center thickness of the unaffected base material and shall be tested in accordance with the requirements of NC-2321.1.

NC-4335  Impact Test Requirements

When materials are required to be impact tested per NC-2300, impact tests of the weld metal and heat-affected zone shall be performed in accordance with the following subparagraphs. Exemption from impact testing under NC-2311(a)(8) does not apply to weld metal unless the specific weld metal used is included in Table NC-2311(a)-1. Exemption from impact testing of the heat-affected zone of those base materials exempted by NC-2311(a)(8) is not permitted. The weld procedure qualification impact test specimens shall be prepared and tested in accordance with the applicable requirements of NC-2330 and NC-4334. Retests in accordance with the provisions of NC-2350 are permitted.

NC-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 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 NC-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 NC-2310, regardless of the depth of the repair. Exemption from impact testing under NC-2311(a)(8) does not apply to weld metal of welding procedure qualification tests for either production weld joints or base material repairs unless the specific weld metal used is included in Table NC-2311(a)-1.

(b) The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in NC-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 by NCA-1280 or other parts of this Section.

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

NC-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 5/8 in. (16 mm) and either of the base materials require impact testing in accordance with the rules of NC-2310. Exemption of base materials by NC-2311(a)(8) does not apply to the welding procedure qualification of 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-No. 1 and 3 and SA-336 F12 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 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 3/16 in. (5 mm) thickness, whichever is less.
4. Charpy V-notch testing shall be performed as specified in (1) through (6).
5. Charpy V-notch test specimens representing both the heat-affected zone and the unaffected base material specimens shall be tested. The unaffected base material shall be tested at a temperature equal to or below the lowest service temperature.
6. The Charpy V-notch tests of the unaffected base material shall meet the applicable requirements of Table NC-2332.1-1 or Table NC-2332.1-2, as applicable, or additional testing shall be performed at higher temperatures until either of the above requirements are met.
7. 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.
8. 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 are not less than that specified in (2). The average applicable 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 are not less than that specified in Table NC-2332.1-1 or Table NC-2332.1-2, as applicable, and the average of the heat-affected zone specimens is not less than 7 ft-lb (10 N·m) 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 (−9°C).
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 [ND-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.

**ND-4335 Impact Test Requirements**

When materials are required to be impact tested per ND-2300, impact tests of the weld metal and heat-affected zone shall be performed in accordance with the following subparagraphs. Exemption from impact testing under ND-2311(a)(8) does not apply to weld metal unless the specific weld metal used is included in Table ND-2331(a)-1. Exemption from impact testing of the heat-affected zone of those base materials exempted by ND-2311(a)(8) is not permitted. The weld procedure qualification impact test specimens shall be prepared and tested in accordance with the applicable requirements of ND-2330 and ND-4334. Retests in accordance with the provisions of ND-2350 are permitted.

(19) **ND-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 \( \frac{3}{8} \) 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 ND-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 ND-2310. Exemption from impact testing of the weld metal qualification tests for either production weld joints or base material repairs unless the specific weld metal used is included in Table ND-2311(a)(8).

(b) The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in ND-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 by NCA-1280 or other parts of this Section.

(c) A Welding Procedure Specification qualified to the impact testing requirements of Subsection NB, NC, or NE may be accepted as an alternative to the Welding Procedure Specification impact testing requirements of this Subsection. Use of this alternative shall be identified on the Welding Procedure Qualification Record.

**ND-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 \( \frac{3}{8} \) in. (16 mm) and either of the base materials require impact testing in accordance with the rules of ND-2310. Exemption of base materials by ND-2311(a)(8) 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-No. 1 and 3 and SA-336 F12 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 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 of \( \frac{3}{16} \) 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 specimens shall be tested at a temperature equal to or below the lowest service temperature.
2. The Charpy V-notch tests of the unaffected base material shall meet the applicable requirements of Table ND-2331(a)-1 or Table ND-2331(a)-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 applicable average toughness values of the heat-affected zone specimens shall equal or exceed the applicable average 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 are not less than that specified in (2). The applicable average toughness values of the heat-affected zone shall equal or exceed the applicable average toughness values of the unaffected base material specimens, or the adjustment given in (4) through (6) shall be made.
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 are no less than the values specified in Table ND-2331(a)-1 or Table ND-2331(a)-2, as applicable, and the average of the heat-affected zone specimens is not less than 7 ft-lb (10 N·m) or 5 mils (0.13 mm) below the average applicable toughness values of the unaffected base material, $T_{ADJ}$ may be taken as $15\degree F (-9\degree C)$.

(6) As a second alternative to (4), if the applicable toughness values of the heat-affected zone are no less than the values specified in Table ND-2331(a)-1 or Table ND-2331(a)-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) below.

(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 lowest service temperature specified in the Design Specification for all material to be welded in production WPSs supported by this 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 that they exhibit toughness values that are no less than the minimum required toughness value specified in ND-2300 plus the difference in applicable 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 shall be noted on the PQR and on the WPS. More than one compensation method may be used on a par basis.

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

ND-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 ND-4331 to ND-4335, inclusive.

ND-4350 SPECIAL QUALIFICATION REQUIREMENTS FOR TUBE-TO-TUBESHEET WELDS

The welding procedure for tube-to-tubesheet welds shall be qualified in accordance with the ASME Section IX, QW-202.6 using a demonstration mockup in accordance with Section IX, QW-193. The weld throat (minimum leakage path) shall be not less than two-thirds of the tube wall thickness. Welders and welding procedures shall be qualified by demonstration mockup practice with Section IX, QW-303.5.

ND-4400 RULES GOVERNING MAKING, EXAMINING, AND REPAIRING WELDS

ND-4410 PRECAUTIONS TO BE TAKEN BEFORE WELDING

ND-4411 Identification, Storage, and Handling of Welding Materials

Each Certificate Holder is responsible for control of the welding electrodes and other materials that are used in the fabrication and installation of components (ND-4120). Suitable identification, storage, and handling of electrodes, flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by electrodes and flux.

ND-4412 Cleanliness and Protection of Welding Surfaces

The method used to prepare the base metal shall leave the weld preparation with reasonably smooth surfaces. The surfaces for welding shall be free of scale, rust, oil, grease, and other deleterious material. The work shall be protected from deleterious contamination and from rain, snow, and wind during welding. Welding shall not be performed on wet surfaces.

ND-4420 RULES FOR MAKING WELDED JOINTS

ND-4421 Backing Rings

Backing rings that remain in place may be used for piping in accordance with the requirements of ND-3661.2. The materials for backing rings shall be compatible with the base metal, but spacer pins shall not be incorporated into the weld.

ND-4422 Backup Plates, Backing Rings, and Compression Rings or Stiffeners for Storage Tanks

Backup plates and backing rings that remain in place and compression rings or stiffeners of storage tanks, such as angles, bars, and ring girders, may be used. The materials used for such backup plates, backing rings, and
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 $\frac{5}{16}$ 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-NE or NE materials that are postweld heat treated and any process other than electroslag, electron beam, or laser beam welding shall be noted on the procedure specifications (WPS) supported by this procedure qualification record (PQR) and any offsetting toughness requirements on the production material may be reduced by ADJ.

2. The qualification for weld deposit cladding or hardfacing on any base material.

3. That portion of the heat-affected zone associated with GTAW root deposits with a maximum of two layers or $\frac{5}{16}$ 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 tests 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, NC, 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.