Article NCD-2000
Material

NC-NCD-2100 General Requirements for Material

NC-NCD-2110 Scope of Principal Terms Employed

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

(b) The term pressure-retaining materials as used in this Subsection applies to vessel shells, heads, and nozzles; pipes, tubes, and fittings; valve bodies, bonnets, and disks; pump casings and covers; and bolting that joins pressure-retaining items.

(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 ≤ 2 in. (50 mm), the axial length is the nominal thickness. For axial length > 2 in. (50 mm), the radial thickness is the nominal thickness.
(-d) **rectangular solid forgings**: the least rectangular dimension is the nominal thickness.

(3) **Castings**

(-a) Thickness $t$ for fracture toughness testing is defined as the nominal pipe wall thickness of the connecting piping.

(-b) Thickness $t$ for heat treatment purposes is defined as the thickness of the pressure-retaining wall of the casting excluding flanges and sections designated by the designer as nonpressure retaining.

**NC-NCD-2120 Pressure-Retaining Material**

**NC-NCD-2121 Permitted Material Specifications**

(a) Pressure-retaining material shall conform to the requirements of one of the specifications for materials given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, including all applicable notes in the tables, 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 pressure-retaining function shall be pressure-retaining material. For vessels that are designed in accordance with NC-D-3200, the materials shall be restricted to those materials listed in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4, including all applicable notes in the tables, and to the following clad product specifications, provided they are composed of materials listed in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4:

1. SA-263, Specification for Corrosion-Resisting Chromium-Steel Clad Plate, Sheet, and Strip
2. SA-264, Specification for Corrosion-Resisting Chromium-Nickel Steel Clad Plate, Sheet, and Strip
3. SA-265, Specification for Nickel and Nickel-Base Alloy Clad Steel Plate

(b) The requirements of this Article do not apply to material for items not associated with the pressure-retaining function of a component such as shafts, stems, trim, spray nozzles, bearings, bushings, springs, wear plates, nor to seals, packing, gaskets, valve seats, and ceramic insulating materials and special alloys used as seal materials in electrical penetration assemblies.

(c) Material made to specifications other than those specified in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 may be used for the following applications:

1. **safety valve disks and nozzles** — when the nozzles are internally contained by the external body structure
2. **control valve disks and cages** — when the valves function for flow control only
3. **line valve disks in valves** — whose inlet connections are NPS 2 (DN 50) and smaller
(d) Material for line fittings and valves, 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, the valves meet the requirements of NC-3500, and the material is determined to be adequate for the service conditions by the piping system designer for fittings.

(e) 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.

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

NC-NCD-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 NC-2500. Any examination, repair, test, or treatment required by the material specification or by this Article may be performed by the Material Organization or the Certificate Holder as provided in NC-4121. Any hydrostatic or pneumatic pressure test required by a material specification need not be performed, provided the material is identified as not having been pressure tested and it is subsequently pressure tested in accordance with NC-6114, except where the location of the material in the component or the installation would prevent performing any nondestructive examination required by the material specification to be performed subsequent to the hydrostatic or pneumatic test.

(a) The stress rupture test of SA-453 and SA-638 for Grade 660 (UNS S66286) is not required for design temperatures of 800°F (427°C) and below.

(b) In addition to tension testing required by the material specification, forgings produced for flat heads and tubesheets with integrally forged hubs, for butt welding to the adjacent shell, head, or other pressure part, shall have tensile tests performed in accordance with NC-4243. The tension test specimen shall be located in accordance with NC-4243.1 and Figure NC-NCD-4243.1-1.

NC-NCD-2124 Material Size Ranges and Tolerances

(a) Material outside the limits of size or thickness given in any specification in Section II may be used if the material is in compliance with the other requirements of the specification and no size limitation is given in this Subsection. In those specifications in which chemical composition or mechanical properties are indicated to vary with size or thickness, any material outside the specification range shall be required to conform to the composition and mechanical properties shown for the nearest specified range (NCA-4256).

(b) Plate material shall be ordered not thinner than the design thickness. Components, except for piping, made of plate furnished with an undertolerance of not more than the lesser value of 0.01 in. (0.25 mm) or 6% of the ordered thickness, may be used at the full design pressure for the thickness ordered. If the specification to which the plate is ordered allows a greater undertolerance, the ordered
thickness of the material shall be sufficiently greater than the design thickness so that the thickness of
the material furnished is not more than the lesser of 0.01 in. (0.25 mm) or 6% under the design
thickness.

(c) If pipe or tube is ordered by its nominal wall thickness, the manufacturing undertolerance on wall
thickness shall be taken into account. The manufacturing undertolerances are given in the several pipe
and tube specifications listed in the applicable Tables in Section II, Part D, Subpart 1. After the
minimum wall thickness is determined \([\text{NC-NCD-3641.1}]\), it shall be increased by an amount sufficient to
provide for the manufacturing undertolerance allowed in the pipe or tube specification.

### NC-NCD-2125 Material in Combination 1

A component may be constructed of any combination of materials permitted in Article NC-NCD-2000,
provided the applicable rules are followed and the requirements of Section IX for welding dissimilar
metals are met.

### NC-NCD-2126 Finned Tubes

#### NC-NCD-2126.1 Integrally Finned Tubes.

Integrally finned tubes may be made from tubes that conform to one of the specifications for tubes listed
in Section II, Part D, Subpart 1, Tables 1A and 1B and to all of the special requirements of this Article
that apply to that product form. In addition, the following requirements shall apply:

(a) The requirements of \([\text{NC-NCD-2550}]\) shall be met by the tube before finning.

(b) The tubes after finning shall conform to the applicable heat treatment requirements of the basic
material specification.

(c) The allowable stress values shall be those given in Section II, Part D, Subpart 1, Tables 1A and 1B
for the tube material from which the finned tube is made.

(d) After finning, each tube shall be subjected to one of the following tests:

1. an internal pneumatic pressure test at not less than 250 psi (1.7 MPa) without evidence of
   leakage; the test method, such as immersion of the tube under water during the test, shall
   permit visual detection of any leakage;

2. an individual tube hydrostatic test at 1.25 times the Design Pressure that permits complete
   examination of the tube for leakage.

(e) A visual examination shall be performed after finning. Material having discontinuities, such as
laps, seams, or cracks, is unacceptable. The visual examination personnel shall be trained and
qualified in accordance with the Material Organization’s Quality System Program or the Certificate
Holder’s Quality Assurance Program. These examinations are not required to be performed either in
accordance with procedures qualified to \([\text{NC-NCD-5100}]\) or by personnel qualified in accordance with
\([\text{NC-NCD-5500}]\).
**NC-NCD-2126.2 Welded Finned Tubes.**

Welded finned tubes may be made from P-No. 1 and P-No. 8 tubular products (pipe or tubing) that conform to one of the specifications for tubes listed in Section II, Part D, Subpart 1, Table 1A, and to all of the special requirements of this Article which apply to that product form. Heat transfer fins shall be of the same P-Number as the tube and shall be attached by a machine welding process, such as the electric resistance welding or the high frequency resistance welding process. In addition, the following requirements shall apply:

(a) The heat transfer fins need not be certified material. The material for the heat transfer fins shall be identified and suitable for welding; however, Certified Material Test Reports are not required.

(b) The machine welding process used to weld the heat transfer fins to the tubular material shall be performed in accordance with a Welding Procedure Specification.

(c) The procedure qualification shall require that a minimum of 12 cross-sections through the weld zone shall be examined at 5× minimum magnification. There shall be no cracks in the base material or weld; and the weld penetration shall be limited to 20% of the nominal tube wall thickness.

(d) For P-No. 1 material, the weld that attaches the fins to the tubing shall be heat treated after welding to a minimum temperature of 1,000°F (540 °C).

(e) The fin is not considered to provide any support to the tube under pressure loading.

**NC-NCD-2128 Bolting Material**

(a) Material for bolts and studs shall conform to the requirements of one of the specifications listed in Section II, Part D, Subpart 1, Table 3. Material for nuts shall conform to SA-194 or to the requirements of one of the specifications for nuts or bolting listed in Section II, Part D, Subpart 1, Table 3. Refer to Section II, Part D, Subpart 1, Table 4 for bolting material for vessels designed to the requirements of NC-D-3200.

(b) The use of washers is optional. When used, they shall be made of wrought material with mechanical properties compatible with the nuts with which they are to be employed.

**NC-NCD-2130 Certification of Material**

**NCD-2130.1 For Class 2 Components** (note to editors: text came from NC-2130)

All materials used in the construction of components shall be certified as required in NCA-3862 and NCA-3861. Certified Material Test Reports are required for pressure-retaining material except as provided by NCA-3861. A Certificate of Compliance may be provided in lieu of a Certified Material Test Report for all other material. Copies of all Certified Material Test Reports and Certificates of Compliance applicable to material used in a component shall be furnished with the material.

**NCD-2130.2 For Class 3 Components** (note to editors: text came from ND-2130)

All materials used in the construction of components shall be certified as required in NCA-3862 and NCA-3861. Certified Material Test Reports are required for pressure-retaining material, except as
provided by NCA-3861, and for small products as defined in NCD-2610(c). A Certificate of Compliance may be provided in lieu of a Certified Material Test Report for all other material. Copies of all Certified Material Test Reports and Certificates of Compliance applicable to material used in a component shall be furnished with the material.

**NC-NCD-2140 Welding Materials**

For the requirements governing the materials to be used for welding, see NC D-2400.

**NC-NCD-2150 Material Identification**

NCD-2150.1 For Class 2 Components (note to editors: text came from NC-2150)

The identification of pressure-retaining material shall meet the requirements of NCA-4256. Material for small items shall be controlled during manufacture and installation of the component so that they are identifiable as acceptable material at all times. Welding and brazing materials shall be controlled during the repair of material and the manufacture and installation so that they are identifiable as acceptable until the material is actually consumed in the process (NCD-4122).

NCD-2150.2 For Class 3 Components (note to editors: text came from ND-2150)

All material shall be marked in accordance with the marking requirements of the material specification. Material for small items shall be controlled during manufacture and installation of the component so that they are identifiable as acceptable material at all times. Welding and brazing material shall be controlled during the repair of material and the manufacture and installation so that they are identifiable as acceptable until the material is actually consumed in the process (NCD-4122).

**NC-NCD-2160 Deterioration of Material in Service**

Consideration of deterioration of material caused by service is generally outside the scope of this Subsection. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (NCA-3250), with specific attention being given to the effects of service conditions upon the properties of the material.

**NC-NCD-2170 Heat Treatment to Enhance Impact Properties**

Carbon steels, low alloy steels, and high alloy chromium (Series 4XX) steels may be heat treated by quenching and tempering to enhance their impact properties. Postweld heat treatment of the component at a temperature of not less than 1,100°F (595°C) may be considered to be the tempering phase of the heat treatment.
NC-NCD-2180 Procedures for Heat Treatment of Material

When heat treating temperature or time is required by the material specification and the rules of this Subsection, the heat treating shall be performed in temperature-surveyed and temperature-calibrated furnaces or the heat treating shall be controlled by measurement of material temperature by thermocouples in contact with the material or attached to blocks in contact with the material or by calibrated pyrometric instruments. Heat treating shall be performed under furnace loading conditions such that the heat treatment is in accordance with the material specification and the rules of this Subsection.

NC-NCD-2190 Non-Pressure-Retaining Material

(a) Material in the component support load path and not performing a pressure-retaining function (see NC-D-1130) welded to pressure-retaining material shall meet the requirements of Article NF-2000.

(b) Material not performing a pressure-retaining function and not in the component support load path (nonstructural attachments) welded at or within 2t of the pressure-retaining portion of the component need not comply with Article NC-D-2000 or Article NF-2000 provided the requirements of NC-D-4430 are met.

(c) Structural steel rolled shapes, which are permitted by this Subsection to be furnished with a Certificate of Compliance, may be repaired by welding using the welders, documentation, and examination requirements specified in SA-6.

NC-NCD-2200 Material Test Coupons and Specimens for Ferritic Steel Material

NC-NCD-2210 Heat Treatment Requirements

NC-NCD-2211 Test Coupon Heat Treatment for Ferritic Material

Where ferritic steel material is subjected to heat treatment during fabrication or installation of a component, the material used for the tensile and impact test specimens shall be heat treated in the same manner as the component, except that test coupons and specimens for P-No. 1 Group Nos. 1 and 2 material with a nominal thickness of 2 in. (50 mm) or less are not required to be so heat treated where nominal thickness for flanges refers to the wall thickness at the weld joint to the pipe or component. The Certificate Holder shall provide the Material Organization with the temperature and heating and cooling rate to be used. In the case of postweld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80% of the total time at temperature or temperatures during actual postweld heat treatment of the material, and the total time at temperature or temperatures for the test material, coupon, or specimen may be performed in a single cycle.

NC-NCD-2212 Test Coupon Heat Treatment for Quenched and Tempered Material

NC-NCD-2212.1 Cooling Rates.

Where ferritic steel material is subjected to quenching from the austenitizing temperature, the test coupons representing those materials shall be cooled at a rate similar to and no faster than the rate at which the main body of the material was cooled, except in the case of certain forgings and castings (NC-2223.1.3 for Class 2, NC-2223.2.3 for Class 3, and NC-2226). This rule shall apply for coupons taken directly from the material as well as
for separate test coupons representing the material, and one of the general procedures described in NCD-2212.2 or one of the specific procedures described in NCD-2220 shall be used for each product form.

**NC-NCD-2212.2 General Procedures.**

One of the general procedures in (a), (b), and (c) below may be applied to quenched and tempered material or test coupons representing the material, provided the specimens are taken relative to the surface of the product in accordance with NCD-2220. Further specific details of the methods to be used shall be the obligation of the Material Organization and the Certificate Holder.

(a) Any procedure may be used which can be demonstrated to produce a cooling rate in the test material that matches the cooling rate of the main body of the product at the region midway between midthickness and the surface \((\frac{1}{4}t)\) and no nearer any heat-treated edge than a distance equal to the nominal thickness \(t\) being quenched within \(25^\circ F\) \((14 ^\circ C)\) and 20 sec at all temperatures after cooling begins from the austenitizing temperature.

(b) If cooling rate data for the material and cooling rate control devices for the test specimens are available, the test specimens may be heat treated in the device to represent the material, provided that the provisions of (a) above are met.

(c) When any of the specific procedures described in NCD-2220 are used, faster cooling rates at the edges may be compensated for by:

1. taking the test specimens at least \(t\) from a quenched edge, where \(t\) equals the material thickness;
2. attaching a steel pad at least \(t\) wide by a partial penetration weld (which completely seals the buffered surface) to the edge where specimens are to be removed; or
3. using thermal barriers or insulation at the edge where specimens are to be removed.

It shall be demonstrated (and this information shall be included in the Certified Material Test Report) that the cooling rates are equivalent to (a) or (b) above.

**NC-NCD-2220 Procedure for Obtaining Test Coupons and Specimens for Quenched and Tempered Material**

**NC-NCD-2221 General Requirements**

The procedure for obtaining test specimens for quenched and tempered material is related to the product form. Coupon and specimen location shall be as required by the material specification, except as stated in the following paragraphs of this subarticle. References to dimensions signify nominal values.

**NC-NCD-2222 Plates**

**NC-NCD-2222.1 Orientation and Location of Coupons.**

Coupons shall be taken so that specimens shall have their longitudinal axes at least \(\frac{1}{4}t\) from a rolled surface and with the midlength of the specimen at least \(t\) from any heat-treated edge, where \(t\) is the nominal thickness of the material.
NC-NCD-2222.2 Requirements for Separate Test Coupons.

Where a separate test coupon is used to represent the component material, it shall be of sufficient size to ensure that the cooling rate of the region from which the test coupons are removed represents the cooling rate of the material at least \( \frac{1}{4}t \) deep and \( t \) from any edge of the product. Unless cooling rates applicable to the bulk pieces or product are simulated in accordance with NC-NCD-2212.2, the dimensions of the coupon shall be not less than \( 3t \times 3t \times t \), where \( t \) is the nominal material thickness.

NC-NCD-2223 Forgings

NCD-2223.1 Location of Test Coupons for Class 2 Forgings (note to editors: text for this subparagraph and its subsubparagraphs is from NC-2223 and its subparagraphs)

NC-NCD-2223.1.1 Forgings With 2 in. (50 mm) Maximum Thickness.

For forgings with a maximum thickness of 2 in. (50 mm), the coupons shall be taken so that specimens shall have their longitudinal axes at the midplane of the thickness or the center of the cross section and with the midlength of the specimens at least 2 in. (50 mm) from any second surface.

NC-NCD-2223.1.2 Forgings With Thickness Exceeding 2 in. (50 mm).

For forgings exceeding a thickness of 2 in. (50 mm), the coupons shall be taken so that specimens shall have their longitudinal axes at least \( \frac{1}{4}t \) of the maximum heat-treated thickness from any surface and with the midlength of the specimens at least \( t \) from any second surface. This is normally referred to as \( \frac{1}{4}t \times t \), where \( t \) is the maximum heat-treated thickness. A thermal buffer may be used to achieve the above conditions unless cooling rates applicable to the bulk forgings are simulated in accordance with NC-NCD-2212.2.

NC-NCD-2223.1.3 Very Thick and Complex Forgings.

Test coupons for forgings which are both very thick and complex, such as contour nozzles, thick tubesheets, flanges, nozzles, and other complex forgings that are contour shaped or machined to essentially the finished product configuration prior to heat treatment, may be removed from prolongations or other stock provided on the product. The Certificate Holder shall specify the surfaces of the finished product subjected to high tensile stresses in service. The coupons shall be taken so that specimens shall have their longitudinal axes at a distance below the nearest heat-treated surface, equivalent to at least the greatest distance that the indicated high tensile stress surface will be from the nearest surface during heat treatment, and with the midlength of the specimens a minimum of twice this distance from a second heat-treated surface. In any case, the longitudinal axes of the specimens shall not be nearer than \( \frac{3}{4} \) in. (19 mm) to any heat-treated surface and the midlength of the specimens shall be at least \( 1 \frac{1}{2} \) in. (38 mm) from any heat-treated surface.

NC-NCD-2223.1.4 Coupons From Separately Produced Test Forgings.

Test coupons representing forgings from one heat and one heat treatment lot may be taken from a separately forged piece under the conditions given in (a) through (e) below.

(a) The separate test forging shall be of the same heat of material and shall be subjected to substantially the same reduction and working as the production forging it represents.

(b) The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forging.

(c) The separate test forging shall be of the same nominal thickness as the production forging.
(d) Test coupons for simple forgings shall be taken so that specimens shall have their longitudinal axes at the region midway between mid thickness and the surface and with the mid length of the specimens no nearer any heat treated edge than a distance equal to the forging thickness, except when the thickness to length ratio of the production forging does not permit, in which case a production forging shall be used as the test forging and the mid length of the specimens shall be at the mid length of the test forging.

(e) Test coupons for complex forgings shall be taken in accordance with NCD-2223.

NCD-2223.1.5 Test Specimens for Forgings.

When test specimens for forgings are to be taken under the applicable specification, the Inspector shall have the option of witnessing the selection, placing an identifying stamp on them, and witnessing the testing of these specimens.

NCD-2223.2 Location of Test Coupons for Class 3 Forgings. Note to editors: text for this subparagraph and its subsubparagraphs is from ND-2223 and its subparagraphs, except for reference changes.

NCD-2223.2.1 General Requirement

The longitudinal axis of the test specimens shall be located at least $\frac{1}{4}t$ from the nearest surface. The gauge length of tension test specimens and the area under the notch of Charpy specimens shall be located at a distance of at least $t$ from any second surface to compensate for faster cooling rates at the edges. The variable $t$ is the maximum nominal heat treated thickness or cross section of the forging. Either of the following methods may be used to obtain the required distance from any second surface.

(a) Method A. A thermal buffer ring, at least $t \times t$ in cross section, or sections of such a ring at least 3/ in length, shall be welded to the test end of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low alloy steel and shall be joined to the forging with a partial penetration type weld that completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If ring segments are used, the test coupons shall be removed from the forging in the area under the center one-third of the buffer ring segment length. In either case, the longitudinal axis of the test specimens shall be located at a minimum distance of $\frac{1}{2}$ in. (13 mm) from the buffered surface of the forging, and at least $\frac{1}{4}t$ from a quenched surface of the forging.

(b) Method B. Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the product surface where specimens are to be removed. It shall be demonstrated that the cooling rate of the test specimen location is no faster than that attained by the method described in NCD-2223.1.4, or Method A. Test specimen locations shall be the same as stated for Method A. Details of thermal insulation, including substantiation data, shall be available from the agency performing the heat treatment.

NCD-2223.2.2 Very Thick and Complex Forgings.

For forgings that are very thick and complex (for example, thick tubesheets, flanges, nozzles, pump and valve bodies, and other complex forgings that are contour-shaped or machined essentially to the inservice configuration prior to heat treatment), the purchaser shall specify the surfaces of the
finished product subjected to significant tension loading in service. The test specimens shall be removed from a prolongation or other stock from the forging or from a test forging in accordance with NCD-2223.2.1. They shall be taken so that the longitudinal center line is at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the significantly stressed location is from the nearest heat-treated surface. The gage length of tension test specimens and the area under the notch of Charpy specimens, shall be located at least twice this distance from any second heat-treated surface. These respective locations, however, shall not be closer than \( \frac{3}{4} \) in. (19 mm) from the nearest surface and \( \frac{1}{2} \) in. (38 mm) from any second surface.

NCD-2223.2.3 Multiple Forgings

(a) Multiple Forgings Separated Into Identical Individual Forgings Prior to Quenching and Tempering Treatment. At least one individual forging from each multiple forging in each heat treating lot shall be tested using the test specimen locations of NCD-2223.2.1 or NCD-2223.2.2 as specified on the purchase order, except that test specimens located at midlength may be closer to the ends of the production forging than the specified distance to the second surfaces. All forgings shall be quenched simultaneously and tempered in the same furnace charge. All forgings from the multiple shall be Brinell hardness tested after heat treatment and forgings not tested for mechanical properties shall have a BHN within 20 points of the BHN of the forging that has been tested for mechanical properties.

(b) Multiple Forgings Separated After Quench and Temper Treatment. The multiple forging shall have an integral prolongation and when the heat-treated length of the multiple (excluding test metal) exceeds 80 in. (2 000 mm), each end shall have an integral prolongation. Test specimen locations shall meet the requirements of NCD-2223.2.1 or NCD-2223.2.2 as specified on the purchase order.

NCD-2223.2.4 Forgings Tested With Representative, Separately Forged Test Pieces.

Separately forged test pieces shall be used. Test specimens shall be taken from a representative separate test forging made from the same heat of steel as the production forgings. Separate test forgings shall receive substantially the same reduction and type of hot working as the production forgings, except that a longitudinal forged bar with dimensions not less than \( 3t \times t \) may be used to represent a ring forging. Test forgings shall be of the same nominal thickness as the as-quenched production forgings, and shall be heat treated in the same furnace charge and under the same conditions as the production forgings. For forgings requiring impact testing, the use of representative separate test pieces shall be limited to forgings with machined weights of 1,000 lb (450 kg) or less, except in the case of forgings covered by NCD-2223.2.4. Test specimen locations shall meet the requirements of NCD-2223.2.1 or NCD-2223.2.2 as applicable. When destructively tested production forgings are not of sufficient length to obtain the \( t \) distance from a second surface, the location from the second surface may be at midlength of the forging.

NCD-2223.2.5 Quenched and Tempered Bars.

(a) For bars (other than those used for bolting materials) the coupons shall be taken so that specimens shall have their longitudinal axes at least \( \frac{1}{4}t \) from the outside or rolled surface. The gage length of tension test specimens and the area under the notch of Charpy specimens shall be indented at least one diameter or thickness from a heat-treated end.
Bars With Thicknesses Exceeding 1\(\frac{1}{2}\) in. (38 mm). For bars (other than those used for bolting materials) with diameters or thickness over 1\(\frac{1}{2}\) in. (38 mm), the coupons shall be taken so that specimens shall have their longitudinal axes at least \(\frac{1}{4}d\) from the outside or rolled surface. The gage length of tension test specimens and the area under the notch of Charpy specimens shall be located at least one diameter or thickness from a heat-treated end.

**NC-NCD-2224 Bars and Bolting Material**

**NC-NCD-2224.1 Bars With 2 in. (50 mm) Maximum Thickness.**
For bars with diameters or thicknesses 2 in. (50 mm) or less, the coupons shall be taken so that specimens shall have their longitudinal axes on a line representing the center of the thickness and with the midlength of the specimens at least one diameter or thickness from a heat-treated end.

**NC-NCD-2224.2 Bars With Thicknesses Exceeding 2 in. (50 mm).**
For bars with diameters or thicknesses over 2 in. (50 mm), the coupons shall be taken so that specimens shall have their longitudinal axes at least \(\frac{1}{4}t\) from the outside or rolled surface and with the midlength of the specimens at least \(t\) from a heat-treated end, where \(t\) is either the bar diameter or thickness.

**NC-NCD-2224.3 Bolting Material.**
For bolting material, the coupons shall be taken in conformance with the applicable material specification and with the midlength of the specimen at least one diameter or thickness from a heat-treated end. When the studs, nuts, or bolts are not of sufficient length, the midlength of the specimen shall be at the midlength of the studs, nuts, or bolts. The studs, nuts, or bolts selected to provide test coupon material shall be identical with respect to the quenched contour and size except for length, which shall equal or exceed the length of the represented studs, nuts, or bolts.

**NC-NCD-2225 Tubular Products**

**NC-NCD-2225.1 Tubular Products With 2 in. (50 mm) Maximum Thickness.**
For tubular products with 2 in. (50 mm) maximum wall thickness, the coupons shall be taken so that specimens shall have their longitudinal axes on a surface midway between the outside and inside surfaces and with the midlength of the specimens at least one wall thickness from a heat-treated end.

**NC-NCD-2225.2 Tubular Products Exceeding 2 in. (50 mm) Nominal Thickness.**
For tubular products with nominal wall thicknesses exceeding 2 in. (50 mm), the coupons shall be taken so that specimens shall have their longitudinal axes at least \(\frac{1}{4}t\) from the outside surface and with the midlength of the specimens at least one wall thickness from a heat-treated end.

**NC-NCD-2225.3 Separately Produced Coupons Representing Fittings.**
Separately produced test coupons representing fittings may be used. When separately produced coupons are used, the requirements of NC-2223.4.1 for Class 2 and NC-2223.4.2 for Class 3 shall be met.

**NC-NCD-2226 Tensile Test Specimen Location (for Quenched and Tempered Ferritic Steel Castings)**

Note: Users of this requirement should note that the hardenability of some grades may limit the usable section size.
(a) This section applies only to quenched-and-tempered ferritic steel castings with a thickness \( t \) exceeding 2 in. (50 mm), where \( t \) is the thickness of the pressure-retaining wall of the casting excluding flanges and sections designated by the designer as nonpressure retaining. The order, inquiry, and drawing shall designate what the thickness \( t \) is for the casting.

(b) One of the following shall apply:

1. The longitudinal centering of the thickness of the tension test specimen shall be taken at least \( \frac{1}{4} t \) from the \( t \) dimension surface. For cylindrical castings, the longitudinal center line of the specimen shall be taken at least \( \frac{1}{4} t \) from the outside or inside surface, and the gage length at least \( t \) from the as-heat-treated end.

2. Where separately cast test coupons are used, their dimensions shall be not less than \( 3t \times 3t \times Tt \), and each specimen cut from it shall meet the requirements of (b1). The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. (Centrifugal castings may be represented by statically cast coupons.) The test coupon shall be heat treated under the same conditions as the production casting(s). The \( t \) dimension of the test coupon shall be the same maximum thickness \( t \) as defined in (a) above. Where separate test blocks require reheat treatment, thermal buffers in accordance with (b4) may be used.

3. Where specimens are to be removed from the body of the casting, a steel, thermal buffer pad \( 1t \times 1t \times \text{at least } 3t \) shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface prior to the heat treatment process. The test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of \( \frac{1}{2} \) in. (13 mm) from the buffered surface and \( \frac{1}{4} t \) from the other heat-treated surfaces.

4. Where specimens are to be removed from the body of the casting, thermal insulation or other thermal barriers shall be used during the heat treatment process adjacent to the casting edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the test specimen is no faster than that of specimens taken by the method described in (1). This information shall be included in the test reports.

5. Where castings are cast or machined to essentially the finished product configuration prior to heat treatment, the test specimens shall be removed from a casting prolongation or other stock on the product at a location below the nearest heat-treated surface indicated on the order. The specimens shall be located with their longitudinal axes a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high tensile stress surface will be from the nearest heat-treated surface, and with their midlength a minimum of twice this distance from a second heat-treated surface. In any case, the longitudinal axes of the test specimens shall be no nearer than \( \frac{1}{4} \) in. (6 mm) to a heat-treated surface and the midlength shall be at least \( 1\frac{1}{2} \) in. (38 mm) from a second heat-treated surface. The component manufacturer shall specify the surfaces of the finished product subjected to high tensile stress in service.
(a) Pressure-retaining material shall be impact tested in accordance with the requirements of NC-NCD-2330, except that impact testing of materials described in (1) through (9) below is not a requirement of this Subsection:

(1) material with a nominal section thickness of 5/8 in. (16 mm) and less where thicknesses shall be taken as defined in (-a) through (-e) below:

(-a) for pumps, valves, and fittings, use the largest nominal pipe wall thickness of the connecting pipes;

(-b) for vessels and tanks, use the nominal thickness of the shell or head, as applicable;

(-c) for nozzles or parts welded to vessels, use the lesser of the vessel shell thickness to which the item is welded or the maximum radial thickness of the item exclusive of integral shell butt welding projections;

(-d) for flat heads, tubesheets, or flanges, use the maximum shell thickness associated with the butt welding hub;

(-e) For Class 2 only: for integral fittings used to attach process piping to the containment vessel (Figure NE-1110-1), use the larger nominal thickness of the pipe connections.

(2) bolting, including studs, nuts, and bolts, with a nominal size of 1 in. (25 mm) or less;

(3) bar with a nominal cross-sectional area that does not exceed 1 in.² (650 mm²);

(4) all thicknesses of material for pipe, tube, fittings, pumps, and valves with a diameter of NPS 6 (DN 150) and smaller;

(5) material for pumps, valves, and fittings with all pipe connections of 5/8 in. (16 mm) nominal wall thickness and less;

(6) austenitic stainless steels, including precipitation hardened austenitic Grade 660 (UNS S66286);

(7) nonferrous materials;

(8) For Class 2 only:

(-a) materials listed in Table NC-NCD-2311-2311(a)-1 for which the listed value of $T_{NDT}$ is lower than the Lowest Service Temperature (LST) by an amount established by
the rules in Section III Appendices, Nonmandatory Appendix R. This exemption does not exempt either the weld metal (NCD-2430) or the welding procedure qualification (NCD-4335) from impact testing. (Note to Editors: this was NC-2311(a)(8)).

(-b) (9) materials for components for which the Lowest Service Temperature exceeds 150°F (65 °C). (Note to Editors: this was NC-2311(a)(9)).

(9) For Class 3 only:

(-a) materials listed in Table NCD-2311-2 in the thicknesses shown and for Lowest Service Temperatures equal to or more than the tabulated temperatures. This exemption does not exempt either the weld metal (NCD-2430) or the welding procedure qualification (NCD-4335) from impact testing. (Note to Editors: this was ND-2311(a)(8)).

(-b) materials for components for which the Lowest Service Temperature exceeds 100°F (38°C). (Note to Editors: this was ND-2311(a)(9)).

(b) The Design Specification shall state the Lowest Service Temperature for the component.

(c) For Class 2 only: Drop weight tests are not required for the martensitic high alloy chromium (Series 4XX) steels and precipitation-hardening steels listed in Section II, Part D, Subpart 1, Table 1A. The other requirements of NCD-2331 and NCD-2332 apply for these steels. For nominal wall thicknesses greater than 2 1/2 in. (64 mm), the required C_v values shall be 40 mils (1.0 mm) lateral expansion.

Table NC-NCD-2311-1 2311(a)-1 — Exemptions From Impact Testing Under NC-2311(a)(8) – Class 2 only (Note to Editors: this was Table NC-2311(a)-1).

<table>
<thead>
<tr>
<th>Material</th>
<th>Material Condition</th>
<th>T_{NDT}, °F (°C)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-537, Class 1</td>
<td>N</td>
<td>−30 (−35)</td>
<td></td>
</tr>
<tr>
<td>SA-516, Grade 70</td>
<td>Q &amp; T</td>
<td>−10 (−25)</td>
<td></td>
</tr>
<tr>
<td>SA-516, Grade 70</td>
<td>N</td>
<td>0 (−20)</td>
<td></td>
</tr>
<tr>
<td>SA-508, Class 1</td>
<td>Q &amp; T</td>
<td>+10 (−10)</td>
<td></td>
</tr>
<tr>
<td>SA-533, Grade B</td>
<td>Q &amp; T</td>
<td>+10 (−10)</td>
<td></td>
</tr>
<tr>
<td>SA-299 [Note (5)]</td>
<td>N</td>
<td>+20 (−7)</td>
<td></td>
</tr>
<tr>
<td>SA-216, Grades WCB and WCC</td>
<td>Q &amp; T</td>
<td>+30 (0)</td>
<td></td>
</tr>
<tr>
<td>SA-36 (Plate)</td>
<td>HR</td>
<td>+40 (+5)</td>
<td></td>
</tr>
<tr>
<td>SA-508, Class 2</td>
<td>Q &amp; T</td>
<td>+40 (+5)</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
(1) These materials are exempt from toughness testing when \( LST - T_{NTD} \) is satisfied in accordance with the rules established in Section III Appendices, Nonmandatory Appendix R.

(2) Material Condition letters refer to:

- \( N \) = normalize
- \( Q \& T \) = quench and temper
- \( HR \) = hot rolled

(3) These values for \( T_{NTD} \) were established from data on heavy section steel [thickness greater than 2\( \frac{1}{2} \) in. (64 mm)]. Values for sections less than 2\( \frac{1}{2} \) in. (64 mm) thick are held constant until additional data are obtained.

(4) \( T_{NTD} \) = temperature at or above nil-ductility transition temperature NDT (ASTM E208); \( T_{NTD} \) is 10°F (5°C) below the temperature at which at least two specimens show no-break performance.

(5) Materials made to a fine grain melting practice.

Table NCD-2311-2 — Exemptions From Impact Testing Under NCD-2311(a)(9) — Class 3 Only

<table>
<thead>
<tr>
<th>Material</th>
<th>Material Condition [Note (1)]</th>
<th>Lowest Service Temperature for the Thickness Shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-516 Grade 70</td>
<td>N</td>
<td>(-30^\circ F) ((-34^\circ C)) (-20^\circ F) ((-29^\circ C)) (0^\circ F) ((-18^\circ C)) (0^\circ F) ((-18^\circ C))</td>
</tr>
<tr>
<td>SA-537 Class 1</td>
<td>N</td>
<td>(-40^\circ F) ((-40^\circ C)) (-30^\circ F) ((-34^\circ C)) (-30^\circ F) ((-34^\circ C)) (-30^\circ F) ((-34^\circ C))</td>
</tr>
<tr>
<td>SA-516 Grade 70</td>
<td>Q &amp; T</td>
<td>[Note (2)]</td>
</tr>
<tr>
<td>SA-508 Class 1</td>
<td>Q &amp; T</td>
<td>[Note (2)]</td>
</tr>
<tr>
<td>SA-508 Class 2</td>
<td>Q &amp; T</td>
<td>[Note (2)]</td>
</tr>
<tr>
<td>SA-533 Grade B</td>
<td>Q &amp; T</td>
<td>[Note (2)]</td>
</tr>
<tr>
<td>Class 1 [Note (3)]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SA-216 Grades WCB, WCC</td>
<td>Q &amp; T</td>
<td>[Note (2)]</td>
</tr>
<tr>
<td>SA-299 [Note (3)]</td>
<td>N</td>
<td>[Note (2)]</td>
</tr>
</tbody>
</table>

Notes:

(1) Material Condition letters refer to:
(2) The lowest service temperature shown in the column Over 1 1/2 in. to 2 1/2 in. (38 mm to 64 mm) may be used for these thicknesses.

(3) Material made to a fine grain melting practice.

NC-NCD-2320 Impact Test Procedures

NC-NCD-2321 Types of Tests

NC-NCD-2321.1 Drop Weight Tests. (Class 2 only)
The drop weight test, when required, shall be performed in accordance with ASTM E208. Specimen types P-1, P-2, or P-3 may be used. When drop weight tests are performed to meet the requirements of NC-NCD-2300, the test temperature and the results shall be reported on the Certified Material Test Report.

NC-NCD-2321.2 Charpy V-Notch Tests.
The Charpy V-notch test ($C_v$), when required, shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Figure 11, Type A. A test shall consist of a set of three full-size 10 mm × 10 mm specimens. The lateral expansion and absorbed energy, as applicable, and the test temperature, as well as the orientation and location of all tests performed to meet the requirements of NC-NCD-2330 shall be reported in the Certified Material Test Report.

NC-NCD-2322 Test Specimens

NC-NCD-2322.1 Location of Test Specimens.
Impact test specimens shall be removed from a depth within the material that is at least as far from the material surface as that specified for tensile test specimens in the material specification. For bolting, the $C_v$ impact test specimens shall be taken with the longitudinal axis of the specimen located at least one-half radius or 1 in. (25 mm) below the surface plus the machining allowance per side, whichever is less. The fracture plane of the specimen shall be at least one diameter or thickness from the heat-treated end. When the studs, nuts, or bolts are not of sufficient length, the midlength of the specimen shall be at the midlength of the studs, nuts, or bolts. The studs, nuts, or bolts selected to provide test coupon material shall be identical with respect to the quenched contour and size except for length, which shall equal or exceed the length of the represented studs, nuts, or bolts.

NC-NCD-2322.2 Orientation of Impact Test Specimens.

NCD-2322.2.1 Orientation of Specimens for $C_v$ Impact Test [Note to Editors: was NC-2322.2(a)]
(a) Specimens for CV impact tests shall be oriented as required in NCD-2200 for the tensile test specimen or, alternatively, the orientation may be in the direction of maximum stress. The notch of the CV specimen shall be normal to the surface of the material.

NCD-2322.2.2 Orientation of Specimens for Drop Weight Tests (Class 2 only) [Note to Editors: was NCD-2322.2(b)]

(b) Specimens for drop weight tests may have their axes oriented in any direction.

NC-NCD-2330 Test Requirements and Acceptance Standards

NC-NCD-2331 Pressure-Retaining Material Test Methods and Temperature (Class 2 only)

Pressure-retaining material shall be impact tested in accordance with one of the test methods indicated below:

(a) Charpy V-notch testing at or below the Lowest Service Metal Temperature\(5^\circ \text{ F} \pm \Delta \)\footnote{Ref. 5 to 6}

(b) drop weight testing to show that the Lowest Service Metal Temperature\(5^\circ \text{ F} \) \((\text{LST} - T_{\text{NDT}}^\circ \text{ F})\) is satisfied in accordance with the rules established in Section III Appendices, Nonmandatory Appendix R.

NC-NCD-2332 Specific Test Methods and Acceptance Standards for Pressure-Retaining Material for Tests Based on Lowest Service Metal Temperatures (Class 2 only)

NC-NCD-2332.1 Pressure-Retaining Material Other Than Bolting Material With 2\(\frac{1}{2}\) in. (64 mm) Maximum Thickness\footnote{Ref. 7}.

Except as limited in NCD-4332, apply one of the methods of NCD-2331 to test: base material; the base material, the heat-affected zone, and weld metal for the weld procedure qualification tests of NCD-4335; and the weld metal for NCD-2431. The impact test results shall meet one of the acceptance standards applicable to the specified test method.

(a) Charpy V-Notch Testing for Lateral Expansion Values. The test results of the three specimens, collectively and singly, shall meet the respective requirements of Table NCD-2332.1-1.

(b) Charpy V-Notch Testing for Absorbed Energy Values. The test results of the three specimens, collectively and singly, shall meet the respective requirements of Table NCD-2332.1-2.

(c) Drop Weight Testing. An acceptance test shall consist of at least two no-break specimens as described in ASTM E208.

Table NCD-2332.1-1 — Required CV Lateral Expansion Values for Pressure-Retaining Material Other Than Bolting Material – Class 2 Only

<table>
<thead>
<tr>
<th>Nominal Wall Thickness, in. (mm)</th>
<th>Lateral Expansion, mils (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of 3</td>
<td>Lowest 1 of 3</td>
</tr>
<tr>
<td>(\frac{5}{8}) (16) or less [Note (2)]</td>
<td>…</td>
</tr>
<tr>
<td>Over (\frac{5}{8}) to 1 (16 to 25), incl.</td>
<td>20 (0.50)</td>
</tr>
</tbody>
</table>
Nominal Wall Thickness, in. (mm) [Note (1)] | Lateral Expansion, mils (mm) Average of 3 Lowest 1 of 3
---|---
Over 1 to 1\(\frac{1}{2}\) (25 to 38), incl. | 25 (0.64) 20 (0.50)
Over 1 \(\frac{1}{2}\) to 2 \(\frac{1}{2}\) (38 to 64), incl. | 35 (0.89) 30 (0.75)
Over 2\(\frac{1}{2}\) (64) [Note (3)] | 45 (1.14) 40 (1.0)

GENERAL NOTES:

(a) Where weld metal tests of NC\(D\)-2400 are made to these requirements, the impact lateral expansion shall conform to the requirements of either of the base materials being joined.

(b) Where two base materials having different required lateral expansion values are joined, the weld metal lateral expansion requirements of NC\(D\)-4330 shall conform to the requirements of either of the base materials.

NOTES:

(1) For pumps, valves, and fittings, use the nominal pipe wall thickness of the connecting pipe. For vessels use the least of:
   (a) the maximum radial thickness of the item exclusive of integral butt welded projections;
   (b) the vessel shell thickness to which the item is welded;
   (c) the maximum shell thickness associated with the item for flat heads, tubesheets, or flanges.

(2) No test required.

(3) For use with NC\(D\)-2332.2(a-b).

Table NC\(D\)-2332.1-2 — Required Cv Energy Values for Pressure-Retaining Material Other Than Bolting Material – Class 2 Only

| Nominal Wall Thickness, in. (mm) [Note (2)] | Energy, ft-lb (J) for Base Materials [Note (1)] of Specified Minimum Yield Strength, ksi (MPa) |
|---|---|---|---|---|
| | Over 55 ksi to 75 ksi (380 MPa to 515 MPa), Incl. | Over 75 ksi to 105 ksi (515 MPa to 725 MPa), Incl. |
| Average of 3 Lowest 1 of 3 | Average of 3 Lowest 1 of 3 | Average of 3 Lowest 1 of 3 |
| 5/8 (16) or less [Note (3)] | 20 (27) 20 (27) 20 (27) | 30 (41) 30 (41) 25 (34) |
| Over 5/8 to 1 (16 to 25), incl. | 25 (34) 20 (27) 25 (34) | 35 (47) 35 (47) 30 (41) |
| Over 1 to 1\(\frac{1}{2}\) (25 to 38), incl. | 35 (47) 30 (41) 40 (54) | 45 (61) 45 (61) 40 (54) |
| Over 1 \(\frac{1}{2}\) to 2 \(\frac{1}{2}\) (38 to 64), incl. | 35 (47) 30 (41) 40 (54) | 45 (61) 45 (61) 40 (54) |
### Nominal Wall Thickness, in. (mm)

<table>
<thead>
<tr>
<th>Energy, ft-lb (J) for Base Materials [Note (1)] of Specified Minimum Yield Strength, ksi (MPa)</th>
<th>Over 55 ksi to 75 ksi (380 MPa to 515 MPa), Incl.</th>
<th>Over 75 ksi to 105 ksi (515 MPa to 725 MPa), Incl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Wall Thickness, in. (mm) [Note (2)]</td>
<td>Average of 3</td>
<td>Lowest 1 of 3</td>
</tr>
<tr>
<td>Over 2½ (64) [Note (4)]</td>
<td>45 (61)</td>
<td>40 (54)</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:**

Where weld metal tests of [NC-D-2400] are made to these requirements, the impact energy shall conform to the requirements of either of the base materials being joined.

**NOTES:**

(1) Where two base materials having different required energy values are joined, the weld metal impact energy requirements of the procedure qualification tests of [NC-D-4331] shall conform to the requirements of either of the base materials.

(2) For pumps, valves, and fittings, use the nominal pipe wall thickness of the connecting pipe. For vessels use the least of:

   (a) the maximum radial thickness of the item exclusive of integral butt welded projections;

   (b) the vessel shell thickness to which the item is welded;

   (c) the maximum shell thickness associated with the item for flat heads, tubesheets, or flanges.

(3) No test required.

(4) For use with [NC-D-2332.2(b)].

**NC-D-2332.2 Pressure-Retaining Material Other Than Bolting Material With Thickness Exceeding 2½ in. (64 mm).**

(a) The base material, and the weld procedure qualification weld metal tests of [NC-D-4331], shall be tested by the drop weight method as specified in [NC-D-2321] and [NC-D-2331(b)].

(b) Except as limited in [NC-D-4331], apply one of the methods of [NC-D-2331] to test: the base material and the heat-affected zone of the weld procedure qualification tests for [NC-D-4331]; and the weld metal for [NC-D-2331].

(c) The acceptance standards shall be as given in [NC-D-2332.1(a)], [NC-D-2332.1(b)], or [NC-D-2332.1(c)], as applicable.
**NC-NCD-2332.3 Bolting Material.**

For bolting material, including nuts, studs, and bolts, a Charpy V-notch test shall be performed. The tests shall be performed at or below the Lowest Service Metal Temperature, and all three specimens shall meet the requirements of Table NC-NCD-2332.3-1.

**Table NC-NCD-2332.3-1 — Required Cv Values for Bolting Material Tested in Accordance With NC-NCD-2332.3 — Class 2 only**

<table>
<thead>
<tr>
<th>Nominal Diameter, in. (mm)</th>
<th>Lateral Expansion, mils (mm)</th>
<th>Absorbed Energy, ft-lb (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (25) or less</td>
<td>No test required</td>
<td>No test required</td>
</tr>
<tr>
<td>Over 1 through 4 (25 through 25 (0.64) 100)</td>
<td>25 (0.64)</td>
<td>45 (61)</td>
</tr>
</tbody>
</table>

**NCD-2333 Pressure-Retaining Material Test Methods and Temperature (Class 3 only)**

**NCD-2333.1 Pressure-Retaining Material Other Than Bolting Material**

Pressure-retaining material other than bolting for vessels, tanks, piping (pipe and tubes), pumps, valves, and fittings shall be tested as required by (a) and (b) below:

(a) A Charpy V-notch test shall be performed at a temperature lower than or equal to the Lowest Service Temperature. All three specimens shall meet one of the acceptance standards applicable to the specific test method.

(1) *Charpy V-Notch Testing for the Lateral Expansion Values.*

The test results of the three specimens, collectively and singly, shall meet the respective requirements of Table NCD-2333.1-1.

(2) *Charpy V-Notch Testing for Absorbed Energy Values.*

The test results of the three specimens, collectively and singly, shall meet the respective requirements of Table NCD-2333.1-2.

(b) Apply the procedures of (a) above to:

(1) the base material;
(2) the base material, the heat-affected zone, and weld metal from the weld procedure qualification tests in accordance with NC-NCD-2431; and
(3) the weld metal of NC-NCD-2431.

**Table NCD 2333.1-1 — Required Cv Lateral Expansion Values for Pressure-Retaining Material Other than Bolting Material – Class 3 only**

<table>
<thead>
<tr>
<th>Nominal Wall Thickness, in. (mm)</th>
<th>Lateral Expansion, mils</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Note (1)]</td>
<td>Average of 3</td>
</tr>
<tr>
<td>5/8 (16) or less</td>
<td>13 (0.33)</td>
</tr>
<tr>
<td>Over 5/8 to 3/4 (16 to 19), incl.</td>
<td>15 (0.38)</td>
</tr>
<tr>
<td>Over 3/4 to 1 (19 to 25), incl.</td>
<td>20 (0.50)</td>
</tr>
<tr>
<td>Over 1 to 1 1/4 (25 to 38), incl.</td>
<td></td>
</tr>
<tr>
<td>Nominal Wall Thickness, in. (mm) [Note (1)]</td>
<td>Lateral Expansion, mils</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td></td>
<td>Average of 3</td>
</tr>
<tr>
<td>Over 1(\frac{1}{2}) to 2(\frac{1}{2}) (38 to 64), incl.</td>
<td>25 (0.64)</td>
</tr>
<tr>
<td>Over 2(\frac{1}{2}) (64)</td>
<td>30 (0.75)</td>
</tr>
</tbody>
</table>

**GENERAL NOTES:**

(a) When two base materials having different specified minimum lateral expansion values are joined, the weld impact lateral expansion requirements of the welding procedure qualification (NCD-4330) shall conform to the requirements of either of the base materials.

(b) When the weld metal tests of NCD-2400 are performed to these requirements, the impact lateral expansion shall conform to the requirements of either of the base materials being joined.

**NOTES:**

(1) See (a) through (d) below.

(a) For pumps, valves, and fittings, use the largest nominal wall thickness of the connecting pipes.

(b) For vessels and tanks, use the nominal thickness of the shell or head, as applicable.

(c) For nozzles or other items welded to vessels, use the lesser of the vessel shell thickness to which the item is welded or the maximum radial thickness of the item exclusive of integral shell butt welding projections.

(d) For flat heads, tubesheets, or flanges, use the maximum shell thickness associated with the butt welding hub.

(2) No test required.
Table NCD-2333.1-2 — Required Cv Energy Values for Pressure-Retaining Material Other than Bolting Material – Class 3 only  

<table>
<thead>
<tr>
<th>Nominal Wall Thickness, in. (mm) [Note (1)]</th>
<th>Energy, ft-lb (J), for Materials of Specified Minimum Yield Strength, ksi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 ksi (275 MPa) or Below</td>
</tr>
<tr>
<td></td>
<td>Average of 3 Lowest 1 of 3</td>
</tr>
<tr>
<td>5/8 (16) or less [Note (2)]</td>
<td></td>
</tr>
<tr>
<td>Over 5/8 to 3/4 (16 to 19), incl.</td>
<td>13 (18)</td>
</tr>
<tr>
<td>Over 3/4 to 1 (19 to 25), incl.</td>
<td>15 (20)</td>
</tr>
<tr>
<td>Over 1 to 1 1/2 (25 to 38), incl.</td>
<td>20 (27)</td>
</tr>
<tr>
<td>Over 1 1/2 to 2 1/2 (38 to 64), incl.</td>
<td>25 (34)</td>
</tr>
<tr>
<td>Over 2 1/2 (64)</td>
<td>30 (41)</td>
</tr>
</tbody>
</table>

**GENERAL NOTES:**
(a) When two base materials having different specified minimum energy values are joined, the weld impact energy requirements of the welding procedure qualification (ND-4330) shall conform to the requirements of either of the base materials.
(b) When the weld metal tests of ND-2400 are performed to these requirements, the impact energy shall conform to the requirements of either of the base materials being joined.

**NOTES:**
(1) See (a) through (d) below.
(a) For pumps, valves, and fittings, use the largest nominal wall thickness of the connecting pipes.
(b) For vessels and tanks, use the nominal thickness of the shell or head, as applicable.
(c) For nozzles or other items welded to vessels, use the lesser of the vessel shell thickness to which the item is welded or the maximum radial thickness of the item exclusive of integral shell butt welding projections.
(d) For flat heads, tubesheets, or flanges, use the maximum shell thickness associated with the butt welding hub.
(2) No test required.

**NCD-2333.2 Bolting Material** [Note to Editors: was ND-2333]

This Section NCD-2333.2 was accidentally dropped from the previous version. It is identical except for numbering to ND-2333 that this comes from. This was an comment on ballot 20-651.
For bolting material, including studs, nuts, and bolts, a Charpy V-notch test shall be performed at a temperature equal to or less than the preload temperature or the Lowest Service Temperature, whichever is less. All three specimens shall meet the requirements of Table NCD-2333.2-1.

**Table NCD-2333.2-1**

Required $C_V$ Values for Bolting Material

<table>
<thead>
<tr>
<th>Nominal Diameter, in. (mm)</th>
<th>Lateral Expansion, mils (mm)</th>
<th>Absorbed Energy, ft-lb (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (25) or less</td>
<td>No test required</td>
<td>No test required</td>
</tr>
<tr>
<td>Over 1 through 4 (25 through 100)</td>
<td>15 (0.38)</td>
<td>30 (41)</td>
</tr>
<tr>
<td>Over 4 (100)</td>
<td>20 (0.50)</td>
<td>35 (48)</td>
</tr>
</tbody>
</table>

This Table NCD-2333.2-1 was accidentally dropped from the previous version. It is identical except for numbering to Table ND-2333-1 that this comes from. This was an comment on ballot 20-651.

**NC-NCD-2340 Number of Impact Tests Required**

**NC-NCD-2341 Plates**

One test shall be made from each plate as heat treated. Where plates are furnished in the non-heat-treated condition and qualified by heat-treated test specimens, one test shall be made for each plate as rolled. The term *as-rolled* refers to the plate rolled from a slab or directly from an ingot, not to its heat-treated condition.

**NC-NCD-2342 Forgings and Castings**

(a) Where an individual forging or casting is less than 1,000 lb (450 kg), one test shall be made to represent each heat in each heat treatment charge.

(b) When heat treatment is performed in a continuous-type furnace with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a heat treatment charge shall be considered as the lesser of a continuous run not exceeding 8 hr duration or a total weight, so treated, not exceeding 2,000 lb (900 kg).

(c) One test shall be made for each forging or casting of 1,000 lb to 10,000 lb (450 kg to 4,500 kg).

(d) As an alternative to (c), a separate test forging or casting may be used to represent forgings or castings of different sizes in one heat and heat treat lot, provided the test piece is a representation of the greatest thickness in the heat treat lot. In addition, test forgings shall have been subjected to substantially the same reduction and working as the forgings represented.

(e) For Class 2 Only:

(1) Forgings or castings larger than 10,000 lb (4,500 kg) shall have two tests per part for Charpy V-notch and one test for drop weights. The location of drop weight or $C_V$ test specimens shall be
selected so that an equal number of specimens is obtained from positions in the forging or casting 180 deg apart. [Note to Editors: was NC-2342(e)]

(2) As an alternative to (e)(1) for static castings, a separately cast coupon [NC-2226(b)(2)] may be used; one test shall be made for Charpy V-notch and one test for drop weight. [Note to Editors: was NC-2342(f)]

(f) For Class 3 Only:

(1) Forgings or castings larger than 10,000 lb (4 500 kg) shall have two tests per part for Charpy V-notch. The location of C, impact test specimens shall be selected so that an equal number of specimens is obtained from positions in the forging or casting 180 deg apart. [Note to Editors: was ND-2342(e)]

(2) As an alternative to (1) for static castings, a separately cast coupon [NC-D-2226(b)(2)] may be used; one test shall be made for Charpy V-notch. [Note to Editors: was ND-2342(f)]

**NC-NCD-2343 Bars**

One test shall be made for each lot of bars with a cross-sectional area greater than 1 in.\(^2\) (650 mm\(^2\)) where a lot is defined as one heat of material heat treated in one charge or as one continuous operation, not to exceed 6,000 lb (2 700 kg).

**NC-NCD-2344 Tubular Products and Fittings**

On products which are seamless or welded without filler metal, one test shall be made from each lot. On products which are welded with filler metal, one additional test with the specimens taken from the weld area shall also be made on each lot. A lot shall be defined as stated in the applicable material specification, but in no case shall a lot consist of products from more than one heat of material and of more than one diameter, with the nominal thickness of any product included not exceeding that to be impact tested by more than \(\frac{1}{4}\) in. (6 mm); such a lot shall be in a single heat treatment load or in the same continuous run in a continuous furnace controlled within a 50 °F (28°C) range and equipped with recording pyrometers.

**NC-NCD-2345 Bolting Material**

One test shall be made for each lot of material where a lot is defined as one heat of material heat treated in one charge or as one continuous operation, not to exceed in weight the following:

<table>
<thead>
<tr>
<th>Diameter, in. (mm)</th>
<th>Weight, lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{1}{4}) (44) and less</td>
<td>1,500 (680)</td>
</tr>
<tr>
<td>Over (\frac{1}{4}) to 2 (\frac{1}{2}) (44 to 64)</td>
<td>3,000 (1 350)</td>
</tr>
<tr>
<td>Diameter, in. (mm)</td>
<td>Weight, lb (kg)</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Over 2½ to 5 (64 to 125)</td>
<td>6,000 (2,700)</td>
</tr>
<tr>
<td>Over 5 (125)</td>
<td>10,000 (4,500)</td>
</tr>
</tbody>
</table>

**NC-NCD-2350 Retests**

**NC-NCD-2351 Retests for Material Other Than Bolting**

NCD-2351.1 For Class 2 Only [Note to Editor: was NC-2351]

(a) For Charpy V-notch tests required by NC-D-2330, one retest at the same temperature may be conducted, provided:

1. the average value of the test results meets the average of three requirements specified in Table NC-D-2332.1-1 or Table NC-D-2332.1-2, as applicable;

2. not more than one specimen per test is below the lowest one of three requirements specified in Table NC-D-2332.1-1 or Table NC-D-2332.1-2, as applicable;

3. the specimen not meeting the requirements is not lower than 5 ft-lb (6.8 J) or 5 mils (0.13 mm) below the lowest one of three requirements specified in Table NC-D-2332.1-1 or Table NC-D-2332.1-2, as applicable.

(b) A retest consists of two additional specimens taken as near as practicable to the failed specimens. For acceptance of the retests, both specimens shall be equal to or greater than the average of three requirements specified in Table NC-D-2332.1-1 or Table NC-D-2332.1-2, as applicable.

NCD-2351.2 For Class 3 Only [Note to Editor: was ND-2351 except for renumbered table references]

(a) For Charpy V-notch tests required by NC-D-2330, one retest at the same temperature may be conducted, provided:

1. the average value of the test results meets the average of three requirements specified in Table NC-D-2333.1-1 or Table NC-D-2333.1-2, as applicable;

2. not more than one specimen per test is below the lowest one of three requirements specified in Table NC-D-2333.1-1 or Table NC-D-2333.1-2, as applicable;

3. the specimen not meeting the requirements is not lower than 5 ft-lb (6.8 J) or 5 mils (0.13 mm) below the lowest one of three requirements specified in Table NC-D-2333.1-1 or Table NC-D-2333.1-2, as applicable.

(b) A retest consists of two additional specimens taken as near as practicable to the failed specimens. For acceptance of the retests, both specimens shall be equal to or greater than the average of three requirements specified in Table NC-D-2333.1-1 or Table NC-D-2333.1-2, as applicable.
NC-NCD-2352 Retests for Bolting Material

(a) For Charpy V-notch tests required by NC-NCD-2330, one retest at the same temperature may be conducted, provided:

1. not more than one specimen per test is below the acceptance requirements;
2. the specimen not meeting the acceptance requirements is not lower than 5 ft-lb (6.8 J) or 5 mils (0.13 mm) below the acceptance requirements.

(b) A retest consists of two additional specimens taken as near as practicable to the failed specimens. For acceptance of the retests, both specimens shall meet the specified acceptance requirements.

NC-NCD-2360 Calibration of Instruments and Equipment

Calibration of temperature instruments and C_v impact test machines used in impact testing shall be performed at the frequency specified in (a) or (b) below.

(a) Temperature instruments used to control test temperature of specimens shall be calibrated and the results recorded to meet the requirements of NCA-4258.2 at least once in each 3-month interval.

(b) C_v impact test machines shall be calibrated and the results recorded to meet the requirements of NCA-4258.2. The calibrations shall be performed using the frequency and methods outlined in ASTM E23 and employing standard specimens obtained from the National Institute of Standards and Technology, or any supplier of subcontracted calibration services accredited in accordance with the requirements of NCA-3126 and NCA-4255.3(c).

NC-NCD-2400 Welding Material

NC-NCD-2410 General Requirements

(a) All welding material used in the construction and repair of components or material, except welding material used for cladding or hard surfacing, shall conform to the requirements of the welding material specification or to the requirements for other welding material as permitted in Section IX. In addition, welding material shall conform to the requirements stated in this subarticle and to the rules covering identification in NC-NCD-2150.

(b) The Certificate Holder shall provide the organization performing the testing with the information listed below, as applicable:

1. welding process;
2. SFA specification and classification;
3. other identification if no SFA specification applies;
4. minimum tensile strength [NC-NCD-2431.1(d)] of the material in either the as-welded or heat-treated condition, or both [NC-NCD-2431.1(e)].
(5) **For Class 2 only** - drop weight test results for material in either the as-welded or heat-treated condition, or both (see **NC-NCD-2332**);

(6) Charpy V-notch test results for material in either the as-welded, or heat treated condition, or both (NC-NCD-2331 for Class 2 or NC-NCD-2333 for Class 3); both the test temperature and either the lateral expansion or the absorbed energy shall be provided;

(7) the preheat and interpass temperatures to be used during welding of the test coupon [NC-NCD-2431.1(e)];

(8) postweld heat treatment time, temperature range, and maximum cooling rate, if the production weld will be heat treated [NC-NCD-2431.1(e)];

(9) elements for which chemical analysis is required per the SFA specification or WPS, and NC-NCD-2431;

(10) minimum delta ferrite [NC-NCD-2433].

**NC-NCD-2420 Required Tests**

The required tests shall be conducted for each lot of covered, flux-cored, or fabricated electrodes; for each heat of bare electrodes, rod, or wire for use with the OFW, GMAW, GTAW, PAW, and EGW (electrogas welding) processes (Section IX, QG-109); for each heat of consumable inserts; for each combination of heat of bare electrodes and lot of submerged arc flux; for each combination of lot of fabricated electrodes and lot of submerged arc flux; for each combination of heat of bare electrodes or lot of fabricated electrodes, and dry blend of supplementary powdered filler metal, and lot of submerged arc flux; or for each combination of heat of bare electrodes and lot of electroslag flux. The definitions in SFA-5.01 and the Lot Classes specified in (a) through (e) below shall apply.

(a) each Lot Class C3 of covered electrodes.

(b) each Lot Class T2 of tubular-cored electrodes and rods (flux cored or fabricated).

(c) each Lot Class S2 of fully metallic solid welding consumables (bare electrode, rod, wire, consumable insert, or powdered filler metal).

(d) each Lot Class S2 of fully metallic solid welding electrodes or each Lot Class T2 of tubular-cored (fabricated) electrodes and each Lot Class F2 of submerged arc or electroslag welding flux.

(e) each Lot Class S2 of fully metallic solid welding electrodes or each Lot Class T2 of tubular-cored (fabricated) electrodes and each Lot Class F2 of submerged arc or electroslag welding flux and each Lot Class S2 of supplementary powdered filler metal. The chemical analysis range of the supplemental powdered filler metal shall be the same as that of the welding electrode, and the ratio of powder to electrode used to make the test coupon shall be the maximum permitted for production welding.

In all cases, when filler metal of controlled chemical composition (as opposed to heat control) is used, each container of welding consumable shall be coded for identification and shall be traceable to the production period, the shift, the manufacturing line, and the analysis of the steel rod or strip. Carbon,
manganese, silicon, and other intentionally added elements shall be identified to ensure that the material conforms to the SFA or user's material specification. The use of controlled chemical composition is only permitted for carbon and low alloy steel consumables. Tests performed on welding material in the qualification of weld procedures will satisfy the testing requirements for the lot, heat, or combination of heat and batch of welding material used, provided the tests required by Article NC-D-4000 and this subarticle are made and the results conform to the requirements of this Article.

**NC-NCD-2430 Weld Metal Tests**

**NC-NCD-2431 Mechanical Properties Test**

Tensile and impact tests shall be made in accordance with this paragraph, of welding materials which are used to join P-Nos. 1, 3, 4, 5, 6, 7, 9, and 11 base materials in any combination, with the exceptions listed in (a) through (d) below.

(a) austenitic stainless steel and nonferrous welding material used to join the listed P-Numbers;

(b) consumable inserts (backing filler material);

(c) welding material used for GTAW root deposits with a maximum of two layers;

(d) welding material to be used for the welding of base materials exempted from impact testing by NC-D-2311(a)(1) through NC-D-2311(a)(7) or NC-D-2311(a)(8)(b) for Class 2 or NC-D-2311(a)(9) shall also be exempted from the impact testing required by this paragraph.

**NC-NCD-2431.1 General Test Requirements.**

The welding test coupon shall be made in accordance with (a) through (f) below, using each process with which the weld material will be used in production welding.

(a) Test coupons shall be of sufficient size and thickness such that the test specimens required herein can be removed.

(b) The weld metal to be tested for all processes except electroslag welding shall be deposited in such a manner as to substantially eliminate the influence of the base material on the results of the tests. Weld metal to be used with the electroslag process shall be deposited in such a manner as to conform to one of the applicable Welding Procedure Specifications (WPS) for production welding. The base material shall conform to the requirements of Section IX, QW-403.1 or QW-403.4, as applicable.

(c) The welding of the test coupon shall be performed within the range of preheat and interpass temperatures that will be used in production welding. Coupons shall be tested in the as-welded condition, or they shall be tested in the applicable postweld heat-treated condition when the production welds are to be postweld heat treated. The postweld heat treatment holding time shall be at least 80% of the maximum time to be applied to the weld metal in production application. The total time for postweld heat treatment of the test coupon may be applied in one heating cycle. The cooling rate from the postweld heat treatment temperature shall be of the same order as that applicable to the weld metal in the component. In addition, weld coupons for weld metal to be used with the electroslag process, which are tested in the as-welded condition or following a postweld heat treatment within the holding temperature ranges of Table NC-D-4622.1 or Table NC-D-4622.4(e), shall have a thickness within the range of 0.5 to 1.1 times the thickness of the welds to be made in
production. Electroslag weld coupons to be tested following a postweld heat treatment, which will include heating the coupon to a temperature above the Holding Temperature Range of Table NC-D-4622.1 for the type of material being tested, shall have a thickness within the range of 0.9 to 1.1 times the thickness of the welds to be made in production.

(d) The tensile specimens, and the C, impact specimens when required, shall be located and prepared in accordance with the requirements of SFA-5.1 or the applicable SFA Specification. Drop weight impact test specimens, where required, shall be oriented so that the longitudinal axis is transverse to the weld, with the notch in the weld face or in a plane parallel to the weld face. For impact specimen preparation and testing, the applicable parts of NC-D-2331 and NC-D-2332 shall apply. The longitudinal axis of the specimen shall be at a minimum depth of \( \frac{1}{4}t \) from a surface, where \( t \) is the thickness of the test weld.

(e) One all-weld-metal tensile specimen shall be tested and shall meet the specified minimum tensile strength requirements of the base material specification. Where base materials of different specifications are to be welded, the tensile strength requirements shall conform to the specified minimum tensile strength requirement of either of the base material specifications.

(f) Impact specimens of the weld metal shall be tested where impact tests are required for either of the base materials of the production weld. The weld metal shall conform to the parts of NC-D-2331, NC-D-2332 or NCD-2333 applicable to the base material. Where different requirements exist for the two base materials, the weld metal may conform to either of the requirements for either base material.

NC-NCD-2431.2 Standard Test Requirements.

In lieu of the use of the General Test Requirements specified in NC-D-2431, tensile and impact tests may be made in accordance with this subparagraph where they are required for mild and low alloy steel covered electrodes. The material combinations to require weld material testing, as listed in NC-D-2431, shall apply for this option. The limitations and testing under this option shall be in accordance with (a) through (f) below.

(a) Testing to the requirements of this subparagraph shall be limited to electrode classifications included in SFA-5.1 or SFA-5.5.

(b) The assembly required by SFA-5.1 or SFA-5.5, as applicable, shall be used for test coupon preparation, except that it shall be increased in size to obtain the number of impact specimens required by NC-D-2331 or NC-D-2332 or NCD-2333, as applicable.

(c) The welding of the test coupon shall conform to the requirements of the SFA specification for the classification of electrode being tested. Coupons shall be tested in the as-welded condition and also the postweld heat-treated condition. The postweld heat treatment temperatures shall be in accordance with Table NC-D-4622.1 for the applicable P-Number equivalent. The time at postweld heat treatment temperature shall be 8 hr (this qualifies postweld heat treatments of 10 hr or less). When the postweld heat treatment of the production weld exceeds 10 hr or the PWHT temperature is other than that required, the general test of NC-D-2431 shall be used.

(d) The tensile and C, specimens shall be located and prepared in accordance with the requirements of SFA-5.1 or SFA-5.5, as applicable. Drop weight impact test specimens, where required, shall be located and oriented as specified in NC-D-2431.1(d).
One all-weld-metal tensile specimen shall be tested and shall meet the specified minimum tensile strength requirement of the SFA specification for the applicable electrode classification.

The requirements of NC-NCD-2431.1(f) shall be applicable to the impact testing.

NC-NCD-2432 Chemical Analysis Test

Chemical analysis of filler metal or weld deposits shall be made in accordance with NC-NCD-2432 and as required by the following subparagraphs.

NC-NCD-2432.1 Test Method.

The chemical analysis test shall be performed in accordance with this subparagraph and Table NC-NCD-2432.1-1, and the results shall conform to NC-NCD-2432.2.

Table NC-NCD-2432.1-1 — Sampling of Welding Materials for Chemical Analysis

<table>
<thead>
<tr>
<th>Welding Material</th>
<th>GTAW/PAW</th>
<th>GMAW</th>
<th>All Other Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-No. 8 filler metal</td>
<td>Filler metal or weld deposit</td>
<td>Weld deposit</td>
<td>Weld deposit</td>
</tr>
<tr>
<td>All other filler metal</td>
<td>Filler metal or weld deposit</td>
<td>Filler metal or weld deposit</td>
<td>Weld deposit</td>
</tr>
</tbody>
</table>

(a) A-No. 8 welding material to be used with GTAW and PAW processes and any other welding material to be used with any GTAW, PAW, or GMAW process shall have chemical analysis performed either on the filler metal or on a weld deposit made with the filler metal in accordance with (c) or (d) below.

(b) A-No. 8 welding material to be used with other than the GTAW and PAW processes and other welding material to be used with other than the GTAW, PAW, or GMAW process shall have chemical analysis performed on a weld deposit of the material or combination of materials being certified in accordance with (c) or (d) below. The removal of chemical analysis samples shall be from an undiluted weld deposit made in accordance with (c) below. As an alternative, the deposit shall be made in accordance with (d) below for material that will be used for corrosion resistant overlay cladding. Where the Welding Procedure Specification or the welding material specification specifies percentage composition limits for analysis, it shall state that the specified limits apply for the filler metal analysis, the undiluted weld deposit analysis, or the in situ cladding deposit analysis in conformance with the above required certification testing.

(c) The preparation of samples for chemical analysis of undiluted weld deposits shall comply with the method given in the applicable SFA specification. Where a weld deposit method is not provided by the SFA specification, the sample shall be removed from a weld pad, groove, or other test weld made using the welding process that will be followed when the welding material or combination of welding materials being certified is consumed. The weld for A-No. 8 material to be used with the GMAW or EGW process shall be made using the shielding gas composition specified in the Welding Procedure Specifications that will be followed when the material is consumed. The test sample for ESW shall be removed from the weld metal of the mechanical properties test coupon. Where a chemical analysis is required for a welding material which does not have a mechanical properties test requirement, a chemical analysis test coupon shall be prepared as required by NC-NCD-2431.1(f), except that heat...
treatment of the coupon is not required and the weld coupon thickness requirements of NC
2431.1(e) do not apply.

(d) The alternate method provided in (b) above for the preparation of samples for chemical analysis of welding material to be used for corrosion resistant overlay cladding shall require a test weld made in accordance with the essential variables of the welding procedure specification that will be followed when the welding material is consumed. The test weld shall be made in conformance with the requirements of Section IX, QW-214.1. The removal of chemical analysis samples shall conform with Section IX, QW-453 for the minimum thickness for which the Welding Procedure Specification is qualified.

NC-NCD-2432.2 Requirements for Chemical Analysis.
The chemical elements to be determined, the composition requirements of the weld metal, and the recording of results of the chemical analysis shall be in accordance with (a), (b), and (c) below.

(a) Welding material of ferrous alloy A-No. 8 (Section IX, Table QW-442) shall be analyzed for the elements listed in Table NC-D-2432.2-1 and for any other elements specified either in the welding material specification referenced by the Welding Procedure Specification or in the Welding Procedure Specification.

(b) The chemical composition of the weld metal or filler metal shall conform to the welding material specification for elements having specified percentage composition limits. Where the Welding Procedure Specification contains a modification of the composition limits of SFA or other referenced welding material specifications, or provides limits for additional elements, these composition limits of the Welding Procedure Specification shall apply for acceptability.

(c) The results of the chemical analysis shall be reported in accordance with NCA-3862.1. Elements listed in Table NC-D-2432.2-1 but not specified in the welding material specification or Welding Procedure Specification shall be reported for information only.

<table>
<thead>
<tr>
<th>Table NCD-2432.2-1 — Welding Material Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Cr–Ni stainless materials</td>
</tr>
</tbody>
</table>

NC-NCD-2433 Delta Ferrite Determination

A determination of delta ferrite shall be performed on A-No. 8 weld material (Section IX, Table QW-442) backing filler metal (consumable inserts); bare electrode, rod, or wire filler metal; or weld metal, except that delta ferrite determinations are not required for SFA-5.4 Type 16-8-2 or A-No. 8 weld filler metal to be used for weld metal cladding.

NC-NCD-2433.1 Method.

Delta ferrite determinations of welding material, including consumable insert material, shall be made using a magnetic measuring instrument and weld deposits made in accordance with (b) below. Alternatively, the delta ferrite determinations for welding materials may be performed by the use of the chemical analysis of NC-D-2432 in conjunction with Figure NC-D-2433.1-1.

(a) Calibration of magnetic instruments shall conform to AWS-A 4.2.
(b) The weld deposit for magnetic delta ferrite determination shall be made in accordance with NC-2433.1(e).

(c) A minimum of six ferrite readings shall be taken on the surface of the weld deposit. The readings obtained shall be averaged to a single Ferrite Number (FN).

**Figure NCD-2433.1-1 — Weld Metal Delta Ferrite Content**

**GENERAL NOTES:**
(a) The actual nitrogen content is preferred. If this is not available, the following applicable nitrogen value shall be used:

1. GMAW welds — 0.08%, except that when self-shielding flux-cored electrodes are used — 0.12%.
2. Welds made using other processes — 0.06%.

(b) This diagram is identical to the WRC-1992 Diagram, except that the solidification mode lines have been removed for ease of use.

**NC-NCD-2433.2 Acceptance Standards.**
The minimum acceptable delta ferrite shall be 5FN (Ferrite Number). The results of the delta ferrite determination shall be included in the Certified Material Test Report of NC-NCD-2130 or NC-NCD-4120.
NC-NCD-2440 Storage and Handling of Welding Material

Suitable storage and handling of electrodes, flux, and other welding materials shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.

NC-NCD-2500 Examination and Repair of Pressure-Retaining Material

NC-NCD-2510 Pressure-Retaining Material

Pressure-retaining material shall be examined and repaired in accordance with the material specification and as otherwise required by this subarticle. Pressure-retaining material for ASME B16.34 Special Class category valves shall be examined and repaired in accordance with the requirements therein and as otherwise required by this subarticle. If the examination and repair requirements of this subarticle either duplicate or exceed the ASME B16.34 requirements, then only the requirements of this subarticle need to be met. Size exclusions or quality factor pressure ratings of this subarticle shall not be applied so as to reduce the examination requirements of ASME B16.34 for Special Class category valves.

NC-NCD-2530 Examination and Repair of Plate

NC-NCD-2531 Required Examination

Plates shall be examined in accordance with the requirements of the material specification.

NC-NCD-2537 Time of Examination

Acceptance examinations shall be performed at the time of manufacture as required in (a) through (c) below.

(a) Examinations required by the material specification shall be performed at the time of manufacture as specified in the material specification.

(b) Radiographic examination of repair welds, when required, may be performed prior to any required postweld heat treatment.

(c) Magnetic particle or liquid penetrant examination of repair welds shall be performed after any required postweld heat treatment, except for P-No. 1 material, which may be examined before or after any required postweld heat treatment.

NC-NCD-2538 Elimination of Surface Defects

Surface defects shall be removed by grinding or machining, provided the requirements of (a) and (b) below are met:

(a) The depression, after defect elimination, is blended uniformly into the surrounding surface.

(b) When the elimination of the defect reduces the thickness of the section below the minimum required by the design, the material shall be repaired in accordance with NC-NCD-2539.
NC-NCD-2539 Repair by Welding

The Material Organization may repair by welding materials from which defects have been removed, provided the depth of the repair cavity does not exceed one-third of the nominal thickness and the requirements of the following subparagraphs are met. Prior approval of the Certificate Holder shall be obtained for the repair of plates to be used in the manufacture of vessels.

NC-NCD-2539.1 Defect Removal.
The defect shall be removed or reduced to an imperfection of acceptable limit by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair (NC-D-4211.1).

NC-NCD-2539.2 Qualification of Welding Procedures and Welders.
The welding procedure and welders or welding operators shall be qualified in accordance with Article NC-D-4000 and Section IX.

NC-NCD-2539.3 Blending of Repaired Areas.
After repair, the surface shall be blended uniformly into the surrounding surface.

NC-NCD-2539.4 Examination of Repair Welds.
Each repair weld shall be examined by the magnetic particle method (NC-D-2545) or by the liquid penetrant method (NC-D-2546). In addition, when the depth of the repair cavity exceeds the lesser of 3/8 in. (10 mm) or 10% of the section thickness, the repair weld shall be radiographed in accordance with and to the applicable acceptance standards of NC-D-5320. The image quality indicator (IQI) shall be based upon the section thickness of the repaired area.

NC-NCD-2539.5 Heat Treatment After Repairs.
The product shall be heat treated after repair in accordance with the requirements of NC-D-4620.

NC-NCD-2539.6 Material Report Describing Defects and Repair.
Each defect repair that is required to be radiographed shall be described in the Certified Material Test Report. The Certified Material Test Report for each piece shall include a chart which shows the location and size of the prepared cavity, the welding material identification, the welding procedure, the heat treatment, and a report of the results of the examinations, including radiographs.

NC-NCD-2540 Examination and Repair of Forgings and Bars

NC-NCD-2541 Required Examinations

Forgings and bars shall be examined in accordance with the requirements of the material specification, except when magnetic particle or liquid penetrant examination is specifically required by the rules of this Subsection, in which case the examination shall conform to the requirements of NC-D-2545 or NC-D-2546, as applicable.

NC-NCD-2545 Magnetic Particle Examination

NC-NCD-2545.1 Examination Procedure.
The procedure for magnetic particle examination shall be in accordance with the methods of Section V, Article 7.
NC-NCD-2545.2 Evaluation of Indications.

(a) Mechanical discontinuities at the surface are revealed by the retention of the examination medium. All indications are not necessarily defects, however, since certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant.

(b) Any indication in excess of the NC-NCD-2545 acceptance standards which is believed to be nonrelevant shall be reexamined by the same or other nondestructive examination methods to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications which would mask defects are unacceptable.

(c) Relevant indications are those which result from imperfections. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length equal to or less than three times the width. Indications resulting from nonmetallic inclusions are not considered relevant indications.

NC-NCD-2545.3 Acceptance Standards.

(a) Only imperfections producing indications with major dimensions greater than 1/16 in. (1.5 mm) shall be considered relevant imperfections.

(b) Imperfections producing the following relevant indications are unacceptable:

1. any linear indications greater than 1/16 in. (1.5 mm) long for material less than 5/8 in. (16 mm) thick, greater than 1/8 in. (3 mm) long for material from 5/8 in. (16 mm) thick to under 2 in. (50 mm) thick, and 1/16 in. (5 mm) long for material 2 in. (50 mm) thick and greater;

2. rounded indications with dimensions greater than 1/8 in. (3 mm) for thicknesses less than 5/8 in. (16 mm) and greater than 3/16 in. (5 mm) for thicknesses 5/8 in. (16 mm) and greater;

3. four or more relevant indications in a line separated by 1/16 in. (1.5 mm) or less edge to edge;

4. ten or more relevant indications in any 6 in.² (4 000 mm²) of area whose major dimension is no more than 6 in. (150 mm) with the dimensions taken in the most unfavorable location relative to the indications being evaluated.

NC-NCD-2546 Liquid Penetrant Examinations

NC-NCD-2546.1 Examination Procedure.

The procedure for liquid penetrant examination shall be in accordance with the methods of Section V, Article 6.

NC-NCD-2546.2 Evaluation of Indications.

(a) Mechanical discontinuities at the surface are revealed by bleeding out of the penetrant; however, localized surface discontinuities, such as may occur from machining marks or surface conditions, may produce similar indications which are not relevant.
(b) Any indication in excess of the NC-NCD-2546.3 acceptance standards, which is believed to be nonrelevant, shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications and broad areas of pigmentation which would mask defects are unacceptable.

(c) Relevant indications are those which result from imperfections. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length equal to or less than three times the width.

NC-NCD-2546.3 Acceptance Standards.

(a) Only imperfections producing indications with major dimensions greater than \(\frac{1}{16}\) in. (1.5 mm) shall be considered relevant.

(b) Imperfections producing the following relevant indications are unacceptable:

1. any linear indications greater than \(\frac{1}{16}\) in. (1.5 mm) long for material less than \(\frac{5}{8}\) in. (16 mm) thick, greater than \(\frac{1}{8}\) in. (3 mm) long for material from \(\frac{5}{8}\) in. (16 mm) thick to under 2 in. (50 mm) thick, and \(\frac{3}{16}\) in. (5 mm) long for material 2 in. (50 mm) thick and greater;

2. rounded indications with dimensions greater than \(\frac{1}{6}\) in. (3 mm) for thicknesses less than \(\frac{5}{8}\) in. (16 mm) and greater than \(\frac{1}{16}\) in. (5 mm) for thicknesses \(\frac{5}{8}\) in. (16 mm) and greater;

3. four or more relevant indications in a line separated by \(\frac{1}{16}\) in. (1.5 mm) or less edge to edge;

4. ten or more relevant indications in any 6 in.\(^2\) (4 000 mm\(^2\)) of area whose major dimension is no more than 6 in. (150 mm) with the dimensions taken in the most unfavorable location relative to the indications being evaluated.

NC-NCD-2547 Time of Examination

The requirements for time of examination shall be the same as stated in NC-NCD-2537 except that

(a) magnetic particle or liquid penetrant examination shall be performed in the finished condition

(b) forged and rolled bars that are to be bored or turned to form tubular products or fittings shall be examined after boring or turning, except for threaded or drilled holes

NC-NCD-2548 Elimination of Surface Defects

(a) Unacceptable surface defects shall be removed by grinding or machining, provided the requirements of (1) through (4) below are met.

1. The remaining thickness of the section is not reduced below that required by Article NC-NCD-3000.

2. The depression, after defect elimination, is blended uniformly into the surrounding surface.
(3) After defect elimination, the area is reexamined by the magnetic particle method in accordance with NC-D-2545 or the liquid penetrant method in accordance with NC-D-2546 to ensure that the defect has been removed or the indication reduced to an acceptable size.

(4) Areas ground to remove oxide scale or other mechanically caused impressions for appearance or to facilitate proper ultrasonic testing need not be examined by the magnetic particle or liquid penetrant method.

(b) When the elimination of the defect reduces the thickness of the section below the minimum required to satisfy Article NC-D-3000, the product shall be repaired in accordance with NC-D-2549.

**NC-NCD-2549 Repair by Welding**

The Material Organization may repair by welding material from which defects have been removed, provided the requirements of NC-D-2549.1 through NC-D-2549.6 are met.

**NC-NCD-2549.1 Defect Removal.**
The defect shall be removed or indication reduced to an acceptable size by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair (NC-D-2111).

**NC-NCD-2549.2 Qualification of Welding Procedures and Welders.**
The welding procedure and welders or welding operators shall be qualified in accordance with Article NC-D-4000 and Section IX.

**NC-NCD-2549.3 Blending of Repaired Areas.**
After repair, the surface shall be blended uniformly into the surrounding surface.

**NC-NCD-2549.4 Examination of Repair Welds.**
Each repair weld shall be examined by the magnetic particle method (NC-D-2545) or by the liquid penetrant method (NC-D-2546). In addition, when the depth of the repair cavity exceeds the lesser of \( \frac{3}{8} \) in. (10 mm) or 10% of the section thickness, the repair weld shall be radiographed after repair in accordance with NC-D-5320. The image quality indicator (IQI) and the acceptance standards for radiographic examination of repair welds shall be based on the section thickness at the repaired area.

**NC-NCD-2549.5 Heat Treatment After Repairs.**
The product shall be heat treated after repair in accordance with the heat treatment requirements of NC-D-4620.

**NC-NCD-2549.6 Material Report Describing Defects and Repairs.**
Each defect repair exceeding in depth the lesser of \( \frac{3}{8} \) in. (10 mm) or 10% of the section thickness shall be described in the Certified Material Test Report. The Certified Material Test Report for each piece shall include a chart that shows the location and size of the prepared cavity, the welding material identification, the welding procedure, the heat treatment, and the examination results, including radiographs.
NC-NCD-2550 Examination and Repair of Seamless and Welded (Without Filler Metal) Tubular Products and Fittings

NC-NCD-2551 Required Examination

NCD-2551.1 Class 2 Only [Note to Editors: was NC-2551]

(a) All seam welds in welded (without filler metal) tubular products shall be examined by one of the following methods:

(1) ultrasonic examination in accordance with NC-D-2552;

(2) radiographic examination in accordance with NC-D-2553;

(3) eddy current examination in accordance with NC-D-2554.

(b) Wrought seamless and welded (without filler metal) tubular products and fittings, except copper alloy and nickel alloy tubular products and fittings, shall comply with the requirements of NC-D-2557, NC-D-2558, and NC-D-2559, in addition to the basic material specification.

(c) Copper alloy and nickel alloy wrought seamless and welded (without filler metal) tubular products and fittings shall comply with the requirements of NC-D-2558, in addition to the basic material specification.

NCD-2551.2 Class 3 Only [Note to Editors: was ND-2551]

Wrought seamless and welded (without filler metal) tubular products and fittings shall comply with the requirements of NC-D-2557, NC-D-2558, and NC-D-2559, in addition to the basic material specification.

NC-NCD-2552 Ultrasonic Examination (Class 2 Only)

NC-NCD-2552.1 Examination Procedure for Welds in Pipe and Tubing.

(a) Circumferential Direction — 6 3/4 in. (170 mm) O.D. and Smaller. The welds in pipe and tubing shall be examined in two circumferential directions. The procedure for ultrasonic examination of pipe and tubing in the circumferential direction shall be in accordance with SE-213, Standard Method for Ultrasonic Examination of Pipe and Tubing for Longitudinal Discontinuities, and the requirements of this paragraph. The procedure shall provide a sensitivity which will consistently detect defects that produce indications equal to or greater than the indications produced by standard defects included in the reference specimens specified in NC-D-2552.

(b) Pipe and Tubing Larger Than 6 3/4 in. (170 mm) O.D. The welds in pipe and tubing shall be examined in two circumferential directions. The procedure for ultrasonic examination of pipe and tubing larger than 6 3/4 in. (170 mm) O.D. shall be in accordance either with the requirements of SA-388 for angle beam scanning in the circumferential direction, or with the requirements of SE-213. The reference standard shall be in accordance with NC-D-2552.1 below.
Acceptance Standard. Products with defects that produce indications in excess of the indications produced by the standard defects in the reference specimen are unacceptable unless the defects are eliminated or repaired in accordance with NC-NCD-2558 or NC-NCD-2559.

NC-NCD-2552.2 Examination Procedure for Welds in Fittings.

(a) Procedure. The procedure for ultrasonic examination of welds in fittings shall be in accordance with the requirements of Recommended Practice SA-388 for angle beam examination in two circumferential directions.

(b) Acceptance Standard. Fittings shall be unacceptable if angle beam examination results show one or more reflectors which produce indications exceeding in amplitude the indications from the calibrated notch.

NC-NCD-2552.3 Reference Specimens.

(a) The reference specimen shall be of the same nominal diameter and thickness and of the same nominal composition and heat-treated condition as the product which is being examined. For circumferential scanning, the standard defects shall be axial notches or grooves on the outside and inside surfaces of the reference specimen and shall have a length of approximately 1 in. (25 mm) or less, a width not to exceed \(\frac{1}{16}\) in. (1.5 mm) for a square notch or U-notch, a width proportional to the depth for a V-notch, and a depth not greater than the larger of 0.004 in. (0.10 mm) or 5% of the nominal wall thickness.

(b) The reference specimen shall be long enough to simulate the handling of the product being examined through the examination equipment. When more than one standard defect is placed in a reference specimen, the defects shall be located so that indications from each defect are separate and distinct without mutual interference or amplification. All upset metal and burrs adjacent to the reference notches shall be removed.

NC-NCD-2552.4 Checking and Calibration of Equipment.

The proper functioning of the examination equipment shall be checked, and the equipment shall be calibrated by the use of the reference specimens, as a minimum:

(a) at the beginning of each production run of a given size and thickness of a given material;

(b) after each 4 hr or less during the production run;

(c) at the end of the production run;

(d) at any time that malfunctioning is suspected.

If, during any check, it is determined that the testing equipment is not functioning properly, all of the product that has been tested since the last valid equipment calibration shall be reexamined.

NC-NCD-2553 Radiographic Examination (Class 2 Only)

(a) General. When radiographic examination is performed as an alternative to ultrasonic examination of the entire volume of the material, it shall apply to the entire volume of the pipe, tube, or fitting.
material. Acceptance standards specified for welds shall apply to the entire volume of material examined.

(b) **Examination Procedure.** The radiographic examination shall be performed in accordance with Section V, Article 2, as modified by NC-NCD-5111.

(c) **Acceptance Standard.** Welds that are shown by radiography to have any of the following types of discontinuities are unacceptable:

1. any type of crack or zone of incomplete fusion or penetration;
2. any other elongated indication which has a length greater than:
   - (a) $1/4$ in. (6 mm) for $t$ up to $3/4$ in. (19 mm), inclusive
   - (b) $1/3t$ for $t$ from $3/4$ in. (19 mm) to $21/4$ in. (57 mm), inclusive
   - (c) $3/4$ in. (19 mm) for $t$ over $21/4$ in. (57 mm)

   where $t$ is the thickness of the thinner portion of the weld;

3. any group of aligned indications having an aggregate length greater than $t$ in a length of $12t$, unless the minimum distance between successive indications exceeds $6L$, in which case the aggregate length is unlimited, $L$ being the length of the largest indication;

4. rounded indications in excess of that shown as acceptable in Section III Appendices, Mandatory Appendix VI.

**NC-NCD-2554 Eddy Current Examination (Class 2 Only)**

This examination method is restricted to materials with uniform magnetic properties and of sizes for which meaningful results can be obtained.

**NC-NCD-2554.1 Examination Procedure.**

The procedure for eddy current examination shall provide a sensitivity that will consistently detect defects by comparison with the standard defects included in the reference specimen specified in NC-NCD-25522. Products with defects that produce indications in excess of the reference standards are unacceptable unless the defects are eliminated or repaired in accordance with NC-NCD-2558 or NC-NCD-2559 as applicable.

**NC-NCD-2554.2 Reference Specimens.**

The reference specimen shall be of the same nominal diameter and thickness and of the same nominal composition and heat-treated condition as the product that is being examined. The standard shall contain tangential or circumferential notches on the outside surface plus a $1/16$ in. (1.5 mm) diameter hole drilled through the wall. These shall be used to establish the rejection level for the product to be tested. The reference notches shall have a depth not greater than the larger of 0.004 in. (0.10 mm) or 5% of the wall thickness. The width of the notch shall not exceed $1/16$ in. (1.5 mm). The length shall be approximately 1 in. (25 mm) or less. The size of reference specimens shall be as specified in NC-NCD-25522.
NC-NCD-2554.3 Checking and Calibration of Equipment.
The checking and calibration of examination equipment shall be the same as in NC-NCD-2552.4.

NC-NCD-2557 Time of Examination

(a) Products that are quenched and tempered shall be examined, as required, after the quenching and tempering heat treatment.

(b) Products that are not quenched and tempered shall receive the required examinations as follows:

(1) (Class 2 Only) Ultrasonic or eddy current examination, when required, shall be performed after final heat treatment, except postweld heat treatment.

(2) (Class 2 Only) Radiographic examination, when required, may be performed prior to any required postweld heat treatment.

(3) Magnetic particle or liquid penetrant examination of welds, including repair welds, shall be performed after final heat treatment, except that the examination may be performed prior to postweld heat treatment for P-No. 1 (Section IX of the Code) materials of 2 in. (50 mm) and less nominal thickness.

(4) Forgings and rolled bars which are to be bored and/or turned to form tubular parts or fittings shall be examined after boring and/or turning, except for threading; fittings shall be examined after final forming.

(5) When surface examination is required, all external surfaces and all accessible internal surfaces shall be examined, except for bolt holes and threads.

NC-NCD-2558 Elimination of Surface Defects

Surface defects shall be removed by grinding or machining, provided the requirements of (a) through (c) below are met:

(a) the depression, after defect elimination, is blended uniformly into the surrounding surface;

(b) after defect elimination, the area is examined by the method which originally disclosed the defect to assure that the defect has been removed or reduced to an imperfection of acceptable size;

(c) if the elimination of the defect reduces the thickness of the section below the minimum required to satisfy the rules of Article NC-NCD-3000, the product shall be repaired in accordance with NC-NCD-2559.

NC-NCD-2559 Repair by Welding

Repair of defects shall be in accordance with NC-NCD-2532, except repair by welding is not permitted on copper alloy and nickel alloy heat exchanger tubes.
NC-NCD-2560 Examination and Repair of Tubular Products and Fittings Welded With Filler Metal

NC-NCD-2561 Required Examination

\[\text{NCD-2561.1 Class 2 only (Note to Editors: was NC-2561)}\]

(a) Welded (with filler metal) tubular products, such as pipe made in accordance with SA-358, SA-409, SA-671, SA-672, and SA-691 and fittings made in accordance with the WPW grades of SA-234, SA-403, and SA-420, which are made by welding with filler metal, shall be treated as material; however, inspection by an Inspector and stamping with the Certification Mark with NPT Designator shall be in accordance with Section III requirements. In addition to the Certification Mark with NPT Designator, a numeral 2 shall be stamped below and outside the official Certification Mark.

(b) In addition to the requirements of the material specification and of this Article, all welds shall be examined 100% by radiography in accordance with the basic material specification. When radiographic examination is not specified in the basic material specification, the welds shall be examined in accordance with NC-D-2563.

(c) Tubular products and fittings which have been radiographed shall be marked to indicate that radiography has been performed. The radiographs and a radiographic report showing exposure locations shall be provided with the Certified Material Test Report.

(d) The Authorized Inspector shall certify by signing the Partial Data Report Form NM-1 (see Section III Appendices, Mandatory Appendix V) in accordance with NCA-5290.

\[\text{NCD-2561.2 Class 3 Only (Note to Editors: was ND-2561)}\]

(a) Welded (with filler metal) tubular products such as pipe made in accordance with SA-134, SA-358, SA-409, SA-671, SA-672, and SA-691 and fittings made in accordance with the WPW grades of SA-234, SA-403, and SA-420 that are made by welding with filler metal shall be treated as materials; however, inspection by an Inspector and stamping with the Certification Mark with NPT Designator shall be in accordance with Section III.
requirements. In addition to the Certification Mark with NPT Designator, the numeral 3 shall be stamped below and outside the official Certification Mark.

(b) In addition to the requirements of the material specification, tubular products shall comply with this Article.

(c) Weld joint efficiency factors listed in Section II, Part D, Subpart 1, Tables 1A and 1B shall apply.

(d) Tubular products and fittings that have been radiographed shall be marked to indicate that radiography has been performed. The radiographs and a radiographic report showing exposure locations shall be provided with the Certified Material Test Report.

(e) The Authorized Inspector shall certify by signing the Partial Data Report Form NM-1 (see Section III Appendices, Mandatory Appendix V) in accordance with NCA-5290.

**NC-NCD-2563 Radiographic Examination (Class 2 Only)**

The radiographic examination shall be performed in accordance with the requirements of NC-NCD-2553.

**NC-NCD-2567 Time of Examination**

The time of examination shall be in accordance with the requirements of NC-NCD-2557.

**NC-NCD-2568 Elimination of Surface Defects**

Unacceptable surface defects shall be removed in accordance with the requirements of NC-NCD-2558.

**NC-NCD-2569 Repair by Welding**

When permitted by the basic material specification, base material defects shall be repair welded in accordance to the requirements of NC-NCD-2559. Repair welding of weld seam defects shall be in accordance with NC-NCD-4450.

**NC-NCD-2570 Examination and Repair of Statically and Centrifugally Cast Products**

In addition to the requirements of the material specification and of this Article NC-NCD-2000, statically and centrifugally cast products shall comply with the following paragraphs.

**NC-NCD-2571 Required Examination**

**NCD-2571.1 Class 2 Only (Note to Editors: was NC-2571)**

(a) Cast products shall be examined by volumetric and/or surface methods, including repairs, as required for the product form by Table NC-NCD-2571.1-1 Class 2 castings.

(b) For cast valves furnished to ASME B16.34 Special Class category, neither the size exclusions nor the quality factor pressure ratings of Table NC-NCD-2571.1-1 shall be applied so as to reduce the required examinations of that Standard. The required examinations by ASME B16.34 for Special
Class category valves shall be performed in accordance with the procedures and acceptance standards of this Subsection.

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Item</th>
<th>Applicable Special Requirements for Class 2 Castings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet piping connections of NPS 2 (DN 50) and less</td>
<td>Cast pipe fittings, pumps, and valves</td>
<td>None, except for ASME B16.34 Special Class category valves which shall be in accordance with NC-D-2571-1(b).</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material other than pipe fittings, pumps, and valves</td>
<td>Cast pressure-retaining materials shall be examined by either radiographic or ultrasonic methods, or a combination of the two methods. Castings or sections of castings, which have coarse grains or configurations which do not yield meaningful results by ultrasonic examination, shall be examined by radiographic methods (NC-D-2575).</td>
</tr>
<tr>
<td></td>
<td>Repair welds in pumps and valves of P-No. 1 or P-No. 8 material</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Repair welds in cast pressure-retaining material other than pumps and valves of P-No. 1 or P-No. 8 material</td>
<td>Each repair weld shall be examined by the magnetic particle method or by the liquid penetrant method. In addition, when radiography of the casting is required, repair welds in cavities, the depth of which exceeds the lesser of ( \frac{3}{8} \text{ in.} (10 \text{ mm}) ) or 10% of the section thickness, shall be radiographed in accordance with NC-D-2575.</td>
</tr>
<tr>
<td>Inlet piping connections over NPS 2 (DN 50) up to and including NPS 4 (DN 100)</td>
<td>Cast pumps and valves with a quality factor of 1.00</td>
<td>Magnetic particle or liquid penetrant examination may be performed on all external surfaces and on all accessible internal surfaces, in lieu of volumetric examination, except the weld ends of cast pumps and valves shall be radiographed for a minimum distance of ( t ) (where ( t ) is the design section thickness of the weld) from the final weld end. For ASME B16.34 Special Class category valves, see NC-D-2571-1(b).</td>
</tr>
<tr>
<td></td>
<td>Cast pumps and valves with a quality factor of 0.70</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material other than cast pumps and valves</td>
<td>Cast pressure-retaining materials shall be examined by either radiographic or ultrasonic methods, or a combination of the two methods. Castings or sections of castings, which have coarse grains or configurations which do not yield meaningful results by ultrasonic examination, shall be examined by radiographic methods.</td>
</tr>
<tr>
<td></td>
<td>Repair welds in pumps and valves of P-No. 1 or P-No. 8 material with a quality factor of 0.70</td>
<td>None</td>
</tr>
</tbody>
</table>
| | Repair welds in cast pressure-retaining material other than pumps | Each repair weld shall be examined by the magnetic particle method or by the liquid penetrant method. In addition, when radiography of the casting is required,
<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Item</th>
<th>Applicable Special Requirements for Class 2 Castings</th>
</tr>
</thead>
<tbody>
<tr>
<td>and valves of P-No. 1 or P-No. 8 material with a quality factor of 0.70 material with a quality factor of 0.70</td>
<td>repair welds in cavities, the depth of which exceeds the lesser of $\frac{3}{8}$ in. (10 mm) or 10% of the section thickness, shall be radiographed in accordance with NCD-2575.</td>
<td></td>
</tr>
<tr>
<td>Inlet piping connections over NPS 4 (DN 100)</td>
<td>Cast pressure-retaining materials</td>
<td>Cast pressure-retaining materials shall be examined by either radiographic or ultrasonic methods, or a combination of the two methods. Castings or sections of castings, which have coarse grains or configurations which do not yield meaningful results by ultrasonic examination, shall be examined by radiographic methods. For ASME B16.34 Special Class category valves, see NCD-2571.2(b).</td>
</tr>
<tr>
<td>Repair welds</td>
<td>Each repair weld shall be examined by the magnetic particle method or by the liquid penetrant method. In addition, when radiography of the casting is required, repair welds in cavities, the depth of which exceeds the lesser of $\frac{3}{8}$ in. (10 mm) or 10% of the section thickness, shall be radiographed in accordance with NCD-2575.</td>
<td></td>
</tr>
</tbody>
</table>

NCD-2571.2 Class 3 Only  
(See to Editors: was ND-2571)

(a) Cast products shall be examined by volumetric and/or surface methods, including repairs, as required for the product form by Table NCD-2571.2-1 Class 3 castings.

(b) For cast valves furnished to ASME B16.34 Special Class category, neither the size exclusions nor the quality factor pressure ratings of Table NCD-2571.2-1 shall be applied so as to reduce the required examinations of that Standard. The required examinations by ASME B16.34 for Special Class category valves shall be performed in accordance with the procedures and acceptance standards of this Subsection.

Table NCD-2571.2-1 — Required Examinations for Class 3 Castings  
(See to Editors: was Table ND-2571-1 except for renumbered references)

<table>
<thead>
<tr>
<th>Nominal Pipe Size</th>
<th>Item</th>
<th>Applicable Special Requirements for Class 3 Castings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet piping connections of NPS 2 (DN 50) and less</td>
<td>Cast Pipe fittings, pump, and valves</td>
<td>None, except for ASME B16.34 special class category valves, which shall be in accordance with NCD-2571.2-1(b).</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material with a quality factor of 0.80, excluding pipe fittings, pumps, and valves</td>
<td>Visual examination required</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material with a quality factor of 0.85, excluding</td>
<td>Magnetic particle or liquid penetrant examination shall be performed on all external surfaces and on all accessible internal surfaces.</td>
</tr>
<tr>
<td>Nominal Pipe Size</td>
<td>Item</td>
<td>Applicable Special Requirements for Class 3 Castings</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td></td>
<td>pipe fittings, pumps, and valves</td>
<td>Radiographic or ultrasonic examination required; magnetic particle or liquid penetrant examination optional</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material with a quality factor of 1.00, excluding pipe fittings, pumps, and valves</td>
<td>Repair welds (a) When magnetic particle or liquid penetrant examination of the casting is required, each repair shall be examined by the magnetic particle method or by the liquid penetrant method. (b) When radiography of the casting is required, repair welds in cavities, the depth of which exceeds the lesser of 3/8 in. (10 mm) or 10% of the section thickness, shall be radiographed in accordance with NCD-2575. (c) When partial radiography of a casting is required, repairs located in an area of the casting which is not covered by radiography need only be examined by the magnetic particle method or by the liquid penetrant method.</td>
</tr>
<tr>
<td>Inlet piping connections over NPS 2 (DN 50)</td>
<td>Cast valves</td>
<td>None, except for ASME B16.34 special class category valves, which shall be in accordance with NCD-2571.2(b). Visual examination required</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material with a quality factor of 0.80, excluding valves</td>
<td>Magnetic particle or liquid penetrant examination shall be performed on all external surfaces and on all accessible internal surfaces.</td>
</tr>
<tr>
<td></td>
<td>Cast pressure-retaining material with a quality factor of 0.85, excluding valves</td>
<td>Radiographic or ultrasonic examination required, magnetic particle or liquid penetrant examination optional</td>
</tr>
<tr>
<td></td>
<td>Repair welds</td>
<td>Repair welds (a) When magnetic particle or liquid penetrant examination of the casting is required, each repair weld shall be examined by the magnetic particle method or by the liquid penetrant method.</td>
</tr>
</tbody>
</table>
### Nominal Pipe Size

<table>
<thead>
<tr>
<th>Item</th>
<th>Applicable Special Requirements for Class 3 Castings</th>
</tr>
</thead>
</table>
|      | (b) When radiography of the casting is required, repair welds in cavities, the depth of which exceeds the lesser of \(\frac{3}{8}\) in. (10 mm) or 10\% of the section thickness, shall be radiographed in accordance with NC-NCD-2575.  
(c) When partial radiography of a casting is required, repairs located in an area of the casting which is not covered by radiography need only be examined by the magnetic particle method or by the liquid penetrant method. |

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**NC-NCD-2572 Time of Nondestructive Examination**

**NC-NCD-2572.1 Acceptance Examinations.**

Acceptance examinations shall be performed at the time of manufacture as stipulated in the following and Table NC(NP)-2572-1 for Class 2 or Table NC(NP)-2572-2 for Class 3 as shown in Table NC-2571-1.

(a) **Ultrasonic Examination.** Ultrasonic examination, if required, shall be performed at the same stage of manufacture as required for radiography.

(b) **Radiographic Examination.** Radiography may be performed prior to heat treatment and may be performed prior to or after finish machining at the following limiting thicknesses.

1. For finished thicknesses under \(2\frac{1}{2}\) in. (64 mm), castings shall be radiographed within \(\frac{1}{2}\) in. (13 mm) or 20\% of the finished thickness, whichever is greater. The IQI and reference radiographs shall be based on the finished thickness.

2. For finished thickness from \(2\frac{1}{2}\) in. (64 mm) up to 6 in. (150 mm), castings shall be radiographed within 20\% of the finished thickness. The IQI and the acceptance reference radiographs shall be based on the finished thickness.

3. For finished thicknesses over 6 in. (150 mm), castings shall be radiographed within \(\frac{1}{2}\) in. (13 mm) or 15\% of the finished thickness, whichever is greater. The IQI and the acceptance reference radiographs shall be based on the finished thickness.

(c) Radiography of castings for pumps and valves may be performed in as-cast or rough machined thickness exceeding the limits of (b)(1), (b)(2), or (b)(3) subject to the following conditions.

1. When the thickness of the as-cast or rough machined section exceeds 2 in. (50 mm) acceptance shall be based on reference radiographs for the next lesser thickness; e.g., if the section being radiographed exceeds \(4\frac{1}{2}\) in. (114 mm), use reference radiographs of ASTM E186. The IQI shall be based on the thickness of the section being radiographed.
When the thickness of the as-cast or rough machined section is 2 in. (50 mm) or less, the reference radiographs of ASTM E446 shall be used, and the IQI shall be based on the final section thickness.

(3) Weld ends for a minimum distance of \( t \) or \( \frac{1}{2} \) in. (13 mm), whichever is less (where \( t \) is the design section thickness of the weld), from the final welding end shall be radiographed at a thickness within the limits given in (b)(1), (b)(2), or (b)(3) as applicable. As an alternative, the weld ends may be radiographed in the as-cast or rough machined thickness in accordance with (1) and (2) above, and the IQI shall be based on the final section thickness.

(d) Magnetic Particle or Liquid Penetrant Examination. Magnetic particle or liquid penetrant examination shall be performed after the final heat treatment required by the material specification. Repair weld areas shall be examined after postweld heat treatment when a postweld heat treatment is performed, except that repair welds in P-No. 1 (see Section IX of the Code) material 2 in. (50 mm) nominal thickness and less may be examined prior to postweld heat treatment. For cast products with machined surfaces, all finished machine surfaces, except threaded surfaces and small deep holes, shall also be examined by magnetic particle or liquid penetrant methods.

**NC-NCD-2573 Provisions for Repair of Base Material by Welding**

The Material Manufacturer may repair, by welding, products from which defects have been removed, provided the requirements of this Article are met.

**NC-NCD-2573.1 Defect Removal.**

The defects shall be removed or reduced to an imperfection of acceptable size by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair. When thermal cutting is performed, consideration shall be given to preheating the material.

**NC-NCD-2573.2 Repair by Welding.**

The Material Manufacturer may repair castings by welding after removing the material containing unacceptable defects. The depth of the repair is not limited. A cored hole or access hole may be closed by the Material Manufacturer by welding in accordance with the requirements of this subparagraph, provided the hole is closed by filler metal only. If the hole is closed by welding in a metal insert, the welding shall be performed by a holder of a Certificate of Authorization in accordance with the requirements of the Code.

**NC-NCD-2573.3 Qualification of Welding Procedures and Welders.**

Each manufacturer is responsible for the welding done by his organization and shall establish the procedures and conduct the tests required by Article NC-D-400 and by Section IX of the Code in order to qualify both the welding procedures and the performance of welders and welding operators who apply these procedures. He is also responsible for the welding performed by his subcontractors and shall assure himself that the subcontractors conduct the tests required by Article NC-D-400 and by Section IX of the Code in order to qualify their welding procedures and the performance of their welders and welding operators.

**NC-NCD-2573.4 Blending of Repaired Areas.**

After repair, the surface shall be blended uniformly into the surrounding surface.
NC-NCD-2573.5 Examination of Repair Welds.

(a) Each repair weld shall be examined by the magnetic particle method in accordance with the requirements of NC-D-2577, or by the liquid penetrant method in accordance with the requirements of NC-D-2576. In addition, when radiography is specified in the order for the original casting, repair cavities, the depth of which exceeds the lesser of 3/8 in. (10 mm) or 10% of the section thickness, shall be radiographed after repair except that weld slag, including elongated slag, shall be considered as inclusions under Category B of the applicable reference radiographs. The total area of all inclusions, including slag inclusions, shall not exceed the limits of the applicable severity level of Category B of the reference radiographs. The IQI and the acceptance standards for radiographic examination of repair welds shall be based on the actual section thickness at the repair area.

(b) Examination of repair welds in P-No. 1 and P-No. 8 materials is not required for pumps and valves with inlet piping connections NPS 2 (DN 50) and less.

NC-NCD-2573.6 Heat Treatment After Repairs.

The material shall be heat treated after repair in accordance with the heat treatment requirements of NC-D-4620, except that the heating and cooling rate limitations of NC-D-4623 do not apply.

NC-NCD-2573.7 Elimination of Surface Defects.

Surface defects shall be removed by grinding or machining, provided the requirements of (a) through (c) below are met:

(a) the depression, after defect elimination, is blended uniformly into the surrounding surface;

(b) after defect elimination, the area is reexamined by the magnetic particle method in accordance with NC-D-2577, or the liquid penetrant method in accordance with NC-D-2576, to assure that the defect has been removed or reduced to an imperfection of acceptable size;

(c) if the elimination of the defect reduces the section thickness below the minimum required by the specification or drawing, the casting shall be repaired in accordance with NC-D-2537.

NC-NCD-2573.8 Material Report Describing Defects and Repairs.

Each defect repair exceeding in depth the lesser of 3/8 in. (10 mm) or 10% of the section thickness shall be described in the Certified Material Test Report. The Certified Material Test Report for each piece shall include a chart that shows the location and size of the prepared cavity, the welding material identification, the welding procedure, the heat treatment, and the examination results, including radiographs, when radiographs are specified in the order for the original casting.

NC-NCD-2574 Ultrasonic Examination of Ferritic Steel Castings

Ultrasonic examination shall be performed in accordance with Section V, Article 5, T-571.4. Each manufacturer shall certify that the procedure is in accordance with the requirements of NC-D-2574 and shall make the procedure available for approval upon request.

NC-NCD-2574.1 Acceptance Standards.

(a) The Quality Levels of SA-609 as shown in Section V shall apply for the casting thicknesses indicated.
(1) Quality Level 1 for thicknesses up to 2 in. (50 mm);

(2) Quality Level 3 for thicknesses 2 in. to 4 in. (50 mm to 100 mm);

(3) Quality Level 4 for thicknesses greater than 4 in. (100 mm).

(b) In addition to the Quality Level requirements stated in (a) above, the requirements in (1) through (5) below shall apply for both straight beam and angle beam examination.

(1) Areas giving indications exceeding the Amplitude Reference Line with any dimension longer than those specified in the following tabulation are unacceptable.

<table>
<thead>
<tr>
<th>UT Quality Level</th>
<th>Longest Dimension of Area, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5 (38)</td>
</tr>
<tr>
<td>2</td>
<td>2.0 (50)</td>
</tr>
<tr>
<td>3</td>
<td>2.5 (64)</td>
</tr>
<tr>
<td>4</td>
<td>3.0 (75)</td>
</tr>
</tbody>
</table>

NOTES:
(1) The areas for the Ultrasonic Quality Levels in SA-609 refer to the surface area on the casting over which a continuous indication exceeding the transfer corrected distance amplitude curve is maintained.
(2) Areas are to be measured from dimensions of the movement of the search unit, using the center of the search unit as the reference point.
(3) In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting. In such cases, other criteria that incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

(2) Quality Level 1 shall apply for the volume of castings within 1 in. (25 mm) of the surface regardless of the overall thickness.

(3) Discontinuities indicated to have a change in depth equal to or greater than 1/2 the wall thickness or 1 in. (25 mm) (whichever is less) are unacceptable.

(4) Two or more imperfections producing indications in the same plane with amplitudes exceeding the Amplitude Reference Line and separated by a distance less than the longest dimension of the larger of the adjacent indications are unacceptable if they cannot be encompassed within an area less than that of the quality level specified in (1) above.

(5) Two or more imperfections producing indications greater than permitted for Quality Level 1 for castings less than 2 in. (50 mm) in thickness, greater than permitted for Quality Level 2 for thicknesses 2 in. (50 mm) through 4 in. (100 mm), and greater than permitted for Level 3 for thicknesses greater than 4 in. (100 mm), separated by a distance less than the longest dimension of the larger of the adjacent indications are unacceptable, if they cannot be encompassed in an area less than that of the Quality Level requirements stated in (a) above.
**NC-NCD-2575 Radiographic Examination**

**NC-NCD-2575.1 Examination.**
Cast pressure-retaining materials shall be examined by radiographic methods when specified in the order for the original castings, except that cast ferritic steels may be examined by either radiographic or ultrasonic methods, or a combination of both methods. Castings or sections of castings that have coarse grains or configurations that do not yield meaningful examination results by ultrasonic methods shall be examined by radiographic methods.

**NC-NCD-2575.2 Extent.**
Radiographic examination shall be performed on pressure-retaining castings such as vessel heads and flanges, valve bodies, bonnets and disks, pump casings and covers, and piping and fittings. The extent of radiographic coverage shall be of the maximum feasible volume and, when the shape of the casting precludes complete coverage, the coverage shall be at least as exemplified in the typical sketches as shown in Figure NC-NCD-2575.2.1.
Figure NCD-2575.2-1 — Typical Pressure-Retaining Parts of Pumps and Valves (Note to Editor: Use Figure ND-2575.2-1 as the basis, they have identical content but the ND figure is cleaner)
(a) Typical Valve-Type Pump Case

(b) Typical Diffuser-Type Pump Case

(c) Typical Diffuser-Type Pump Case Detail
GENERAL NOTE:
(a) Radiographic examination areas shall be indicated by a circle at each change of direction. The examination symbol for radiography shall be indicated as RT.
(b) For nondestructive examination areas of revolution, the area shall be indicated by the examine-all-around symbol: – RT – .
(c) The sketches are typical and are to be used as a guide for minimum required coverage. Even though a sketch may be titled “pump” or “valve,” the coverage shown by the configurations may be applied interchangeably.

NC-NCD-2575.3 Examination Requirements.
Radiographic examination shall be performed in accordance with Section V, Article 2, Mandatory Appendix VII, Radiographic Examination of Metallic Castings, with the following modifications:

(a) The geometric unsharpness limitations of Section V, Article 2, T-274.2 need not be met.

(b) The examination procedure or report shall also address the following:

(1) type and thickness of filters, if used

(2) for multiple film techniques, whether viewing is to be single or superimposed, if used

(3) blocking or masking technique, if used
(4) orientation of location markers

(5) description of how internal markers, when used, locate the area of interest

(c) The location of location markers (e.g., lead numbers or letters) shall be permanently stamped on the surface of the casting in a manner permitting the area of interest on a radiograph to be accurately located on the casting and providing evidence on the radiograph that the extent of coverage required by NC-NCD-2575.2 has been obtained. For castings or sections of castings where stamping is not feasible, the radiographic procedure shall so state, and a radiographic exposure map shall be provided.

NC-NCD-2575.6 Acceptance Criteria.
Castings shall meet the acceptance requirements of Severity Level 2 of ASTM E446, Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness, ASTM E186, Reference Radiographs for Heavy-Walled [2 in. to 4\(\frac{1}{2}\) in. (51 mm to 114 mm)] Steel Castings, or ASTM E280, Reference Radiographs for Heavy Walled [4\(\frac{1}{2}\) in. to 12 in. (114 mm to 305 mm)] Steel Castings, as applicable for the thickness being radiographed, except Category D, E, F, or G defects are not acceptable. The requirements of ASTM E280 shall apply for castings over 12 in. (300 mm) in thickness.

NC-NCD-2576 Liquid Penetrant Examination

(a) Castings shall be examined, if required, on all accessible surfaces by liquid penetrant method in accordance with Section V of the Code.

(b) Evaluation of Indications. All indications shall be evaluated in terms of the acceptance standards. Mechanical discontinuities intersecting the surface are indicated by bleeding out of the penetrant; however, localized surface discontinuities, as may occur from machining marks, scale, or dents, may produce indications which are not relevant. Any indication in excess of the acceptance standards believed to be nonrelevant shall be reexamined to verify whether actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications and broad areas of pigmentation that would mask indications of defects are unacceptable. Relevant indications are those which result from imperfections and have a major dimension greater than \(\frac{1}{16}\) in. (1.5 mm). Linear indications are those whose length is more than three times the width. Rounded indications are those which are circular or elliptical with the length less than three times the width.

(c) Acceptance Standards. The following relevant indications are unacceptable:

(1) linear indications greater than \(\frac{1}{16}\) in. (1.5 mm) long for materials less than \(\frac{5}{8}\) in. (16 mm) thick, greater than \(\frac{1}{8}\) in. (3 mm) long for materials from \(\frac{5}{8}\) in. (16 mm) thick to under 2 in. (50 mm) thick, and \(\frac{1}{16}\) in. (5 mm) long for materials 2 in. (50 mm) thick and greater;

(2) rounded indications with dimensions greater than \(\frac{1}{8}\) in. (3 mm) for thicknesses less than \(\frac{5}{8}\) in. (16 mm), and greater than \(\frac{3}{16}\) in. (5 mm) for thicknesses \(\frac{5}{8}\) in. (16 mm) and greater;

(3) four or more indications in a line separated by \(\frac{1}{16}\) in. (1.5 mm) or less edge to edge;

(4) ten or more indications in any 6 in.\(^2\) (4 000 mm\(^2\)) of surface with the major dimension of this area not to exceed 6 in. (150 mm) taken in the most unfavorable orientation relative to the indications being evaluated.
(a) Castings of magnetic material shall be examined, if required, on all accessible surfaces by a magnetic particle method in accordance with Section V of the Code.

(b) Evaluation of Indications. All indications shall be evaluated in terms of the acceptance standards. Mechanical discontinuities intersecting the surface are indicated by retention of the examination medium. All indications are not necessarily defects since certain metallurgical discontinuities and magnetic permeability variations may produce indications that are not relevant. Any indication in excess of the acceptance standards believed to be nonrelevant shall be reexamined to verify whether actual defects are present. Nonrelevant indications which would mask indications of defects are unacceptable. Surface conditioning may precede the reexamination. Relevant indications are those which result from imperfections and have a major dimension greater than $\frac{1}{16}$ in. (1.5 mm). Linear indications are those whose length is more than three times the width. Rounded indications are those which are circular or elliptical with the length less than three times the width.

(c) Acceptance Standards. The following relevant indications are unacceptable:

1. Linear indications greater than $\frac{1}{16}$ in. (1.5 mm) long for materials less than $\frac{5}{8}$ in. (16 mm) thick; greater than $\frac{1}{8}$ in. (3 mm) long for materials from $\frac{5}{8}$ in. (16 mm) thick to under 2 in. (50 mm) thick; and $\frac{3}{16}$ in. (5 mm) long for materials 2 in. (50 mm) thick and greater;

2. Rounded indications with dimensions greater than $\frac{1}{8}$ in. (3 mm) for thicknesses less than $\frac{5}{8}$ in. (16 mm), and greater than $\frac{3}{16}$ in. (5 mm) for thicknesses $\frac{5}{8}$ in. (16 mm) and greater;

3. Four or more relevant indications in a line separated by $\frac{1}{16}$ in. (1.5 mm) or less edge to edge;

4. Ten or more relevant indications in any 6 in.$^2$ (4 000 mm$^2$) of surface with the major dimension of this area not to exceed 6 in. (150 mm) taken in the most unfavorable orientation relative to the indications being evaluated.

NC-NCD-2580 Examination of Bolts, Studs, and Nuts

NC-NCD-2581 Requirements

All bolting material shall be visually examined in accordance with NC-NCD-2582.

NC-NCD-2582 Visual Examination

The final surfaces of threads, shanks, and heads shall be visually examined for workmanship, finish, and appearance in accordance with the requirements of ASTM F788 for bolting material and ASTM F812 for nuts. The visual examination personnel shall be trained and qualified in accordance with the Material Organization’s Quality System Program or the Certificate Holder’s Quality Assurance Program. These examinations are not required to be performed either in accordance with procedures qualified to NC-NCD-5500 or by personnel qualified in accordance with NC-NCD-5100.
NC-NCD-2600 Material Organizations’ Quality System Programs

NC-NCD-2610 Documentation and Maintenance of Quality System Programs

(a) Except as provided in (b) below, Material Organizations shall have a Quality System Program that meets the requirements of NCA-3800.

(b) The requirements of NCA-3862 shall be met as required by NC-D-2130. The other requirements of NCA-3800 and NCA-4200 need not be used by Material Organizations for small products, as defined in (c) below, for brazing material, and for material which is allowed by this Subsection to be furnished with a Certificate of Compliance. For these products, the Certificate Holder’s Quality Assurance Program (NCA-4100) shall include measures to provide assurance that the material is furnished in accordance with the material specification and with the applicable requirements of this Subsection.

(c) For the purpose of this paragraph, small products are defined as given in (1) through (4) below:

1. pipe, tube (except heat exchanger tube), pipe fittings, and flanges NPS 2 (DN 50) and less;
2. bolting materials, including studs, nuts, and bolts of 1 in. (25 mm) nominal diameter and less;
3. bars with a nominal cross-sectional area of 1 in.² (650 mm²) and less;
4. material for pumps and valves with inlet pipe connections of NPS 2 (DN 50) and less;
5. materials exempted by NC-D-2121[c].

NC-NCD-2700 Dimensional Standards

Dimensions of standard items shall comply with the standards and specifications of Table NCA-7100-1.