weld metal with delta ferrite content of at least 7.5 FN shall constitute the first layer of the weld reinforcement that may be credited toward the required thickness. Alternatively, first layers of at least 5 FN are acceptable, provided the carbon content of the deposited weld metal is determined by chemical analysis to be less than 0.02%. A minimum of six FN measurements shall be taken using a magnetic measuring instrument and averaged. Alternatively, the FN may be determined from a representative coupon taken from a mockup prepared in accordance with the Welding Procedure Specification (WPS) for the weld reinforcement using filler material with a FN equal to or less than the filler metal to be used for the weld reinforcement. The mockup base material shall have a Ni_{eq}/Cr_{eq} ratio, in accordance with the equation below, equal to or greater than the Ni_{eq}/Cr_{eq} ratio of the items to be repaired.

$$\frac{Ni_{eq}}{Cr_{eq}} = \frac{Ni + 35C + 20N + 0.25Cu}{Cr + Mo + 0.7Nb}$$

where the values are the weight percentage on the material test report. Use the following values if not reported: 0.06 N, 0.10% Cu, zero Mo, and zero Nb.

(e) The submerged arc welding method shall not be used for weld overlays.
ARTICLE Q-3000
DESIGN CONSIDERATIONS

Design of the weld reinforcement shall provide access for the examinations required by Article Q-4000 and shall be in accordance with (a) and (b).

(a) Flaw characterization and analytical evaluation requirements shall be based on the as-found flaw. However, the size of the as-found flaws shall be projected to the end of design life of the overlay. Crack growth, including stress corrosion cracking and fatigue crack growth, shall be evaluated using the analytical evaluation provisions of IWB-3640. Stress corrosion crack growth analysis is not required within the weld overlay material.

(1) For determining the combined length of circumferential flaws, multiple flaws shall be treated as one flaw of length equal to the sum of the lengths of the individual flaws characterized in accordance with IWA-3300.

(2) For circumferentially-oriented flaws, when the combined length is greater than 10% of the pipe circumference, the flaws shall be assumed to be 100% through the original pipe wall thickness for the entire circumference of the pipe.

(3) For circumferentially-oriented flaws, when the combined length does not exceed 10% of the pipe circumference, the flaws shall be assumed to be 100% through the original pipe wall thickness for a circumferential length equal to the combined length of the flaws.

(4) For axial flaws 1.5 in. (38 mm) or longer, or for five or more axial flaws of any length, the flaws shall be assumed to be 100% through the original pipe wall thickness for the entire axial length of the flaw for the entire circumference of the pipe.

(5) For weldments with four or fewer axial flaws, each shorter than 1.5 in. (38 mm), and no circumferential flaws, the weld reinforcement shall satisfy the requirements of Q-2000(d). No additional structural reinforcement is required. The axial length of the overlay shall cover the weldment and the heat-affected zones, and shall extend at least ½ in. (13 mm) beyond the ends of the observed flaws. The requirements of (b)(1), (b)(3), and (b)(4) need not be met.

(b) The design of the weld overlay shall satisfy the following, using the assumptions and flaw characterization restrictions in (a). The design analysis required by (1) through (4) shall be completed in accordance with IWA-4311.

(1) The axial length and end slope of the weld overlay shall cover the weldment and the heat-affected zones on each side of the weldment, and shall provide for load redistribution from the pipe into the weld overlay and back into the pipe without violating applicable stress limits for primary local and bending stresses and secondary and peak stresses, as required by the Construction Code. Any laminar flaws in the weld overlay shall be evaluated in the analysis to ensure that load redistribution complies with the preceding information. These requirements will usually be satisfied if the overlay full thickness length extends axially beyond the projected flaw by at least \( \frac{3}{4} \sqrt{Rt} \), where \( R \) is the outer radius of the pipe and \( t \) is the nominal wall thickness of the pipe.

(2) Unless specifically analyzed in accordance with (b)(1), the end transition slope of the overlay shall not exceed 45-30 deg. A slope of not more than 1:3 is recommended.

(3) The overlay design thickness of items meeting (a)(2), (a)(3), or (a)(4) shall be based on the measured diameter, using the thickness of the weld overlay as restricted by Q-2000(d). The wall thickness at the weld overlay, any planar flaws in the weld overlay, and the effects of any discontinuity (e.g., another weld overlay or reinforcement for a branch connection) within a distance of 2.5\( \sqrt{Rt} \) from the toes of the weld overlay, shall be evaluated and shall meet the requirements of IWB-3640, IWC-3640, or IWD-3640, as applicable.

(4) The effects of any changes in applied loads, as a result of weld shrinkage, on existing flaws previously accepted by analytical evaluation shall be evaluated in accordance with IWB-3640, IWC-3640, or IWD-3640, as applicable.
ARTICLE Q-4000
EXAMINATION AND TESTING

Ultrasonic examination personnel shall be certified in accordance with the Owner’s written practice. Procedures and personnel shall be qualified in accordance with Mandatory Appendix VIII.

Q-4100 EXAMINATION

(a) The weld overlay shall have a surface finish of 250 μin. (6.3 μm) RMS or better and a flatness sufficient to allow for adequate examination in accordance with procedures qualified in accordance with Mandatory Appendix VIII. The weld overlay shall be examined to verify acceptable configuration.

(b) Examination Surface A-B in Figure Q-4100-1, which includes the weld overlay and adjacent base material for at least ½ in. (13 mm), the weld overlay and the adjacent base material for at least ½ in. (13 mm) from each side of the weld shall be examined using the liquid penetrant method. The weld overlay shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NB-5300. The adjacent base metal shall satisfy the surface examination acceptance criteria for base material of NB-2500.

(c) The examination volume in Figure Q-4100-1 shall be ultrasonically examined to assure adequate fusion (i.e., adequate bond) with the base metal and to detect welding flaws such as interbead lack of fusion, inclusions, or cracks. The examination volume C-G-I-F and H-D-E-I in Figure Q-4100-1 shall be ultrasonically examined to assure adequate fusion (i.e., adequate bond) with the base metal and to detect laminar flaws in the weld overlay material that might obstruct subsequent in-service examinations. The examination volume G-H-I-J, design reinforcement size required by Q-3000, shall be examined for planar flaws in addition to the laminar flaw examination. Planar flaws in Class 1 piping shall meet the preservice examination standards of Table IWB-3514-1 for Class 1 piping and Table IWC-3514-1 for Class 2 or 3 piping. Alternatively, the assumed flaw shall meet the requirements of IWB-3640, IWC-3640, or IWD-3640, as applicable. Both axial and circumferential planar flaws shall be assumed.

(d) After completion of all welding activities, affected restraints, supports, and snubbers shall be VT-3 visually examined to verify that design tolerances are met.
Q-4200  PRESERVICE INSPECTION

(a) The examination volume in Figure Q-4300-1 shall be ultrasonically examined. The angle beam shall be directed perpendicular and parallel to the pipe axis, with scanning performed in four directions to locate and size cracks that have propagated into the upper 25% of the pipe base material or into the overlay.

(b) For Class 1 piping, the preservice examination acceptance standards of Table IWB-3514-1 shall be satisfied, and for Class 2 or 3 piping, the preservice examination acceptance standards of Table IWC-3514-1 shall be satisfied for the weld overlay. Cracks in the outer 25% of the pipe base metal shall meet the design analysis requirements of Article Q-3000.

Q-4300  INSERVICE INSPECTION

(a) The weld overlay examination volume in Figure Q-4300-1 shall be added to the inspection plan and shall be ultrasonically examined during the first or second refueling outage following application.

(b) The weld overlay examination volume in Figure Q-4300-1 shall be ultrasonically examined to determine if any new or existing cracks have propagated into the upper 25% of the pipe base material or into the overlay. The angle beam shall be directed perpendicular and parallel to the pipe axis, with scanning performed in four directions.

(c) For Class 1 piping, the inservice examination acceptance standards of Table IWB-3514-1 shall be satisfied, and for Class 2 or 3 piping, the inservice examination acceptance standards of Table IWC-3514-1 shall be satisfied for the weld overlay. Alternatively, for Class 1, 2, or 3 piping systems, the acceptance criteria of IWB-3600, IWC-3600, or IWD-3600, as applicable, shall be satisfied for the weld overlay. Cracks in the outer 25% of the pipe base metal shall meet the design analysis requirements of Article Q-3000.

(d) Weld overlay examination volumes that show no indication of crack growth or new cracking shall be placed into a population to be examined on a sampling basis. Twenty-five percent of this population shall be examined once every 10 yr.

(e) If inservice examinations reveal crack growth or new cracking, meeting the acceptance standards, the weld overlay examination volume shall be reexamined during the first or second refueling outage following discovery of the growth or new cracking. Weld overlay examination volumes that show no additional indication of crack growth or new cracking shall be placed into a population to be examined on a sample basis. Twenty-five percent of this population shall be examined once every 10 yr.

(f) For weld overlay examination volumes with unacceptable indications as described in (b) and (c), the weld overlay shall be removed, including the original defective piping weldment, and corrected by a repair/replacement activity in accordance with Article IWA-4000.

Q-4310  ADDITIONAL EXAMINATIONS

If inservice examinations reveal an unacceptable indication, crack growth into the weld overlay design thickness, or axial crack growth beyond the specified examination volumes, additional weld overlays, equal to the number scheduled for the current inspection period, shall be examined prior to return to service. If additional unacceptable indications are found in the second sample, a total of 50% of the total population of weld overlays shall be examined prior to operation. If additional unacceptable indications are found, the entire remaining population of weld overlays shall be examined prior to return to service.

Q-4400  PRESSURE TESTING

Pressure testing shall be conducted in accordance with IWA-4540. Weld overlay of a through-wall flaw shall be considered a welding activity that penetrates the pressure boundary.