WC-2000 MATERIAL

WC-2100 GENERAL REQUIREMENTS FOR MATERIAL

WC-2110 SCOPE OF PRINCIPAL TERMS EMPLOYED

(a) The term material as used in this Subsection is defined in WA-1220. The term Material Organization is defined in Division 1, Article NCA-9000.

(b) The term containment materials, as used in this Subsection applies to containment shells, heads, nozzles and bolting that form part of the containment boundary.

(c) The requirements of this Article make reference to the term thickness. For the purpose intended, the following definitions of nominal thickness apply:

1. plate: the thickness is the dimension of the short transverse direction;
2. forgings: the thickness is the dimension defined as follows:
   - (a) hollow forgings: the nominal thickness is measured between the inside and outside surfaces (radial thickness);
   - (b) disk forgings (axial length less than the outside diameter): the nominal thickness is the axial length;
   - (c) flat ring forgings (axial length less than the radial thickness): for axial length \( \leq 2 \text{ in.} \) (50 mm), the axial length is the nominal thickness. For axial length \( \geq 2 \text{ in.} \) (50 mm), the radial thickness is the nominal thickness.
   - (d) rectangular solid forgings: the least rectangular dimension is the nominal thickness.
3. castings: thickness for fracture toughness testing and heat treatment purposes is defined as the wall thickness of the containment.

WC-2120 CONTAINMENT MATERIAL

WC-2121 Permitted Material Specifications

(a) Containment materials shall conform to the requirements of one of the specifications for materials given in Section II, Part D, Subpart 1, Tables 2A and 2B including all applicable reference notes in the table, and to all of the requirements of this Article that apply to the product form in which the material is used. Attachments that perform a containment function shall be containment material. As an additional control, only the following materials shall be used:

1. materials whose P-Numbers are listed in Table WC-4622.1-1

   (2) ductile cast iron castings per specifications SA-874 or SA/JIS G5504
   (3) SA-263, Specification for Corrosion-Resisting Chromium-Steel Clad Plate, Sheet, and Strip
   (4) SA-264, Specification for Corrosion-Resisting Chromium–Nickel Steel Clad Plate, Sheet, and Strip
   (5) SA-265, Specification for Nickel and Nickel-Based Alloy Clad Steel Plate

(b) The requirements of this Article do not apply to material for items not associated with the containment function of a component such as seals, gaskets, and ceramic insulating materials and special alloys used as seal materials in electrical penetration assemblies.

(c) Material for line fittings, NPS 1 (DN 25) and less, may be of material made to specifications other than those listed in Section II, Part D, Subpart 1, provided that the fittings are in conformance with the requirements of NC-3671.4 and the material is determined to be adequate for the service conditions by the piping system designer.

(d) Welding and brazing materials used in manufacture of items shall comply with an SFA specification in Section II, Part C, except as otherwise permitted in Section IX, and shall also comply with the applicable requirements of this Article. The requirements of this Article do not apply to materials used as backing rings or backing strips in welded joints.

(e) The requirements of this Article do not apply to hard surfacing or corrosion resistant weld metal overlay that is 10% or less of the thickness of the base material (WC-3122).

WC-2122 Special Requirements Conflicting With Permitted Material Specifications

Special requirements stipulated in this Article shall apply in lieu of the requirements of the material specifications wherever the special requirements conflict with the material specification requirements (NCA-4256). Where the special requirements include an examination, test, or treatment which is also required by the material specification, the examination, test, or treatment need be performed only once. Required nondestructive examinations shall be performed as specified for each product form in WC-2500. Any examination, repair, test, or treatment required by the material specification or by this Article may be performed by the Material Manufacturer or the Certificate Holder as provided in WC-4121. Any hydrostatic or pneumatic pressure test required by a material specification need not be performed, provided the...
Preparation of Test Coupons and Specimens

(a) Removal of test coupons from the test weld and the dimensions of specimens made from them shall conform to the requirements of Section IX, except that the removal of impact test coupons and the dimensions of impact test specimens shall be in accordance with (b) below.

(b) Weld deposit of each process in a multiple process weld shall, where possible, be included in the impact test specimens. When each process cannot be included in the full size impact test specimen at the \( \frac{1}{4} t \) location required by this Section, additional full size specimens shall be obtained from locations in the test weld that will ensure that at least a portion of each process has been included in full size test specimens. As an alternative, additional test welds can be made with each process so that full size specimens can be tested for each process.

Coupons Representing the Weld Deposits

Impact test specimens and testing methods shall conform to WC-2321. The impact specimen shall be located so that the longitudinal axis of the specimen is at least \( \frac{1}{4} t \) and, where the thickness of the test assembly permits, not less than \( \frac{3}{8} \) in. (10 mm) from the weld surface of the test assembly. In addition, when the postweld heat treatment temperature exceeds the maximum temperature specified in WC-4620, and the test assembly is cooled at an accelerated rate, the longitudinal axis of the specimen shall be a minimum of \( t \) from the edge of the test assembly. The specimen shall be transverse to the longitudinal axis of the weld with the area of the notch located in the weld. The length of the notch of the Charpy V-notch specimen shall be normal to the surface of the weld. Where drop weight specimens are required, the tension surface of the specimen shall be oriented parallel to the surface of the test assembly.

Coupons Representing the Heat-Affected Zone

Where impact tests of the heat-affected zone are required by WC-4335.2, specimens shall be taken from the welding procedure qualification test assemblies in accordance with (a) through (c) below.

(a) If the qualification test material is in the form of a plate or a forging, the axis of the weld shall be oriented either parallel to or perpendicular to the principal direction of rolling or forging.

(b) The heat-affected zone impact test specimens and testing methods shall conform to the requirements of WC-2321.2. The specimens shall be removed from a location as near as practical to a depth midway between the surface and center thickness. The coupons for heat-affected zone impact specimens shall be taken transverse to the axis of the weld and etched to define the heat-affected zone. 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 heat-affected zone as possible in the resulting fracture. Where the material thickness permits, the axis of a specimen may be inclined to allow the root of the notch to align parallel to the fusion line. When a grain refining heat treatment is not performed on welds made by the electroslag or electrogas welding process, the notch for the impact specimens shall be located in the grain coarsened region.

(c) For the comparison of heat-affected zone values with base material values [WC-4335.2(b)], Charpy V-notch specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material. When required by WC-2330, drop weight specimens shall be removed from a depth as near as practical to midway between the surface and center thickness of the unaffected base material and shall be tested in accordance with the requirements of WC-2321.

Impact Test Requirements

When materials are required to be impact tested per WC-2300, impact tests of the weld metal and heat-affected zone shall be performed in accordance with the following subparagraphs. The weld procedure qualification impact test specimens shall be prepared and tested in accordance with the applicable requirements of WC-2332.1 and WC-4334. Retests in accordance with the provisions of WC-2350 are permitted.

Impact Tests of the Weld Metal

(a) Impact tests of the weld metal shall be required for welding procedure qualification tests for production weld joints exceeding \( \frac{5}{16} \) in. (16 mm) in thickness when the weld will be made on the surface or will penetrate the base material that requires impact testing in accordance with WC-2310. In addition, such testing of the weld metal is required for the welding procedure qualification tests for any weld repair to base material that requires impact testing in accordance with WC-2310, regardless of the depth of the repair.

(b) The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in WC-2330 for the base material to be welded or repaired. Where two materials are to be joined by welding and have different fracture toughness requirements, the test requirements and acceptance standards of either material may be used for the weld metal.

(c) A Welding Procedure Specification qualified to the impact testing requirements of Subsection WB, NB, or NE may be accepted as an alternative to the Welding Procedure Specification impact testing requirements of this Subsection.
WC-4335.2 Impact Tests of Heat-Affected Zone.

(a) Charpy V-notch tests of the heat-affected zone of the welding procedure qualification test assembly are required whenever the thickness of the weld exceeds \( \frac{\sqrt{2}}{6} \) in. (16 mm) and either of the base materials require impact testing in accordance with the rules of WC-2310. Exemption of base materials by WC-2311(a)(7) does not apply to the welding procedure qualification heat-affected zone or unaffected base material for such materials. The only exceptions to the requirements are the following:

(1) the qualification for welds in P-Nos. 1 and 3 materials that are postweld heat treated and are made by any process other than electroslag, electrogas, or thermit;

(2) the qualification for weld deposit cladding or hardfacing on any base material.

(3) The portion of the heat-affected zone associated with GTAW root deposits with a maximum of two layers or \( \frac{\sqrt{2}}{6} \) in. (5 mm) thickness, whichever is less.

(b) Charpy V-notch testing shall be performed as specified in (1) through (6).

(1) Charpy V-notch test specimens representing both the heat-affected zone and the unaffected base material shall be tested. The unaffected base material shall be tested at a temperature equal to or below the LST.

(2) The Charpy V-notch test specimens of the unaffected base material shall meet the applicable requirements of Table WC-2332.1-1 or Table WC-2332.1-2, as applicable, or additional testing shall be performed at higher temperatures until either of the above requirements are met.

(3) The heat-affected zone specimens shall be tested at the test temperature determined in (2). The average applicable toughness values of the heat-affected zone specimens shall equal or exceed the average applicable toughness values of the unaffected base material specimens, or the adjustment given in (4) through (6) shall be made. Alternatively, another test coupon may be welded and tested.

(4) Additional Charpy V-notch tests shall be performed on either the heat-affected zone or the unaffected base material, or both, at temperatures where the applicable toughness values of all three specimens tested is not less than that specified in (2). The applicable average toughness values for each test meeting this requirement shall be plotted on an applicable toughness value versus temperature graph. The difference in temperature \( T_{HAZ} \) and \( T_{UBM} \) where the heat-affected zone and the unaffected base material applicable average toughness values are the same and not less than that specified in (2) shall be used to determine the adjustment temperature \( T_{ADJ} \) where:

\[
T_{ADJ} = T_{HAZ} - T_{UBM}
\]

If \( T_{ADJ} \leq 0 \), then \( T_{ADJ} = 0 \).

(5) As an alternative to (4), if the applicable toughness values of the heat-affected zone specimens is no less than the values specified in Table WC-2332.1-1 or Table WC-2332.1-2, as applicable, and the average of the heat-affected zone specimens is not less than 7 ft-lb (10 J) or 5 mils (0.13 mm) below the average applicable toughness values of the unaffected base material, \( T_{ADJ} \) may be taken as 15°F (–8°C).

(6) As a second alternative to (4), if the applicable toughness values of the heat-affected zone specimens are no less than the values specified in Table WC-2332.1-1 or Table WC-2332.1-2, as applicable, the difference between the average applicable toughness values of the heat-affected zone and the unaffected base material shall be calculated and used as described in (c)(3).

(c) At least one of the following methods shall be used to compensate for the heat-affected zone toughness decrease due to the welding procedure:

(1) The LST specified in the Design Specification for all of the material to be welded in production welding procedure specifications (WPS) supported by this procedure qualification record (PQR) shall be increased by the adjustment temperature \( T_{ADJ} \).

(2) The specified testing temperature for the production material may be reduced by \( T_{ADJ} \).

(3) The materials to be welded may be welded using the WPS provided they exhibit toughness values that are no less than the minimum required toughness values required by WC-2300 plus the difference in the average toughness values established in (b)(6).

(d) The Charpy V-notch testing results shall be recorded on the PQR and any offsetting \( T_{ADJ} \) or increased toughness requirements on the production material on which welding is to be performed shall be noted on the PQR and WPS. More than one compensation method may be used on a par basis.

(e) A WPS qualified to the impact testing requirements of Subsection WB, NB, or NE may be accepted as an alternative to the WPS impact testing requirements of this Subsection.

WC-4336 Qualification Requirements for Built-Up Weld Deposits

Built-up weld deposits for base metal reinforcement shall be qualified in accordance with the requirements of WC-4331 to WC-4335, inclusive.
WD-4333  Heat Treatment of Qualification Welds for Ferritic Material

Postweld heat treatment of procedure qualification welds shall conform to the applicable requirements of WD-4600 and Section IX. The postweld heat treatment time at temperature shall be at least 80% of the maximum time to be applied to the weld material. The postweld heat treatment total time may be applied in one heating cycle.

WD-4334  Preparation of Test Coupons and Specimens

(a) Removal of test coupons from the test weld and the dimensions of specimens made from them shall conform to the requirements of Section IX, except that the removal of impact test coupons and the dimensions of impact test specimens shall be in accordance with (b) below.

(b) Weld deposit of each process in a multiple process weld shall, where possible, be included in the impact test specimens. When each process cannot be included in the full-size impact test specimen at the $\frac{1}{4}t$ location required by this Subsection, additional full-size specimens shall be obtained from locations in the test weld that will ensure that at least a portion of each process has been included in full-size test specimens. As an alternative, additional test welds can be made with each process so that full-size specimens can be tested for each process.

WD-4334.1  Coupons Representing the Weld Deposits. Impact test specimens and testing methods shall conform to WD-2321. The impact specimen shall be located so that the longitudinal axis of the specimen is at least $\frac{1}{4}t$ and, where the thickness of the test assembly permits, not less than $\frac{3}{8}$ in. (10 mm) from the weld surface of the test assembly. In addition, when the postweld heat treatment temperature exceeds the maximum temperature specified in WD-4620 and the test assembly is cooled at an accelerated rate, the longitudinal axis of the specimen shall be a minimum of $t$ from the edge of the test assembly. The specimen shall be transverse to the longitudinal axis of the weld with the area of the notch located in the weld. The length of the notch of the $C_v$ specimen shall be normal to the surface of the weld. Where drop weight specimens are required, the tension surface of the specimen shall be oriented parallel to the surface of the test assembly.

WD-4334.2  Coupons Representing the Heat-Affected Zone. When impact tests of the heat-affected zone are required by WD-4335.2, specimens shall be taken from the welding procedure qualification test assemblies in accordance with (a) through (c) below.

(a) If the qualification test material is in the form of a plate or a forging, the axis of the weld shall be oriented in the direction parallel to the principal direction of rolling or forging.

(b) The heat-affected zone impact test specimens and testing methods shall conform to the requirements of WD-2321.2. The specimens shall be removed from a location as near as practical to a depth midway between the surface and center thickness. The coupons for heat-affected zone impact specimens shall be taken transverse to the axis of the weld and etched to define the heat-affected zone. The notch of the $C_v$ specimen shall be cut approximately normal to the material surface in such a manner as to include as much heat-affected zone as possible in the resulting fracture. Where the material thickness permits, the axis of a specimen may be inclined to allow the root of the notch to align parallel to the fusion line.

(c) For the comparison of heat-affected zone values with base material values [WD-4335.2(b)], $C_v$ specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material. When required by WD-4335.2(b), drop weight specimens shall be removed from a depth as near as practical to midway between the surface and center thickness of the unaffected base material and shall be tested in accordance with the requirements of WD-2321.1.

WD-4335  Impact Test Requirements

When materials are required to be impact tested per WD-2300, impact tests of the weld metal and heat-affected zone shall be performed in accordance with the following subparagraphs. The weld procedure qualification impact test specimens shall be prepared and tested in accordance with the applicable requirements of WD-2330 and WD-4334. Retests in accordance with the provisions of WD-2350 shall be permitted.

WD-4335.1  Impact Tests of Weld Metal.

(a) Impact tests of the weld metal shall be required for welding procedure qualification tests for production weld joints exceeding $\frac{5}{8}$ in. (16 mm) in thickness when the weld will be made on the surface or will penetrate the base material that requires impact testing in accordance with WD-2310. In addition, such testing of the weld metal shall be required for the welding procedure qualification tests for any weld repair to base material that requires impact testing in accordance with WD-2310, regardless of the depth of the repair. Exemption from impact testing under WD-2311(a) shall not apply to weld metal of welding procedure qualification tests for either production weld joints or base metal repairs unless the specific weld metal used is A-No. 8.

(b) The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in WD-2330 for the base material to be welded or repaired. Where two materials are to be joined by welding and have different fracture toughness requirements, the test requirements and
acceptance standards of either material may be used for the weld metal except where otherwise specified in the Design Specification.

(c) A Welding Procedure Specification qualified to the impact testing requirements of Subsection WB, WC, NB, NC, or NE may be accepted as an alternative to the Welding Procedure Specification impact testing requirements of this Subsection.

WD-4335.2 Impact Tests of Heat-Affected Zone.

(a) Cv tests of the heat-affected zone of the welding procedure qualification test assembly are required whenever the thickness of the weld exceeds $\frac{5}{6}$ in. (16 mm) and either of the base materials requires impact testing in accordance with the rules of WD-2310. The only exceptions to the requirements are the following:

(1) the qualification for welds in P-Nos. 1 and 3 and SA-336 F12 materials that are postweld heat treated and are made by any process other than thermit;

(2) the qualification for weld deposit cladding or hard-facing on any base material;

(3) that portion of the heat-affected zone associated with GTAW root deposits with a maximum of two layers or $\frac{7}{16}$ in. (5 mm) thickness, whichever is less.

(b) The required testing shall be in accordance with (c) below for base material tested under WD-2332 and in accordance with (d) below for base material tested under WD-2331.

(c) For heat-affected zones associated with base material tested under WD-2332, the required testing shall be in accordance with (1) through (7) below.

(1) Determine the $T_{NDT}$ of the unaffected base material to be used in the welding procedure qualification test assembly.

(2) $C_v$ specimens representing both the heat-affected zone and the unaffected base material shall be tested at the ($T_{NDT} + 60^\circ$F) ($T_{NDT} + 33^\circ$C) temperature.

(3) The $C_v$ tests of the unaffected base material shall meet the applicable requirements of WD-2332 or additional testing shall be performed at higher temperatures until the requirements of WD-2332 are met.

(4) The heat-affected zone specimens shall be tested at the test temperature determined in (3) above. If the average lateral expansion value of the specimens equals or exceeds the average lateral expansion value of the unaffected base material, the qualification test shall be acceptable for the essential and supplemental essential variables recorded on the Welding Procedure Qualification Record. If the heat-affected zone average lateral expansion value is less than the unaffected base material average lateral expansion value, the adjustment given in (5) through (7) below shall be determined and applied as provided in (e) below. Alternatively, another test coupon may be welded and tested.

(5) Additional $C_v$ tests shall be performed on either the heat-affected zone or the unaffected base material, or both, at temperatures where the lateral expansion value of all three specimens tested is not less than 35 mils (0.89 mm). The average lateral expansion value for each test meeting this requirement shall be plotted on a lateral expansion versus temperature graph. The difference in temperature between $T_{HAZ}$ and $T_{UBM}$, where the heat-affected zone and the unaffected base material average lateral expansion values are the same and not less than 35 mils (0.89 mm), shall be used to determine the adjustment temperature $T_{ADJ}$, where

$$T_{ADJ} = T_{HAZ} - T_{UBM}$$

If $T_{ADJ} \leq 0$, then $T_{ADJ} = 0$.

(6) As an alternative to (5) above, if the average lateral expansion value of the heat-affected zone specimens is no less than 35 mils (0.89 mm) and the average of the heat-affected zone specimens is not less than 5 mils (0.13 mm) below the average lateral expansion value of the unaffected base material specimens, $T_{ADJ}$ may be taken as $15^\circ$F ($8^\circ$C).

(7) As a second alternative to (5) above, if the average lateral expansion value of the heat-affected zone specimens is no less than 35 mils (0.89 mm), the difference between the average lateral expansion of the heat-affected zone and the unaffected base material specimens shall be calculated and used as described in (e)(3) below.

(d) For heat-affected zones associated with base materials tested under WD-2331, the required testing shall be in accordance with (1) through (5) below.

(1) Three $C_v$ specimens shall be removed from both the unaffected base material and the heat-affected zone. The unaffected base material specimens shall be tested at the LST established in the Design Specification or additional testing shall be performed at higher temperatures until the applicable requirements of Table WD-2331(a)-1 are met for the thickness of material to be welded in production.

(2) The heat-affected zone specimens shall be tested at the test temperature determined in (1) above. If the average lateral expansion value of the specimens equals or exceeds the average lateral expansion value of the unaffected base material, the qualification test shall be acceptable for the essential and supplemental essential variables recorded on the Welding Procedure Qualification Record. If the heat-affected zone average lateral expansion value is less than the unaffected base material lateral expansion value, the adjustment given in (3) through (5) below shall be determined and applied as provided in (e) below. Alternatively, another test coupon may be welded and tested.

(3) Additional $C_v$ tests shall be performed on either the heat-affected zone or the unaffected base material, or both, at temperatures where the lateral expansion value of all three specimens tested is not less than the values shown in Table WD-2331(a)-1 for the thickness of base material to be welded in production. The average lateral expansion value for each test meeting this requirement
shall be plotted on a lateral expansion versus temperature graph. The difference in temperature between $T_{HAZ}$ and $T_{UBM}$, where the heat-affected zone and the unaffected base material average lateral expansion values are the same and not less than that specified in (2) above, shall be used to determine the adjustment temperature $T_{ADJ}$, where

$$T_{ADJ} = T_{HAZ} - T_{UBM}$$

If $T_{ADJ} \leq 0$, then $T_{ADJ} = 0$.

(4) As an alternative to (3) above, if the average lateral expansion value of the heat-affected zone is no less than 35 mils (0.89 mm) and the average of the heat-affected zone specimens is not less than 5 mils (0.13 mm) below the average lateral expansion value of the unaffected base material, $T_{ADJ}$ may be taken as 15°F (8°C).

(5) As a second alternative to (3) above, if the average lateral expansion value of the heat-affected zone specimens is no less than 35 mils (0.89 mm), the difference between the average lateral expansion of the heat-affected zone and the unaffected base material specimens shall be calculated and used as described in (e)(3) below.

(e) At least one of the following methods shall be used to compensate for the heat-affected zone toughness decrease due to the welding procedure effects:

(1) The $RT_{NDT}$ temperature established in WD-2332 or the LST specified in the Design Specification (WD-2331) for all of the material to be welded in production Welding Procedure Specifications supported by this Welding Procedure Qualification Record shall be increased by the adjustment temperature $T_{ADJ}$.

(2) The specified testing temperature for the production material may be reduced by $T_{ADJ}$.

(3) The materials to be welded may be welded using the Welding Procedure Specification provided they exhibit $C_v$ values that are no less than the minimum required lateral expansion value required by WD-2300 plus the difference in average lateral expansion values established in (e)(7) or (d)(5) above.

(4) The $C_v$ testing results shall be recorded on the Welding Procedure Qualification Record and any offsetting $T_{ADJ}$ or increased toughness requirements shall be noted on the Welding Procedure Qualification Record and on the Welding Procedure Specification. More than one compensation method may be documented on the Welding Procedure Qualification Record.

(g) A Welding Procedure Specification qualified to the impact testing requirements of Subsection WB, WC, NB, NC, or NE may be accepted as an alternative to the Welding Procedure impact testing requirements of this Division.