The base material for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded.

### 2.1 PROCEDURE QUALIFICATION

(a) 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) Consideration shall be given to the effects of welding in a pressurized environment. If they exist, they shall be bounded in the test assembly within the limits of Table IWA-4662.1-1.

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

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

(e) The following are procedure qualification requirements:

1. The test assembly base material for the welding procedure qualification 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 (4) 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), the Charpy V-notch test temperature for procedure qualification may be determined in accordance with (-a), (-b), or (-c) below. The Charpy V-notch test temperature shall be in the transition temperature range for the test assembly ferritic base metal.

   (-a) The Charpy V-notch test temperature for the test assembly base metal shall be derived from the full transition temperature curve in the Certified Material Test Report.

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

   (-c) 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.

3. Charpy V-notch tests of weld metal of the procedure qualification shall meet the requirements as determined in (1). Drop-weight tests, when required for the weld metal by the Construction Code in (1), need not be performed.

4. Charpy V-notch tests of the heat-affected zone (HAZ) shall be performed at the same temperature as the base metal. Number, location, and orientation of test specimens shall meet the requirements of (5) through (7).

(2) As an alternative to (1), the ferritic test assembly base material may be tested by Charpy V-notch testing in accordance with the requirements of (-a) and (-b) below. Drop weight testing, when required by the Construction Code, need not be performed.

   (-a) The Charpy V-notch test temperature shall be determined from (-1), (-2), or (-3) and shall be in the transition temperature range of the base material.

   (-1) A full Charpy V-notch transition temperature curve provided in the Certified Material Test Report for the test assembly base material.

   (-2) A full Charpy V-notch transition temperature curve developed by impact testing of the test assembly base material.

   (-3) One or more Charpy V-notch tests of the test assembly base material where test specimens exhibit lateral expansion values of 35 mils to 50 mils (0.89 mm to 1.3 mm)

   (-b) The location and orientation of the test specimens shall be as specified in (4) below, but shall be in the base metal.

8. The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be not less 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 Case, either of the following shall be performed:

   (-a) The welding procedure shall be requalified.

   (-b) An Adjustment Temperature for the procedure qualification shall be determined in accordance with the applicable provisions of NB-4335.2 of the 2001 Edition with the 2002 Addenda or later. The \( RT_{TD, \text{adj}} \) 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.
(b) Existing welding procedure and welding operator qualifications performed in accordance with previous revisions of this Case may be used with this revision without requalification.

2.1 PROCEDURE QUALIFICATION

The base material for the welding procedure qualification shall be of the same P-Number and Group Number as the materials to be welded.

(a) 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) Consideration shall be given to the effects of welding in a pressurized environment. If they exist, they shall be bounded in the test assembly within the limits of Table IWA-4662.1-1.

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

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

(e) The following are procedure qualification requirements:

(1) The test assembly base material for the welding procedure qualification 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 (4) 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 (1), the ferritic test assembly base material may be tested by Charpy V-notch testing in accordance with the requirements of (a) and (b) below. Drop-weight testing, when required by the Construction Code, need not be performed.

(a) The Charpy V-notch test temperature shall be determined from (1), (2), or (3) and shall be in the transition temperature range of the base material.

(1) A full Charpy V-notch transition temperature curve provided in the Certified Material Test Report for the test assembly base material

(2) A full Charpy V-notch transition temperature curve developed by impact testing of the test assembly base material

(b) The location and orientation of the test specimens shall be as specified in (4) below, but shall be in the base metal.

(3) Charpy V-notch tests of weld metal of the procedure qualification shall meet the requirements as determined in (1). Drop-weight tests, when required for the weld metal by the Construction Code in (1), need not be performed.

(4) Charpy V-notch tests of the heat-affected zone (HAZ) shall be performed at the same temperature as the base metal. Number, location, and orientation of test specimens shall meet the requirements of (5) through (7).

(5) 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.

(6) 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.

(7) The Charpy V-notch test shall be performed on the weld metal, the heat affected zone and unaffected base metal in accordance with SA-370. Specimens shall be in accordance with SA-370, Fig. 11, Type A. A 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.

(8) The average lateral expansion value of the three HAZ Charpy V-notch specimens shall be not less than the average lateral expansion value of the three unaffected base metal specimen. 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 Case, either of the following shall be performed:

(a) The welding procedure shall be requalified.

(b) An adjustment temperature or lateral expansion value for the procedure qualification shall be determined and applied in accordance with the applicable provisions of NB-4335.2 of the 2001 Edition with the 2002 Addenda or later.
(c) The interpass temperature shall be determined by direct measurement (e.g., pyrometers, temperature indicating crayons, thermocouples) during welding. If direct measurement is impractical, e.g., because of geometric limitations or radiological reasons, interpass temperature shall be determined in accordance with (1) or (2).

(1) heat flow calculations using the variables listed below as a minimum:
- (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

(2) measurement of the actual 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 potential sources of hydrogen. The surfaces to be welded, filler metal, and shielding gas shall be suitably controlled.

4 EXAMINATION

(a) Except as permitted in (1), the following examinations shall be performed in accordance with the Construction Code or Section III.

(1) Prior to repair welding, surface examination shall be performed on the area to be welded. When surface examination is impractical, materials cannot be cleaned from crevices in the area to be welded (e.g., trapped in crevices remaining after removal of the full thickness of a partial penetration or fillet weld), VT-1 visual examination may be performed, provided the requirements of 4(b) are met.

(2) When ferritic materials are used, the weld shall be nondestructively examined after the completed weld has been at ambient temperature for at least 48 hr. When austenitic materials are used, the weld shall be nondestructively examined after the three tempering layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr. Examination of the welded region shall include both volumetric and surface examination methods.

(3) Demonstration for ultrasonic examination of the repaired volume is required using representative samples that contain construction type flaws.

(4) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(5) Acceptance criteria for surface and volumetric examination shall be in accordance with the Construction Code or Section III.

(b) VT-1 visual examinations performed in accordance with (a)(1)(h) or 4(a)(1) shall meet the following requirements:

(1) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving text with lower case characters without an ascender or descender (e.g., a, c, e, o) not exceeding a height of 0.044 in. (1.1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (610 mm).

(2) VT-1 visual examination personnel shall be qualified in accordance with IWA-2300 and shall receive additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.

(3) Visual examination acceptance standards shall comply with the following:
- (a) Linear indications are indications in which the length is more than three times the width. Rounded indications are circular or elliptical with length equal to or less than three times the width.
- (b) Only indications with major dimensions greater than 1/16 in. (1.5 mm) shall be considered relevant. The following relevant indications are unacceptable.
- (1) any cracks or linear indications
- (2) rounded indications with major dimensions greater than 3/16 in. (5 mm)
- (3) four or more rounded indications in a line separated by 1/16 in. (1.5 mm) or less edge to edge
- (4) ten or more rounded indications in any 6 in.² (4 000 mm²) of surface with major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indication being evaluated
2.2 PERFORMANCE QUALIFICATION

Welding operators shall be qualified in accordance with Section IX.

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) The maximum interpass temperature for field applications shall be $350^\circ\text{F} \ (180^\circ\text{C})$ for all weld layers, regardless of the interpass temperature used during qualification. The interpass temperature limitations of QW-406.3 need not be applied.

(c) The interpass temperature shall be determined by direct measurement (e.g., pyrometers, temperature indicating crayons, thermocouples) during welding. If direct measurement is impractical, e.g., because of geometric limitations or radiological reasons, interpass temperature shall be determined in accordance with (1) or (2).

\begin{enumerate}
\item (1) heat flow calculations using the variables listed below as a minimum:
\begin{itemize}
\item (-a) welding heat input
\item (-b) initial base material temperature
\item (-c) configuration, thickness, and mass of the item being welded
\item (-d) thermal conductivity and diffusivity of the materials being welded
\item (-e) time per weld pass and delay time between each pass
\item (-f) time to complete the weld
\end{itemize}
\item (2) measurement of the actual 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.
\end{enumerate}

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

4 EXAMINATION

(a) Except as permitted in (1), the following examinations shall be performed in accordance with the Construction Code or Section III.

(1) Prior to repair welding, surface examination shall be performed on the area to be welded. Alternatively, if surface examination materials cannot be cleaned from crevices in the area to be welded (e.g., trapped in crevices remaining after removal of the full thickness of a partial penetration or fillet weld), VT-1 visual examination may be performed, provided the requirements of (b) are met.

(2) When ferritic materials are used, the weld shall be nondestructively examined after the completed weld has been at ambient temperature for at least 48 hr. When austenitic materials are used, the completed weld shall be nondestructively examined after the three tempering layers (i.e., layers 1, 2, and 3) have been in place for at least 48 hr. Examination of the welded region shall include both volumetric and surface examination methods.

(3) Demonstration for ultrasonic examination of the repaired volume is required using representative samples that contain construction-type flaws.

(4) Areas from which weld-attached thermocouples have been removed shall be ground and examined using a surface examination method.

(5) Acceptance criteria for surface and volumetric examination shall be in accordance with the Construction Code or Section III.

(b) VT-1 visual examinations performed in accordance with 1(h) or (a)(1) shall meet the following requirements:

\begin{enumerate}
\item (1) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA-2210 and shall be capable of resolving text with lower case characters without an ascender or descender (e.g., a, c, e, o) not exceeding a height of 0.044 in. (1.1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 ft (610 mm).
\item (2) VT-1 visual examination personnel shall be qualified in accordance with IWA-2300 and shall receive additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws.
\item (3) Visual examination acceptance standards shall comply with the following:
\begin{itemize}
\item (-a) Linear indications are indications in which the length is more than three times the width. Rounded indications are circular or elliptical with length equal to or less than three times the width.
\item (-b) Only indications with major dimensions greater than $\frac{1}{16}$ in. (1.5 mm) shall be considered relevant. The following relevant indications are unacceptable.
\item (-1) any cracks or linear indications
\item (-2) rounded indications with major dimensions greater than $\frac{1}{16}$ in. (5 mm)
\item (-3) four or more rounded indications in a line separated by $\frac{1}{16}$ in. (1.5 mm) or less edge to edge
\item (-4) ten or more rounded indications in any 6 in.$^2$ (4 000 mm$^2$) of surface with major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indication being evaluated
\end{itemize}
\end{enumerate}