NC-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 the following:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 7/8 in. (44 mm) and less</td>
<td>1,500 lb (680 kg)</td>
</tr>
<tr>
<td>Over 1 7/8 in. to 2 1/2 in. (44 mm to 64 mm)</td>
<td>3,000 lb (1,350 kg)</td>
</tr>
<tr>
<td>Over 2 1/2 in. to 5 in. (64 mm to 125 mm)</td>
<td>6,000 lb (2,700 kg)</td>
</tr>
<tr>
<td>Over 5 in. (125 mm)</td>
<td>10,000 lb (4,500 kg)</td>
</tr>
</tbody>
</table>

NC-2350 RETESTS

NC-2351 Retests for Material Other Than Bolting

(a) For Charpy V-notch tests required by NC-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-2332.1-1 or Table NC-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-2332.1-1 or Table NC-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-2332.1-1 or Table NC-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-2332.1-1 or Table NC-2332.1-2, as applicable.

NC-2352 Retests for Bolting Material

(a) For Charpy V-notch tests required by NC-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-2360 CALIBRATION OF INSTRUMENTS AND EQUIPMENT

Calibration of temperature instruments and C_n 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-3858.2 at least once in each three month interval.

(b) C_n impact test machines shall be calibrated and the results recorded to meet the requirements of NCA-3858.2. 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-3855.3(c).

NC-2400 WELDING MATERIAL

NC-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-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-2431.1(c)] in either the as-welded or heat treated condition, or both [NC-2431.1(c)];

(5) drop weight test for material in either the as-welded or heat treated condition, or both (NC-2232);

(6) Charpy V-notch test for material as-welded, or heat treated, or both (NC-2231); the test temperature and 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-2431.1(c)];

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

(9) elements for which chemical analysis is required per the SFA specification or WPS, and NC-2432;

(10) minimum delta ferrite (NC-2433).

NC-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, QW-402); for each heat of consumable inserts; for each combination of heat of bare electrodes
heat treatment of the production weld exceeds 10 hr or the PWHT temperature is other than that required, the general test of NC-2431.1 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-2431.1(d).

e) 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.

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

NC-2432 Chemical Analysis Test

Chemical analysis of filler metal or weld deposits shall be made in accordance with NC-2420 and as required by the following subparagraphs.

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

(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-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of NC-2431.1(c) 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 to QW-214.3 for the minimum thickness for which the Welding Procedure Specification is qualified.

NC-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, QW-442) shall be analyzed for the elements listed in Table NC-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.

<table>
<thead>
<tr>
<th>Table NC-2432.1-1 Sampling of Welding Materials for Chemical Analysis</th>
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<tbody>
<tr>
<td>GTAW/PAW</td>
</tr>
<tr>
<td>A-No. 8 filler metal</td>
</tr>
<tr>
<td>All other filler metal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table NC-2432.2-1 Welding Material Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Cr-Ni stainless materials</td>
</tr>
<tr>
<td>Nominal Pipe Size</td>
</tr>
<tr>
<td>-------------------</td>
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<tr>
<td>Inlet piping connections of NPS 2 (DN 50) and less</td>
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<tr>
<td>Inlet piping connections over NPS 2 (DN 50) up to and including NPS 4 (DN 100)</td>
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<td></td>
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<tr>
<td>Inlet piping connections over NPS 4 (DN 100)</td>
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<tr>
<td></td>
</tr>
</tbody>
</table>
(c) **Full Penetration Corner Joints.** Corner joints are those connecting two members approximately at right angles to each other in the form of an L or T and shall be made with full penetration welds.

(d) **Fillet Welded Joints.** Fillet welded joints, permitted by the rules of this subarticle, are those of approximately triangular cross section, joining two surfaces at approximately right angles to each other and having a throat dimension at least 70% of the smaller thickness of the parts being joined but not less than $\frac{3}{8}$ in. (6 mm).

**NC-4263 Category A Weld Joints**

Category A weld joints shall be Type No. 1 butt joints.

**NC-4264 Category B Weld Joints**

Category B weld joints shall be Type No. 1 or Type No. 2 butt joints. Backing strips shall be removed from Type No. 2 joints unless access conditions prevent their removal. Backing strips shall be continuous, and any splices shall be butt welded. Circumferential single welded butt joints with one plate offset to form a backing strip are prohibited.

**NC-4265 Category C Weld Joints**

Category C weld joints shall be Type No. 1 butt joints or full penetration corner joints. Welds in full penetration corner joints shall be groove welds extending completely through at least one of the parts being joined and shall be fully fused to each part. Typical details are shown in Figures NC-4265-1 and NC-4265-2.

**NC-4265.1 Flat Heads and Tubesheets With Hubs.**

(a) Hubs for butt welding to the adjacent shell, head, or other pressure parts, as shown in Figure NC-4243.1-1 for flat heads, shall not be machined from flat plate. The hubs shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material in the direction parallel to the axis of the vessel. Proof of this shall be furnished by a tension test specimen (subsize, if necessary) taken in this direction and as close to the hub as is practical. \(^5\) The minimum height of the hub shall be the lesser of $\frac{1}{2} t_s$ times the thickness of the pressure part to which it is welded or $\frac{3}{8}$ in. (19 mm), but need not be greater than 2 in. (50 mm).

(b) Hubbed flanges, as shown in Figure XI-3120-1 sketches (6), (6a), and (6b), shall not be machined from flat plate.

**NC-4266 Category D Weld Joints**

Category D and similar weld joints shall be welded using one of the details of (a) through (d) below.

(a) **Butt Welded Attachments.** Nozzles shall be attached by Type No. 1 butt welds through either the vessel or the nozzle wall as shown in Figure NC-4266(a)-1.

(b) **Full Penetration Corner Welded Attachment.** Nozzles shall be attached by full penetration welds through the wall of the vessel or nozzle as shown in Figure NC-4266(c)-1. The welds shall be groove welds extending completely through at least one of the parts being joined and shall be fully fused to each part. Backing strips shall be used with welds deposited from only one side or when complete joint penetration cannot be verified by visual inspection. Backing strips, when used, shall be removed after welding.

(c) **Pad and Screwed Fitting Types of Welded Nozzles**

(1) **Inserted Nozzle Necks With Added Reinforcement.** Inserted type necks having added reinforcement in the form of one or more separate reinforcing plates shall be attached by welds at the outer edge of the reinforcement plate and at the nozzle neck periphery. The weld at the outer edge of the reinforcement shall be a fillet weld with a minimum throat dimension of the smaller of 0.7t or 0.7t. The welds attaching the neck to the vessel wall and to the reinforcement shall be full penetration groove welds. Permissible types of weld attachments are shown in Figure NC-4266(c)-1 sketches (a), (b), and (c).

(2) **Studded Connections**

(a) Studded connections, which may have externally imposed loads, shall have tapped holes complying with the requirements of NC-3262.4. The vessel or integral weld buildup shall have a flat surface machined on the shell to receive the connection. Drilled holes to be tapped shall not penetrate within one-fourth of the wall thickness from the inside surface of the vessel after deducting corrosion allowance unless at least the minimum thickness required as above is maintained by adding metal to the inside surface of the vessel.

(b) Studded pad-type connections may be used for connections on which there are essentially no external mechanical loads, such as manways and handholes used only as inspection openings or thermowell connections, provided the requirements of NC-3262.4 are met. The pad shall be attached by a fillet weld along the outer edge and a single bevel weld along the inner edge. Permissible type of weld attachment is shown in Figure NC-4266(c)-1 sketch (d). The tapped holes for stud threads shall comply with NC-3262.4.

(3) **Fittings With Internal Threads.** Internally threaded fittings shall be limited to NPS 2 (DN 50). They shall be attached by means of full penetration groove welds as illustrated in Figure NC-4266(c)-1 sketches (e), (f), and (g), except pad type fittings, such as shown in sketch (h), which may be used if attached by means of fillet welds having a minimum throat dimension of the smaller of 0.7t or 0.7t, as shown in sketch (h).

(d) **Attachment of Nozzles Using Partial Penetration Welds.** Partial penetration welds are limited by the restrictions of NC-3252.4(d). The weld size shall be such that the depth of penetration $t_n$ will be at least $1/6 t_n$. Typical details are shown in Figure NC-4266(d)-1.
NC-4323  Welding Prior to Qualifications

No welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with NC-4320 and Section IX shall be used.

NC-4324  Transferring Qualifications

The welding procedure qualifications and performance qualification tests for welders and welding operators conducted by one Certificate Holder shall not qualify welding procedures, and shall not qualify welders or welding operators to weld for any other Certificate Holder, except as provided in Section IX, QW 201 and QW 300.20.

NC-4330  GENERAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION TESTS

NC-4331  Conformance to Section IX Requirements

All welding procedure qualification tests shall be in accordance with the requirements of Section IX as supplemented or modified by the requirements of this Article.

NC-4333  Heat Treatment of Qualification Welds for Ferritic Materials

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

NC-4334  Preparation of Test Coupons and Specimens

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

(b) Weld deposit of each process in a multiple process weld shall, where possible, be included in the impact test specimens. When each process cannot be included in the full size impact test specimen at the 3/4t location required by this Section, additional full size specimens shall be obtained from locations in the test weld that will ensure that at least a portion of each process has been included in full size test specimens. As an alternative, additional test welds can be made with each process so that full size specimens can be tested for each process.

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

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

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

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

(c) For the comparison of heat affected zone values with base material values [NC-4335.2(b)], Charpy V-notch specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat affected zone specimens, and the axis of the notch shall be normal to the surface of the base material. When required by NC-4335.2(b)(4), drop weight specimens shall be removed from a depth as near as practical to midway between the surface and center thickness of the unaffected base material and shall be tested in accordance with the requirements of NC-2321.1.
NC-4400  RULES GOVERNING MAKING, EXAMINING, AND REPAIRING WELDS

NC-4410  PRECAUTIONS TO BE TAKEN BEFORE WELDING

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

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

NC-4412  Cleanliness and Protection of Welding Surfaces

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

NC-4420  RULES FOR MAKING WELDED JOINTS

NC-4421  Backing Rings

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

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

Backup plates and backing rings which remain in place and compression rings or stiffeners of storage tanks, such as angles, bars, and ring girders, may be used. The materials used for such backup plates, backing rings, and compression rings or stiffeners shall be compatible with the base metal, but spacer pins shall not be incorporated into the weld.

NC-4423  Double Welded Joints, Single Welded Joints, and Peening

NC-4423.1  Double Welded Joints. Before applying weld metal on the second side to be welded, the root of full penetration double welded joints shall be prepared by suitable methods such as chipping, grinding, or thermal gouging, except for those processes of welding by which proper fusion and penetrations are otherwise obtained and demonstrated to be satisfactory by welding procedure qualifications.

NC-4423.2  Single Welded Joints. Where single welded joints are used, particular care shall be taken in aligning and separating the components to be joined so that there will be complete penetration and fusion at the bottom of the joint for its full length.

NC-4423.3  Peening. Controlled peening may be performed to minimize distortion. Peening shall not be used on the internal layer (root) of the weld metal nor on the final layers unless the weld is postweld heat treated.

NC-4424  Surfaces of Welds

As-welded surfaces are permitted except for inertia and continuous drive friction welding where the flash shall be removed to sound metal. For piping, the appropriate stress indices given in Table NB-3683.2-1 shall be applied. However, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to meet the requirements of (a) through (e) below.

(a) The surface condition of the finished weld shall be suitable for the proper interpretation of radiographic and other required nondestructive examination of the weld. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.

(b) Reinforcements are permitted in accordance with NC-4426.1 for vessels, pumps, and valves, and NC-4426.2 for piping.

(c) Undercuts shall not exceed $\frac{3}{16}$ in. (0.8 mm) and shall not encroach on the required section thickness.

(d) Concavity on the root side of a single welded circumferential butt weld is permitted when the resulting thickness of the weld meets the requirements of NC-3000.

(e) If the surface of the weld requires grinding to meet the above criteria, care shall be taken to avoid reducing the weld or base material below the required thickness.

(f) For inertia and continuous drive friction welding, the weld upset shall meet the specified amount within ±10%.

NC-4425  Welding Components of Different Diameters

When components of different diameters are welded together, there shall be a gradual transition between the two surfaces. The slope of the transition shall be such that the length–offset ratio shall not be less than 3:1 (Figures NC-3361-1 and NC-4233-1), unless greater slopes are shown to be acceptable by analysis for vessels designed to NC-3200. The length of the transition may include the weld.

Table NC-3673.2(b)-1
ND-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 (electroslag welding) processes (Section IX, AWS D1.1); 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 supplemental powdered filler metal and lot of submerged arc flux; or for each combination of heat of bare electrodes and lot of electroslag flux. 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 ND-4000 and this Subarticle are made and the results conform to the requirements of this Article. The definitions in (a) through (h) below apply.

(a) A dry batch of covering mixture is defined as the quantity of dry covering ingredients mixed at one time in one mixing vessel; a dry batch may be used singly or may be subsequently subdivided into quantities to which the liquid binders may be added to produce a number of wet mixes.

(b) A dry blend is defined as one or more dry batches mixed in a mixing vessel and combined proportionately to produce a uniformity of mixed ingredients equal to that obtained by mixing the same total amount of dry ingredients at one time in one mixing vessel.

(c) A wet mix is defined as the combination of a dry batch or dry blend [and (b) above, respectively] and liquid binder ingredients at one time in one mixing vessel.

(d) A lot of covered, flux cored, or fabricated electrodes is defined as the quantity of electrodes produced from the same combination of heat of metal and dry batch, dry blend, or chemically controlled mixes of flux or core materials. Alternatively, a lot of covered, flux cored, or fabricated electrodes may be considered one type and size of electrode, produced in a continuous period, not to exceed 24 hr and not to exceed 100,000 lb (45 000 kg), from chemically controlled tube, wire, or strip and a dry batch, a dry blend, or chemically controlled mixes of flux, provided each container of welding materials is coded for identification and traceable to the production period, the shift, line, and the analysis range of both the mix and the rod, tube, or strip used to make the electrode.

(1) Chemically controlled tube, wire, or strip is defined as consumable tube, wire, or strip material supplied on coils with maximum of one splice per coil that has been chemically analyzed to assure that the material conforms to the electrode manufacturer’s chemical control limits for the specific type of electrode. Both ends of each coil shall be chemically analyzed except that those coils which are splice free need only be analyzed on one end of the coil.

(2) Chemically controlled mixes of flux are defined as flux material that has been chemically analyzed to assure that it conforms to the percent allowable variation from the electrode manufacturer’s standard for each chemical element for that type electrode. A chemical analysis shall be made on each mix made in an individual mixing vessel after blending.

(e) A heat of bare electrode, rod, wire, or consumable insert is defined as the material produced from the same melt of metal.

(f) Alternatively, for carbon and low alloy steel bare electrode, rod, wire, or consumable inserts for use with SAW, OFW, GMAW, GTAW, PAW, and EGW processes, a heat may be defined as either the material produced from the same melt of metal or the material produced from one type and size of wire when produced in a continuous period [not to exceed 24 hr and not to exceed 100,000 lb (45 000 kg)] from chemically controlled wire, subject to requirements of (1), (2), and (3) below.

(1) For the chemical control of the product of the rod mill, coils shall be limited to a maximum of one splice prior to processing the wire. Chemical analysis shall be made from a sample taken from both ends of each coil of mill coiled rod furnished by mills permitting spliced coil practice of one splice maximum per coil. A chemical analysis need be taken from only one end of rod coils furnished by mills prohibiting spliced coil practice.

(2) 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.

(3) Each container of wire shall be coded for identification and traceability to the lot, production period, shift, line, and analysis of rod used to make the wire.

(g) A lot of submerged arc or electroslag flux is defined as the quantity of flux produced from the same combination of raw materials under one production schedule.

(h) A dry blend of supplementary powdered filler metal is defined as one or more mixes of material produced in a continuous period, not to exceed 24 hr and not to exceed 20,000 lb (9 000 kg) from chemically controlled mixes of powdered filler metal, provided each container of powdered metal is coded for identification and traceable to the production period, the shift, and the mixing vessel. A chemically controlled mix of powdered filler metal is defined as powdered filler metal material that has been chemically analyzed to assure that it conforms to the percent allowable variation from the powdered filler metal manufacturer’s standard, for each chemical element, for that type of powdered filler metal. A chemical analysis shall be made on each mix made in an individual mixing vessel after blending. The chemical analysis range of the supplemental powdered filler 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.

ND-2430  WELD METAL TESTS

ND-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 materials;
(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 ND-2311(a),(1) through ND-2311(a),(7) or ND-2311(a),(9) shall also be exempted from the impact testing required by this paragraph.

ND-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 eliminate substantially 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 ND-4622.1-1 or Table ND-4622.4(c)-1, 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 ND-4622.1-1 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_{t} 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 test specimens, when required, shall be of 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 requirements of ND-2311 and ND-2321 shall apply. The longitudinal axis of the specimen shall be at a minimum depth of 1/4t 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 results shall conform to either of the base material specifications.
(f) Impact specimens of the weld metal shall be tested when impact tests are required for either of the base materials of the production weld. The weld metal shall conform to the requirements of ND-2330 applicable to the base material. When different requirements exist for the two base materials, the weld metal may conform to either of the two requirements.

ND-2431.2  Standard Test Requirements.  In lieu of the use of the General Test Requirements specified in ND-2431.1, tensile and impact tests may be made in accordance with this subparagraph when they are required for mild and low alloy steel covered electrodes. The material combinations to require weld material testing as listed in ND-2431 shall apply for this Standard Test Requirements option. The limitations and testing under this Standard Test 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 specifications SFA-5.1 or SFA-5.5.
(b) The test 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 C_{t} specimens required by ND-2331 when 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 in the postweld heat treated condition. The PWHT temperatures shall be in accordance with Table ND-4622.1-1 for the applicable P-Number equivalent. The time at PWHT temperature shall be 8 hr.
(this qualifies PWHT of 10 hr or less). When the PWHT of the production weld exceeds 10 hr, or the PWHT temperature is other than that required above, the general test of ND-2431.1 shall be used.

(d) The tensile and Cσ specimens shall be located and prepared in accordance with the requirements of SFA-5.1 or SFA-5.5 as applicable.

(e) One all-weld-metal tensile specimen shall be tested and shall meet the specified minimum tensile strength requirements of the SFA specification for the applicable electrode classification.

(f) The requirements of ND-2431.1(f) shall be applicable to the impact testing of this option.

**ND-2432 Chemical Analysis Test**

Chemical analysis of filler metal or weld deposits shall be made in accordance with ND-2420 and as required by the following subparagraphs.

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

(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 *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 ND-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of ND-2431.1(c) 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 QW-214.1 for the minimum thickness for which the Welding Procedure Specification is qualified.

**ND-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, QW-442) shall be analyzed for the elements listed in Table ND-2432.2-1 and any other elements specified in the welding material specification referenced by 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

<table>
<thead>
<tr>
<th>Table ND-2432.1-1</th>
<th>Sampling of Welding Materials for Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTAW/PAW</td>
<td>GMAW</td>
</tr>
<tr>
<td>A-No. 8 filler metal</td>
<td>Filler metal or weld deposit</td>
</tr>
<tr>
<td>All other filler metal</td>
<td>Filler metal or weld deposit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table ND-2432.2-1</th>
<th>Welding Material Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Elements</td>
</tr>
<tr>
<td>Cr-Ni stainless materials</td>
<td>C, Cr, Mo, Ni, Mn, Si, Cb</td>
</tr>
</tbody>
</table>
Figure ND-4244(a)-1
Nozzles, and Branch and Piping Connections Joined by Full Penetration Butt Welds

(a)

(b)

(c)

(d) [Note (1)]

(e)

(f)

GENERAL NOTE: For definition of symbols, see ND-3352(a).

NOTE:
(1) Sections are perpendicular and parallel to the cylindrical component’s axis.

ND-3352.4(a)
made on an item, the Certificate Holder need not identify
the welder or welding operator who welded each individu-
inal joint, provided

(1) the Certificate Holder maintains a system that will
identify the welders or welding operators who made such
welds on each item so that the Inspector can verify that
the welders or welding operators were all properly
qualified;

(2) the welds in each category are all of the same type
and configuration and are welded with the same Welding
Procedure Specification.

(c) The identification of welder or welding operator is
not required for tack welds.

ND-4323 Welding Prior to Qualification

No welding shall be undertaken until after the welding
procedures which are to be used have been qualified. Only
welders and welding operators who are qualified in accor-
dance with ND-4320 and Section IX shall be used.

ND-4324 Transferring Qualifications

The welding procedure qualifications and performance
qualification tests for welders and welding operators con-
ducted by one Certificate Holder shall not qualify welding
procedures, and shall not qualify welders or welding oper-
ators to weld for any other Certificate Holder, except
as provided in Section IX, QW-291 and QW 300.2.

ND-4330 GENERAL REQUIREMENTS FOR
WELDING PROCEDURE QUALIFICATION
TESTS

ND-4331 Conformance to Section IX
Requirements

All welding procedure qualification tests shall be in accor-
dance with the requirements of Section IX as supple-
mented or modified by the requirements of this Article.

ND-4333 Heat Treatment of Qualification Welds
for Ferritic Material

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

ND-4334 Preparation of Test Coupons and
Specimens

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

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

ND-4334.1 Coupons Representing the Weld Depo-
sites. Impact test specimens and testing methods shall con-
form to ND-2321. The impact specimen shall be located so
that the longitudinal axis of the specimen is at least \( \frac{1}{4}t \)
and, where the thickness of the test assembly permits,
not less than \( \frac{1}{8}t \) in. (10 mm) from the weld surface of
the test assembly. In addition, when the postweld heat

treatment temperature exceeds the maximum tempera-
ture specified in ND-4620, and the test assembly is cooled
at an accelerated rate, the longitudinal axis of the speci-
men shall be a minimum of \( t \) from the edge of the test
assembly. The specimen shall be transverse to the
longitudinal axis of the weld with the area of the notch
located in the weld. The length of the notch of the Charpy
V-notch specimen shall be normal to the surface of the
weld.

ND-4334.2 Coupons Representing the Heat-Affected
Zone. Where impact tests of the heat-affected zone are re-
quired by ND-4335.2, specimens shall be taken from the
welding procedure qualification test assemblies in accor-
dance with (a) through (c) below.

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

(b) The heat-affected zone impact test specimens and
testing methods shall conform to the requirements of
ND-2321. The specimens shall be removed from a location
as near as practical to a depth midway between the sur-
face and center thickness. The coupons for heat-affected
zone impact specimens shall be taken transverse to the
axis of the weld and etched to define the heat-affected
zone. The notch of the Charpy V-notch specimen shall be
cut approximately normal to the material surface in such
a manner as to include as much heat-affected zone as pos-
sible in the resulting fracture. Where the material thick-
ness permits, the axis of a specimen may be inclined to
allow the root of the notch to align parallel to the fusion
line. When a grain refining heat treatment is not per-
formed on welds made by the electroslag or electrogas
welding process, the notch for the impact specimens shall
be located in the grain coarsened region.

(c) For the comparison of heat-affected zone values
with base material values [ND-4335.2(b)], Charpy V-notch
specimens shall be removed from the unaffected base ma-
terial at approximately the same distance from the base
material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material.

ND-4335  Impact Test Requirements

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

ND-4335.1  Impact Tests of Weld Metal.

(a) Impact tests of the weld metal shall be required for welding procedure qualification tests for production weld joints exceeding \( \frac{3}{8} \) in. (16 mm) in thickness when the weld will be made on the surface or will penetrate the base material that requires impact testing in accordance with ND-2310. In addition, such testing of the weld metal is required for the welding procedure qualification tests for any weld repair to base material that requires impact testing in accordance with ND-2310, regardless of the depth of the repair. Exemption from impact testing under ND-2311(a)(8) does not apply to weld metal of welding procedure qualification tests for either production weld joints or base material repairs unless the specific weld metal used is included in Table ND-2331-1. Weld metal exemptions are being developed.

(b) The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in ND-2330 for the base material to be welded or repaired. Where two materials are to be joined by welding, and have different fracture toughness requirements, the test requirements and acceptance standards of either material may be used for the weld metal, except where otherwise specified by NCA-1280 or other parts of this Section.

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

ND-4335.2  Impact Tests of Heat Affected Zone.

(a) Charpy V-notch tests of the heat affected zone of the welding procedure qualification test assembly are required whenever the thickness of the weld exceeds \( \frac{3}{8} \) in. (16 mm) and either of the base materials require impact testing in accordance with the rules of ND-2310. Exemption of base materials by ND-2311(a)(8) does not apply to the welding procedure qualification heat affected zone or unaffected base material for such materials. The only exceptions to the requirements are the following:

1. the qualification for welds in P-No. 1 and 3 and SA-336 F12 materials that are postweld heat treated and are made by any process other than electroslag, electrogas, or thermit;
2. the qualification for weld deposit cladding or hard-facing on any base material.
3. that portion of the heat affected zone associated with GTAW root deposits with a maximum of two layers of \( \frac{3}{16} \) in. (5 mm) thickness, whichever is less.
4. Charpy V-notch testing shall be performed as specified in (1) through (6).

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

(2) The Charpy V-notch tests of the unaffected base material shall meet the applicable requirements of Table ND-2331(a)-1 or Table ND-2331(a)-2, as applicable, or additional testing shall be performed at higher temperatures until either of the above requirements are met.

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

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

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

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

(5) As an alternative to (4), if the toughness values of the heat affected zone are no less than the values specified in Table ND-2331(a)-1 or Table ND-2332(a)-2, as applicable, and the average of the heat affected zone specimens is not less than 7 ft-lb (10 Nm) or 5 mils (0.13 mm) below the average toughness values of the unaffected base material, \( T_{ADJ} \) may be taken as 15°F (8°C).
(6) As a second alternative to (4), if the applicable toughness values of the heat affected zone are no less than the values specified in Table ND-2331(a)-1 or Table ND-2331(a)-2, as applicable, the difference between the average applicable toughness values of the heat affected zone and the unaffected base material shall be calculated and used as described in (c)(3) below.

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

(1) The lowest service temperature specified in the Design Specification for all material to be welded in production WPSs supported by this PQR shall be increased by the adjustment temperature \( T_{ADJ} \).

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

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

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

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

### Table ND-2331(a)-2

<table>
<thead>
<tr>
<th>Table ND-2331(a)-2</th>
</tr>
</thead>
</table>

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

#### ND-4410 PRECAUTIONS TO BE TAKEN BEFORE WELDING

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

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

#### ND-4412 Cleanliness and Protection of Welding Surfaces

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

#### ND-4420 RULES FOR MAKING WELDED JOINTS

#### ND-4421 Backing Rings

Backup plates and backing rings that remain in place, and compression rings or stiffeners of storage tanks such as angles, bars, and ring girders may be used. Their materials shall be compatible with the base metal, but spacer pins shall not be incorporated into the welds.

#### ND-4422 Peening

Controlled peening may be performed to minimize distortion. Peening shall not be used on the initial layer root of the weld metal or on the final layer unless the weld is postweld heat treated.

#### ND-4423 Double Welded Joints, Single Welded Joints, and Plug Welds

**ND-4423.1 Double Welded Joints.** Before applying weld metal on the second side to be welded, the root of full penetration double welded joints shall be prepared by suitable methods such as chipping, grinding, or thermal gouging, except for those processes of welding by which proper fusion and penetrations are otherwise obtained and demonstrated to be satisfactory by welding procedure qualifications.

**ND-4423.2 Single Welded Joints.** Where single welded joints are used, particular care shall be taken in aligning and separating the components to be joined so that there will be complete penetration and fusion at the bottom of the joint for its full length.
ND-4423.3 Plug Welds. In welding plug welds, a fillet around the bottom of the hole shall be deposited first.

ND-4424 Surfaces of Welds

As-welded surfaces are permitted, except for inertia and continuous drive friction welding where the flash shall be removed to sound metal. For piping, the appropriate stress intensification factors given in Table ND-3673 (b)-1 shall be applied. However, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to meet the requirements of (a) through (e) below.

(a) The surface condition of the finished weld shall be suitable for the proper interpretation of radiographic and other required nondestructive examination of the weld. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.

(b) Reinforcements are permitted in accordance with ND-4426.1 for vessels, pumps, and valves, and with ND-4426.2 for piping.

(c) Undercuts shall not exceed 1/32 in. (0.8 mm) and shall not encroach on the required section thickness.

(d) Concavity on the root side of a single welded circumferential but weld is permitted when the resulting thickness of the weld meets the requirements of ND-3000.

(e) If the surface of the weld requires grinding to meet the above criteria, care shall be taken to avoid reducing the weld or base material below the required thickness.

(f) For inertia and continuous drive friction welding, the weld upset shall meet the specified amount within ±10%.

ND-4425 Welding Components of Different Diameters

When components of different diameters are welded together, there shall be a gradual transition between the two surfaces. The length of the transition may include the weld in accordance with ND-3361.

ND-4426 Reinforcement of Welds

ND-4426.1 Thickness of Weld Reinforcement for Vessels, Pumps, and Valves. The surface of the reinforcement of all butt welded joints in vessels, pumps, and valves may be flush with the base material or may have uniform crowns. The height of reinforcement on each face of the weld shall not exceed the thickness in the following tabulation:

<table>
<thead>
<tr>
<th>Nominal Thickness, in. (mm)</th>
<th>Maximum Reinforcement, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1 (25), incl.</td>
<td>1/16 (0.6)</td>
</tr>
<tr>
<td>Over 1 to 2 (25 to 50), incl.</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 2 to 3 (50 to 75), incl.</td>
<td>1/16 (0.6)</td>
</tr>
<tr>
<td>Over 3 to 4 (75 to 100), incl.</td>
<td>3/32 (2.5)</td>
</tr>
</tbody>
</table>

ND-4426.2 Thickness of Weld Reinforcement for Piping. For double welded butt joints, the limitation on the reinforcement given in Column 1 of the following tabulation shall apply separately to both inside and outside surfaces of the joint. For single welded butt joints, the reinforcement given in Column 2 shall apply to the inside surface and the reinforcement given in Column 1 shall apply to the outside surface. The reinforcement shall be determined from the higher of the abutting surfaces involved.

<table>
<thead>
<tr>
<th>Maximum Reinforcement Thickness, in (mm)</th>
<th>Material Nominal Thickness, in (mm)</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1/8 (3), incl.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 1/8 to 1/16 (3 to 5), incl.</td>
<td></td>
<td>1/16 (0.6)</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 1/16 to 1/8 (5 to 13), incl.</td>
<td></td>
<td>3/32 (2.5)</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 1/8 to 1 (13 to 25), incl.</td>
<td></td>
<td>3/32 (2.5)</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 1 to 2 (25 to 50), incl.</td>
<td></td>
<td>3/32 (2.5)</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 2 (50)</td>
<td></td>
<td>3/32 (2.5)</td>
<td>1/8 (3)</td>
</tr>
</tbody>
</table>

ND-4427 Shape and Size of Fillet Welds

(a) Fillet welds may vary from convex to concave. Except as permitted in (b) below, the shape shape and size of the weld shall be in accordance with the requirements of Figure ND-4427-1. A fillet weld in any single continuous weld may be less than the specified fillet weld dimension by not more than 1/16 in. (1.5 mm), provided that the total undersize portion of the weld does not exceed 10% of the length of the weld. Individual undersize weld portions shall not exceed 2 in. (50 mm) in length. In making socket welds, a gap as shown in Figure ND-4427-1 shall be provided prior to welding. The gap need not be present nor be verified after welding. For sleeve type joints without internal shoulder, the gap shall be between the butting ends of the pipe or tube.

(b) Socket welds smaller than those specified in Figure ND-4427-1 may be used provided the requirements of ND-3000 are met.

ND-4428 Seal Welds of Threaded Joints

Where seal welding of threaded pipe joints is performed, the exposed threads shall be either removed entirely or covered with weld metal.
within the temperature range and for the minimum holding time specified in Table ND-4622.1-1, except as otherwise permitted in ND-4622.4(c). For P-No. 11A, Group 1 material, the complete component shall be postweld heat treated within the temperature range specified in Table ND-4622.1-1 and the provisions of ND-4624.2 and ND-4624.3 shall not be applied. P-Number groups in Table ND-4622.1-1 are in accordance with Section IX, QW-420. Except as provided in ND-4624.3, PWHT shall be performed in temperature-surveyed and -calibrated furnaces, or PWHT shall be performed with thermocouples in contact with the material or attached to blocks in contact with the material. In addition, the requirements of the following subparagraphs shall apply.

**ND-4622.2 Time–Temperature Recordings.** Time–temperature recordings of all postweld heat treatments shall be made available for review by the Inspector. Identification on the time–temperature recording shall be to the weld, item, part, or component. A summary of the time–temperature recording may be provided for permanent records in accordance with NCA-4134.17.

**ND-4622.3 Definition of Nominal Thickness Governing PWHT.** Nominal thickness in Table ND-4622.7(b)-1 is the thickness of the weld, the pressure retaining material for structural attachment welds or the thinner of the pressure retaining materials being joined, whichever is least. It is not intended that nominal thickness include material provided for forming allowance, thinning, or mill overrun when the excess material does not exceed 1/8 in. (3 mm). For fillet welds the nominal thickness is the throat thickness, and for partial penetration and material repair welds the nominal thickness is the depth of the weld groove or preparation.

**ND-4622.4 Holding Times at Temperature.**

(a) The holding time at temperature as specified in Table ND-4622.1-1 shall be based on the nominal thickness of the weld. The holding time need not be continuous. It may be an accumulation of the times of multiple postweld heat treat cycles.

(b) Holding time at temperature in excess of the minimum requirements of Table ND-4622.1-1 may be used, provided that specimens so heat treated are tested in accordance with ND-2200, ND-2400, and ND-4300.

(c) Alternatively, when it is impractical to postweld heat treat at the temperature range specified in Table ND-4622.1-1, it is permissible to perform the postweld heat treatment of certain materials at lower temperatures for longer periods of time in accordance with Table ND-4622.4(c)-1 and (1), (2), and (3) below.

(1) Except for P-No. 1 materials, when welds in the materials listed in Table ND-4622.4(c)-1 are to be postweld heat treated at these lower minimum temperatures, the impact test specimens for the welding procedure qualification required by ND-4300 shall be made using the same minimum temperatures and increased minimum holding time. Welding procedures, qualified at the temperature range and minimum holding time specified in Table ND-4622.1-1 and at the lower minimum temperature and increased minimum holding time permitted by Table ND-4622.4(c)-1, are also qualified for any temperature in between. When such an in-between temperature is used, the minimum holding time shall be interpolated from Table ND-4622.1-1 and the alternative requirements of Table ND-4622.4(c)-1.

(2) Except for P-No. 1 materials, when welds in the materials listed in Table ND-4622.4(c)-1 are to be postweld heat treated at these lower minimum temperatures, the welding material certification required by ND-2400 shall be made using the same minimum temperature and increased minimum holding times. Welding material certified at the temperature range and minimum holding time specified in Table ND-4622.1-1 and at the lower minimum temperatures and increased minimum holding times permitted by Table ND-4622.4(c)-1 are also certified for any temperature in between.

(3) Base material certified in accordance with ND-2200 may be postweld heat treated at the lower minimum temperatures and increased minimum holding times without recertification. Postweld heat treatment at these lower minimum temperatures and increased minimum

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**Table ND-4524-1**

<table>
<thead>
<tr>
<th>Filler Metal Classification</th>
<th>Temperature Below Which Only Section IX Tests Are Required, °F (°C)</th>
<th>Temperature Range Requiring Section IX Tests and Additional Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCuP</td>
<td>300 (150)</td>
<td>300 – 350 (150 – 175)</td>
</tr>
<tr>
<td>BAg</td>
<td>400 (205)</td>
<td>400 – 500 (205 – 260)</td>
</tr>
<tr>
<td>BCuZn</td>
<td>400 (205)</td>
<td>400 – 500 (205 – 260)</td>
</tr>
<tr>
<td>BCu</td>
<td>400 (205)</td>
<td>400 – 650 (205 – 345)</td>
</tr>
<tr>
<td>BAlSi</td>
<td>300 (150)</td>
<td>300 – 350 (150 – 175)</td>
</tr>
<tr>
<td>BNi</td>
<td>800 (425)</td>
<td></td>
</tr>
</tbody>
</table>

*GENERAL NOTE: Temperatures are based on AWS recommendations.*
P = \frac{B}{5} \times \frac{SE}{S_{ave}} \quad \text{or} \quad P = \frac{B_f}{5} \times \frac{SE}{S_{ave}} \quad (3)

(2) Parts constructed of cast materials, except cast iron and cast nodular iron that are not permitted

P = \frac{B_f}{5} \times \frac{SE}{S_{ave}} \quad \text{or} \quad P = \frac{B_f}{5} \times \frac{SE}{S_{max}} \quad (4)

where

B = \text{bursting test pressure}
E = \text{efficiency of welded joint, if used (ND-3352-1)}
f = \text{casting quality factor (ND-3115)}
S = \text{specified minimum tensile strength}
S_{ave} = \text{average actual tensile strength of test specimens}
S_{max} = \text{maximum tensile strength of range of specification}

(3) The Design Pressure at other temperatures shall be determined as provided in ND-6911.9.

ND-6923 Strain Measurement Test Procedure

(a) Subject to limitations of ND-6911.1(a), this procedure may be used for components or component parts under internal pressure, constructed of any material permitted to be used under the rules of this Subsection. Strains shall be measured in the direction of the maximum stress at the most highly stressed parts (see ND-6911.6) by means of strain gages of any type capable of indicating strains to 0.00005 in./in. (0.00125 mm/mm). Pressure shall be applied as provided in ND-6911.5.

(b) After each increment of pressure has been applied, readings of the strain gages and the hydrostatic pressure shall be taken and recorded. The pressure shall be released and any permanent strain at each gage shall be determined after any pressure increment that indicates an increase in strain for this increment over the previous equal pressure increment. Only one application of each increment of pressure is required.

(c) Two curves of strain against test pressure shall be plotted for each gage line as the test progresses, one showing the strain under pressure and one showing the permanent strain when the pressure is removed. The test may be discontinued when the test pressure reaches the value \( H \) that will, by the equation, justify the desired Design Pressure, but shall not exceed the pressure at which the plotted points for the most highly strained gage line reach the value given below for the material used

1. 0.2% strain for aluminum-base and nickel-base alloys
2. 0.2% strain for carbon low alloy and high alloy steels
3. 0.5% strain under pressure for copper-base alloys

(d) The Design Pressure \( P \) in psig at test temperature for parts tested under this paragraph shall be computed as stipulated in (1) through (3) below.

(1) If the average yield strength is determined in accordance with ND-6911.8

\[ P = 0.5 \left( \frac{Y_a}{Y_y} \right) \]

(2) If the actual average yield strength is not determined by test specimens

\[ P = 0.4H \]

where

\( H = \text{hydrostatic test pressure at which the test was stopped in accordance with (c) above} \)
\( S = \text{specified minimum tensile strength} \)
\( Y_a = \text{actual average yield strength from test specimens} \)
\( Y_y = \text{specified minimum yield strength, psi (kPa)} \)

(3) The Design Pressure at other temperatures shall be determined as provided in ND-6911.9.

ND-6924 Displacement Measurement Test Procedure

(a) Subject to the limitations of ND-6911.1(a), this procedure may be used only for components and component parts under internal pressure, constructed of materials having a definitely determinable yield point. Displacement shall be measured at the most highly stressed parts (ND-6911.6) by means of measuring devices of any type capable of measuring to 0.001 in. (0.025 mm). The displacement may be measured between two diametrically opposed reference points in a symmetrical structure or between a reference point and a fixed base point. Pressure shall be applied as provided in ND-6911.5.

(b) After each increment of pressure has been applied, readings of the displacement and hydrostatic test pressure shall be taken and recorded. The pressure shall be released, and any permanent displacement shall be determined after any pressure increment that indicates an increase in measured displacement for this increment over the previous equal pressure increment. Only one application of each increment is required. Care must be taken to assure that the readings represent only displacements of the parts on which measurements are being made, and do not include any slip of the measuring devices or any movement of the fixed base points or of the pressure part as a whole.

(c) Two curves of displacement against test pressure shall be plotted for each reference point as the test progresses, one showing the displacement under pressure and one showing the permanent displacement when the pressure is removed. The application of pressure shall be stopped when it is evident that the curve through the points representing displacement under pressure has deviated from a straight line.
(3) other identification if no SFA Specification applies;
(4) minimum tensile strength [NE-2431.1(e)] in the as-welded or heat treated condition, or both [NE-2431.1(c)];
(5) drop weight test for material as-welded or heat treated, or both (NE-2332);
(6) Charpy V-notch test for material as-welded, or heat treated, or both (NE-2331); the test temperature and the lateral expansion or the absorbed energy shall be provided;
(7) the preheat and interpass temperature to be used during welding of the test coupon [NE-2431.1(c)];
(8) postweld heat treatment time, temperature range, and maximum cooling rate, if the production weld will be heat treated [NE-2431.1(c)];
(9) elements for which chemical analysis is required per the SFA Specification or WPS, and NE-2432;
(10) minimum delta ferrite (NE-2433).

**NE-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 (electro-gas welding) processes (Section IX, OW-193); for each heat of consumable inserts; for each combination of bare electrodes and lot of submerged arc flux; 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. 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 NE-4000 and this Subarticle are made and the results conform to the requirements of this Article. The definitions in (a) through (h) below apply.

(a) A dry batch of covering mixture is defined as the quantity of dry covering ingredients mixed at one time in one mixing vessel; a dry batch may be used singly or may be subsequently subdivided into quantities to which the liquid binders may be added to produce a number of wet mixes [(c) below].

(b) A dry blend is defined as one or more dry batches mixed in a mixing vessel and combined proportionately to produce a uniformity of mixed ingredients equal to that obtained by mixing the same total amount of dry ingredients at one time in one mixing vessel.

(c) A wet mix is defined as the combination of a dry batch or dry blend [(a) and (b) above, respectively] and liquid binder ingredients at one time in one mixing vessel.

(d) A lot of covered, flux-cored, or fabricated electrodes is defined as the quantity of electrodes produced from the same combination of heat of metal and dry batch, dry blend, or chemically controlled mixes of flux or core materials. Alternatively, a lot of covered, flux-cored, or fabricated electrodes may be considered one type and size of electrode, produced in a continuous period, not to exceed 24 hr and not to exceed 100,000 lb (45 000 kg), from chemically controlled tube, wire, or strip, and a dry batch, a dry blend, or chemically controlled mixes of flux, provided each container of welding materials is coded for identification and traceable to the production period, the shift, line, and the analysis range of both the mix and the rod, tube, or strip used to make the electrode.

(1) Chemically controlled tube, wire, or strip is defined as consumable tube, wire, or strip material supplied on coils with a maximum of one splice per coil that has been chemically analyzed to assure that the material conforms to the electrode manufacturer’s chemical control limits for the specific type of electrode. Both ends of each coil shall be chemically analyzed, except that those coils which are splice-free need only be analyzed on one end of the coil.

(2) Chemically controlled mixes of flux are defined as flux material that has been chemically analyzed to assure that it conforms to the percent allowable variation from the electrode manufacturer’s standard for each chemical element for that type of electrode. A chemical analysis shall be made on each mix made in an individual mixing vessel after blending.

(e) A heat of bare electrode, rod, wire, or consumable insert is defined as the material produced from the same melt of metal.

(f) Alternatively, for carbon and low alloy steel bare electrode, rod, wire, or consumable inserts for use with SAW, OFW, GMAW, GTAW, PAW, and EGW processes, a heat may be defined as either the material produced from the same melt of metal or the material produced from one type and size of wire when produced in a continuous period, not to exceed 24 hr and not to exceed 100,000 lb (45 000 kg), from chemically controlled wire, subject to requirements of (1), (2), and (3) below.

(1) For the chemical control of the product of the rod mill, coils shall be limited to a maximum of one splice prior to processing the wire. Chemical analysis shall be made from a sample taken from both ends of each coil of mill coiled rod furnished by mills permitting spliced coil practice of one splice maximum per coil. A chemical analysis need be taken only at one end of each coil furnished by mills prohibiting spliced coil practice.

(2) Carbon, manganese, silicon, and other intentionally added elements shall be determined to identify the material to ensure that it conforms to the SFA or user’s material specification.

(3) Each container of wire shall be coded for identification and traceability to the lot, production period, shift, line, and analysis of rod used to make the wire.

(g) A lot of submerged arc or electroslag flux is defined as the quantity of flux produced from the same combination of raw materials under one production schedule.
Standard Test 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 Specification SFA-5.1 or SFA-5.5.

(b) The test 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 $C_v$ specimens or the drop weight test specimens required by NE-2331, where 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 in the postweld heat treated condition. The postweld heat treatment temperatures shall be in accordance with Table NE-4622.1-1 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). Where the postweld heat treatment of the production weld exceeds 10 hr, or the PWHT temperature is other than that required above, the general test of NE-2431.1 shall be used.

(d) The tensile and $C_v$ 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 NE-2431.1(d).

(e) 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.

(f) The requirements of NE-2431.1(f) shall be applicable to the impact testing of this option.

NE-2432 Chemical Analysis Test

Chemical analysis of filler metal or weld deposits shall be made in accordance with NE-2420 and as required by NE-2432.1 and NE-2432.2.

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

<table>
<thead>
<tr>
<th>Table NE-2432.1-1</th>
<th>Sampling of Welding Materials for Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTAW/PAW</td>
<td>GMAW</td>
</tr>
<tr>
<td>All Other Processes</td>
<td></td>
</tr>
<tr>
<td>A-No. 8 filler metal</td>
<td>Filler metal or weld deposit</td>
</tr>
<tr>
<td>weld deposit</td>
<td>Weld deposit</td>
</tr>
<tr>
<td>All other filler metal</td>
<td>Filler metal or weld deposit</td>
</tr>
<tr>
<td>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 either the filler metal analysis or the undiluted weld deposit analysis or for 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 Specification 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 NE-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of NE-2431.1(c) 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-214.3, for the minimum thickness for which the Welding Procedure Specification is qualified.
(c) The identification of welder or welding operator is not required for tack welds.

**NE-4323  Welding Prior to Qualifications**

No welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with **NE-4320** and Section IX shall be used.

**NE-4324  Transferring Qualifications**

The welding procedure qualifications and the performance qualification tests for welders and welding operators conducted by one Certificate Holder shall not qualify welding procedures and shall not qualify welders or welding operators to weld for any other Certificate Holder, except as provided in Section IX, QW-201 and QW-209.2.

**NE-4330  GENERAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION TESTS**

**NE-4331  Conformance to Section IX Requirements**

All welding procedure qualification tests shall be in accordance with the requirements of Section IX as supplemented by the requirements of this Article.

**NE-4333  Heat Treatment of Qualification Welds of Ferritic Material**

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

**NE-4334  Preparation of Test Coupons and Specimens**

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

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

**NE-4334.1  Coupons Representing the Weld Deposits**

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

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

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

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

(c) For the comparison of heat-affected zone values with base material values [NE-4335.2(b)], Charpy V-notch specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material.
(b) For through-thickness temperature differences, adjacent points are defined as any two points on a line normal to any surface.

15 The algebraic range of the difference shall be used.

16 It is permissible to use $1.5S_{m1}$ whenever it is greater than $S_y$.

17 The minimum thickness for all pipe materials is the nominal wall thickness listed in Table 2 of ASME B36.10, less $12/2\%$. For diameters other than those listed in the table, this shall be based on the next largest pipe size.

18 The equations provide safe construction as far as stress is concerned. Greater thickness may be necessary if deflection would cause leakage at threaded or gasketed joints.

19 Since $H, h_r$ in some cases will subtract from the total moment, the moment in the flange ring when the internal pressure is zero may be the determining loading for the flange design.

20 Communicating chambers are defined as appurtenances to the vessel that intersect the shell or heads of a vessel and form an integral part of the pressure-retaining closure.

21 Side plates of a flat-sided vessel are defined as any of the flat plates forming an integral part of the pressure-retaining enclosure.

22 This paragraph is written for fittings with internal threads, but is applicable to externally threaded or butt-welded fittings.

23 $t_f$ is defined in Section III Appendices, Mandatory Appendix XI, XI-3130.

24 For general information, see standards of the Expansion Joint Manufacturers Association, Inc., 25 N. Broadway, Tarrytown, NY 10591.

25 See Section III Appendices, Mandatory Appendix II, II-1520(g).

26 One test specimen may represent a group of forgings, provided they are of the same nominal dimensions, from the same heat of material, the same heat treatment lot, and forged in the same manner.

27 Welds that are exposed to corrosive action should have a resistance to corrosion that is not substantially less than that of the cladding. The use of filler metal that will deposit weld metal which is similar to the composition of the cladding material is recommended. If weld metal of different composition is used, it should have properties compatible with the application.

28 SNT-TC-1A is a Recommended Practice for Nondestructive Testing Personnel Qualification and Certification published by the American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228-0518.

29 Personnel qualified by examination and certified to previous editions of SNT-TC-1A are considered to be qualified to the edition referenced in Table NCA-7100-2 when the recertification is based on continuing satisfactory performance. All reexaminations and new examinations shall be in accordance with the edition referenced in Table NCA-7100-2.

30 Employer as used in Article NE-5000 shall include: N Certificate Holders; Quality System Certificate Holders; Material Organizations who are qualified in accordance with NCA-3842; and organizations who provide subcontracted nondestructive examination services to organizations described above.

31 These tests may be made with the item being tested partially filled with liquid, if desired.

32 Valve capacities published in “Pressure Relief Device Certifications.” This publication may be obtained from the National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, OH 43229.
Table NF-2333-1
Required Cᵥ Values for Bolting Material

<table>
<thead>
<tr>
<th>Nominal Diameter, in. (mm)</th>
<th>Lateral Expansion, mils (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (25) or less</td>
<td>No test required</td>
</tr>
<tr>
<td>Over 1 (25)</td>
<td>25 (0.64)</td>
</tr>
</tbody>
</table>

(4) 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 3” requirements specified.

NF-2352 Retests for Bolting for Charpy V-Notch Tests

For Charpy V-notch tests of bolting required by NF-2333 to meet the acceptance standards of Table NF-2333-1, one retest at the same temperature may be conducted, provided

(a) the average value of the test results meets the minimum requirements.

(b) not more than one specimen per test is below the minimum requirements.

(c) the specimens not meeting the minimum requirements are not lower than 5 mils (0.13 mm) below the specified requirements.

(d) 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 minimum requirements.

NF-2360 CALIBRATION OF INSTRUMENTS AND EQUIPMENT

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

(a) Temperature instruments used to control test temperature of specimens shall be calibrated and the results recorded to meet the requirements of NCA-3858.2 at least once in each 3 month interval.

(b) Cᵥ impact test machines shall be calibrated and the results recorded to meet the requirements of NCA-3858.2. 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-3855.3(c).

NF-2400 WELDING MATERIAL

NF-2410 GENERAL REQUIREMENTS

(a) All welding material used in the construction and repair of supports 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 NF-2150.

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

(1) welding process
(2) SFA Specification and classification
(3) other identification if no SFA Specification applies
(4) minimum tensile strength [NF-2431.1(e)] in either the as-welded or heat treated condition, or both [NF-2431.1(c)]

(5) Charpy V-notch test for material as-welded or heat treated, or both (NF-2331); the test temperature, and the lateral expansion or the absorbed energy, shall be provided

(6) the preheat and interpass temperatures to be used during welding of the test coupon [NF-2431.1(c)]
(7) postweld heat treatment time, temperature range, and maximum cooling rate, if the production weld will be heat treated [NF-2431.1(c)]
(8) elements for which chemical analysis is required per the SFA Specification or WPS and NF-2432
(9) minimum delta ferrite (NF-2433)

NF-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 EW (electro-gas welding) processes (Section IX, eq. 2.4.4.4.1.02); 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. 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 NF-4000 and this Subarticle are made and the results conform to the requirements of this Article. The definitions in (a) through (h) apply.

(a) A dry batch of covering mixture is defined as the quantity of dry covering ingredients mixed at one time in one mixing vessel; a dry batch may be used singly or
chemical analysis performed either on the filler metal or on a weld deposit made with the filler metal in accordance with (c) or (d).

(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). The removal of chemical analysis samples shall be from an undiluted weld deposit made in accordance with (c). As an alternative, the deposit shall be made in accordance with (d) 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 either the filler metal analysis or the undiluted weld deposit analysis or for 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 Specification 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 NF-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of NF-2431.1(c) do not apply.

(d) The alternate method provided in (b) 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 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 QW-214.2 for the minimum thickness for which the Welding Procedure Specification is qualified.

NF-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) through (c).

(a) Welding material of ferrous alloy A-No. 8 (Section IX, QW-442) shall be analyzed for the elements listed in Table NF-2432.2(a)-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 NF-2432.2(a)-1 but not specified in the welding material specification or Welding Procedure Specification shall be reported for information only.

NF-2433 Delta Ferrite Determination

A determination of delta ferrite shall be performed on A-No. 8 weld material (Section IX, 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.

NF-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). Alternatively, the delta ferrite determinations for welding materials may be performed by the use of chemical analysis of NF-2432 in conjunction with Figure NF-2433.1-1.

<table>
<thead>
<tr>
<th>Table NF-2432.2(a)-1</th>
<th>Welding Material Chemical Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
<td><strong>Elements</strong></td>
</tr>
<tr>
<td>Cr-Ni stainless materials</td>
<td>C, Cr, Mo, Ni, Mn, Si,Cb</td>
</tr>
</tbody>
</table>

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and certified by the Certificate Holder by signature or
some other method of control in accordance with the Cer-
tificate Holder’s Quality Assurance Program.

**NF-4322.1 Identification of Joints for Class 1 Com-
ponent Supports.**

(a) For Class 1 Plate- and Shell-Type, and Linear-Type
Component Supports, the welder or welding operator
shall apply the identification mark assigned to him by
the Certificate Holder on or adjacent to all permanent
welds, including fillet welds, at 3 ft (1 m) intervals or less,
except as noted in (b). The marking shall be done with
either blunt nose continuous or blunt nose interrupted
dot die stamps. As an alternative, the Certificate Holder
shall keep a record of permanent welded joints in a com-
ponent support, and of the welders and welding operators
used in making each of the joints.

(b) For partial penetration welds with a depth less than
1 in. (25 mm) and fillet welds with a throat dimension less
than 1 in. (25 mm) in primary members, and for all welds
in secondary members, the Certificate Holder need not
identify the welder or welding operator who welded each
joint provided

(1) the Certificate Holder maintains a system that will
identify the welders or welding operators who made such
welds on each item

(2) the welds in each category are all of the same type
and configuration and are welded with the same Welding
Procedure Specification

**NF-4322.2 Identification of Other Joints.** For all
types of Class 2, 3, and MC component supports and for
all classes of piping supports and Standard Supports, the
Certificate Holder shall certify that only welders and weld-
ning operators qualified in accordance with NF-4321 were
used in making all welds.

**NF-4322.3 Identification of Tack Welds.** The identi-
fication of welder or welding operator is not required
for tack welds.

**NF-4323 Welding Prior to Qualification**

No welding shall be undertaken until after the welding
procedures which are to be used have been qualified. Only
welders and welding operators who are qualified in accor-
dance with NF-4320 and Section IX shall be used.

**NF-4324 Transferring Qualifications**

The welding procedure qualifications and the perfor-
mance qualification tests for welders and welding opera-
tors conducted by one Certificate Holder shall not
qualify welding procedures and shall not qualify welders
or welding operators to weld for any other Certificate
Holder, except as provided in Section IX, QW-201 and
QW-300.

**NF-4330 GENERAL REQUIREMENTS FOR
WELDING PROCEDURE QUALIFICATION
TESTS**

**NF-4331 Conformance to Section IX
Requirements**

All welding procedure qualification tests shall be in ac-
cordance with the requirements of Section IX as supple-
mented by the requirements of this Article.

**NF-4334 Preparation of Test Coupons and
Specimens**

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

(b) Weld deposit of each process in a multiple process
weld shall, where possible, be included in the impact test
specimens. When each process cannot be included in the
full-size impact test specimen at the \( \frac{3}{4} t \) location required
by this Section, additional full-size specimens shall be ob-
tained from locations in the test weld that will ensure that
at least a portion of each process has been included in full-
size test specimens. As an alternative, additional test
welds can be made with each process so that full-size spe-
cimens can be tested for each process.

**NF-4334.1 Coupons Representing the Weld Depo-
its.** Impact test specimen and testing methods shall con-
form to NF-2321. The impact specimen shall be located
so that the longitudinal axis of the specimen is at least
\( \frac{3}{4} t \), and where the thickness of the test assembly permits,
not less than \( \frac{3}{8} \) in. (10 mm) from the weld surface of the
test assembly. In addition, when the postweld heat treat-
ment temperature exceeds the maximum temperature
specified in NF-4620, and the test assembly is cooled at
an accelerated rate, the longitudinal axis of the specimen
shall be a minimum of \( t \) from the edge of the test assembly.
The specimen shall be transverse to the longitudinal axis
of the weld with the area of the notch located in the weld.
The length of the notch of the Charpy V-notch specimen
shall be normal to the surface of the weld.

**NF-4334.2 Coupons Representing the Heat-Affected
Zone.** Where impact tests of the heat-affected zone are re-
quired by NF-4335.2, specimens shall be taken from the
welding procedure qualification test assemblies in accor-
dance with (a) through (c).

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

(b) The heat-affected zone impact test specimens and
testing methods shall conform to NF-2321. The specimens
shall be removed from a location as near as practical to a
depth midway between the surface and center thickness.
The coupons for heat-affected zone impact specimens
shall be taken transverse to the axis of the weld and etched to define the heat-affected zone. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much heat-affected zone as possible in the resulting fracture. Where the material thickness permits, the axis of a specimen may be inclined to allow the root of the notch to align parallel to the fusion line. When a grain refining heat treatment is not performed on welds made by the electroslag or electrogas welding process, the notch for the impact specimens shall be located in the grain coarsened region.

(c) For the comparison of heat-affected zone values with base material values [NF-4335.2(b)], Charpy V-notch specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material.

**NF-4335 Impact Test Requirements**

When materials are required to be impact tested per NF-2300, impact tests of the weld metal and heat-affected zone shall be performed in accordance with the following subparagraphs. Exemptions from impact testing under NF-2311(b)(9) and NF-2311(b)(10) do not apply to weld metal unless the specific weld metal used is included in Table NF-2311(b)-1 (weld metal exemptions are being developed). Exemption from impact testing of the heat-affected zone of those base materials which are exempted by NF-2311(b)(9) and NF-2311(b)(10) is not permitted. The welding procedure qualification impact test specimens shall be prepared and tested in accordance with the applicable requirements of NF-2330 and NF-4334. Retests in accordance with the provisions of NF-2350 are permitted.

**NF-4335.1 Impact Tests of Weld Metal.**

(a) Impact tests of the weld metal shall be required for welding procedure qualification tests for production weld joints exceeding $0.125$ in. (16 mm) in thickness when the weld is made on the surface or penetrates the base material that requires impact testing in accordance with NF-2310. In addition, such testing of the weld metal is required for the welding procedure qualification tests for any weld repair to base material that requires impact testing in accordance with NF-2310, regardless of the depth of the repair. Exemption from impact testing under NF-2311(b)(9) and NF-2311(b)(10) does not apply to weld metal of the welding procedure qualification test for either production weld joints or base material repairs unless the specific weld metal used is included in Table NF-2311(b)-1 (weld metal exemptions are being developed).

(b) The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in NF-2330 for the base material to be welded or repaired. Where two materials which have different fracture toughness requirements are to be joined by welding, the test requirements and acceptance standards of either material may be used for the weld metal, except where otherwise specified by NCA-1280 or other parts of this Section.

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

**NF-4335.2 Impact Tests of Heat-Affected Zone.**

(a) Charpy V-notch tests of the heat-affected zone of the welding procedure qualification test assembly are required whenever the thickness of the weld exceeds $0.125$ in. (16 mm), and either of the base materials requires impact testing in accordance with the rules of NF-2310. Exemption of base materials by NF-2311(b)(9) or NF-2311(b)(10) does not apply to the welding procedure qualification of the heat-affected zone or unaffected base material for such materials. The only exceptions to the requirements are the following:

1. The qualification for welds in P-Nos. 1 and 3 and SA-336 F12 materials that are postweld heat treated and are made by any process other than electroslag, electrogas, or thermite.
2. The qualification for weld deposit cladding or hard-facing on any base material.
3. That portion of the heat-affected zone associated with GTAW root deposits with a maximum of two layers or $0.125$ in. (5 mm) thickness, whichever is less.

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

1. Charpy V-notch test specimens representing both the heat-affected zone and the unaffected base material shall be tested. The unaffected base material shall be tested at a temperature below that specified in NF-2311(c).
2. The Charpy V-notch test specimens shall meet the applicable requirements of Table NF-4334 for the applicable Class and acceptance category. If the requirements are not met at the test temperature, additional testing shall be performed at higher temperatures until the above requirements are met.
3. The heat-affected zone specimens shall be tested at the test temperature determined in (2). If the average applicable toughness value of the heat-affected zone specimens equals or exceeds the average applicable toughness value of the unaffected base material, the qualification test is acceptable for the essential and supplemental essential variables recorded on the Welding Procedure Qualification Record. If the heat-affected zone average applicable toughness value is less than the unaffected base material average applicable toughness value, the adjustment given
in (4) through (6) shall be determined and applied as provided in (c). Alternatively, another test coupon may be welded and tested.

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

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

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

(5) As an alternative to (4), if the applicable toughness values of the heat-affected zone are no less than those specified in Table NF-2330 for the applicable Class and acceptance category and the average applicable toughness value of the heat-affected zone specimens is not less than 7 ft-lb (10 ft) or 5 mils (0.13 mm) below the average applicable toughness value of the unaffected base material, $T_{ADJ}$ may be taken as $15^\circ F$ ($8^\circ C$).

(6) As a second alternative to (4), if the applicable toughness values of the heat-affected zone are no less than those specified in Table NF-2330 for the applicable Class and acceptance category, the difference between the average applicable toughness value of the heat-affected zone and the unaffected base material shall be calculated and used as described in (c)(3).

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

(1) The lowest service temperature specified in the Design Specification for all of the material to be welded in production Welding Procedure Specifications supported by this Welding Procedure Qualification Record shall be increased by the adjustment temperature $T_{ADJ}$.

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

(3) The materials to be welded may be welded using the Welding Procedure Specification, provided they exhibit toughness values that are no less than the minimum required toughness values specified in NF-2300 plus the difference in the average applicable toughness values established in (b)(6).

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

(e) A Welding Procedure Specification qualified to the impact testing requirements of Subsection NB, NC, or NE may be accepted as an alternative to the Welding Procedure Specification impact testing requirements of this Subsection.
(3) other identification if no SFA Specification applies
(4) minimum tensile strength [NG-2431.1(c)] in either the as-welded or heat-treated condition or both [NG-2431.1(c)]
(5) drop weight test for material as-welded or heat treated or both (NG-2332)
(6) Charpy V-notch test for material as-welded or heat treated or both (NG-2331); the test temperature, and 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 [NG-2431.1(c)]
(8) postweld heat treatment time, temperature range, and maximum cooling rate, if the production weld will be heat treated [NG-2431.1(c)]
(9) elements for which chemical analysis is required per the SFA Specification or WPS, and NG-2432
(10) minimum delta ferrite (NG-2433)

NG-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 (electro-gas welding) processes (Section IX, OW-492); 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. 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 NG-4000 and this Subarticle are made and the results conform to the requirements of this Article. The following definitions apply:

(a) dry batch of covering mixture: the quantity of dry covering ingredients mixed at one time in one mixing vessel; a dry batch may be used singly or may be subsequently subdivided into quantities to which the liquid binders may be added to produce a number of wet mixes [see (c)].
(b) dry blend: one or more dry batches mixed in a mixing vessel and combined proportionately to produce a uniformity of mixed ingredients equal to that obtained by mixing the same total amount of dry ingredients at one time in one mixing vessel.
(c) wet mix: the combination of a dry batch or dry blend [(a) and (b), respectively] and liquid binder ingredients at one time in one mixing vessel.
(d) lot of covered, flux cored, or fabricated electrodes: the quantity of electrodes produced from the same combination of heat of metal and dry batch, dry blend, or chemically controlled mixes of flux or core materials.

Alternatively, a lot of covered, flux cored, or fabricated electrodes may be considered one type and size of electrode, produced in a continuous period, not to exceed 24 hr and not to exceed 100,000 lb (45 000 kg), from chemically controlled tube, wire, or strip and a dry batch, a dry blend, or chemically controlled mixes of flux, provided each container of welding materials is coded for identification and traceable to the production period, the shift, line, and the analysis range of both the mix and the rod, tube, or strip used to make the electrodes.

(1) chemically controlled tube, wire, or strip: consumable tube, wire, or strip material supplied on coils with a maximum of one splice per coil that has been chemically analyzed to ensure that the material conforms to the electrode manufacturer’s chemical control limits for the specific type of electrode. Both ends of each coil shall be chemically analyzed, except those coils which are splice free need only be analyzed on one end of the coil.

(2) chemically controlled mixes of flux: flux material that has been chemically analyzed to assure that it conforms to the percent allowable variation from the electrode manufacturer’s standard for each chemical element for that type electrode. A chemical analysis shall be made on each mix made in an individual mixing vessel after blending.

(e) heat of bare electrode, rod, wire, or consumable insert: the material produced from the same melt of metal.
(f) Alternatively, for carbon and low alloy steel bare electrode, rod, wire, or consumable inserts for use with SAW, OFW, GMAW, GTAW, PAW, and EGW processes, a heat may be defined as either the material produced from the same melt of metal, or the material produced from one type and size of wire when produced in a continuous period, not to exceed 24 hr and not to exceed 100,000 lb (45 000 kg), from chemically controlled wire, subject to the following requirements:

(1) For the chemical control of the product of the rod mill, coils shall be limited to a maximum of one splice prior to processing the wire. Chemical analysis shall be made from a sample taken from both ends of each coil of mill coiled rod furnished by mills permitting spliced coil practice of one splice maximum per coil. A chemical analysis need be taken from only one end of rod coils furnished by mills prohibiting spliced coil practice.

(2) Carbon, manganese, silicon, and other intentionally added elements shall be determined to identify the material to ensure that it conforms to the SFA or user’s material specification.

(3) Each container of wire shall be coded for identification and traceability to the lot, production period, shift, line, and analysis of rod used to make the wire.

(g) lot of submerged arc or electroslag flux: the quantity of flux produced from the same combination of raw materials under one production schedule.

(h) dry blend of supplementary powdered filler metal: one or more mixes of material produced in a continuous period, not to exceed 24 hr and not to exceed 20,000 lb
(b) The test 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 C\textsubscript{e} specimens and the drop weight test specimens required by NG-2330, where 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 in the postweld heat treated condition. The postweld heat treatment temperatures shall be in accordance with Table NG-4622.1-1 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). Where the postweld heat treatment of the production weld exceeds 10 hr or the PWHT temperature is other than that required above, the general test of NG-2431.1 shall be used.

(d) The tensile and C\textsubscript{e} 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 NG-2431.1(d).

(e) 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.

(f) The requirements of NG-2431.1(f) shall be applicable to the impact testing of this option.

NG-2432 Chemical Analysis Test

Chemical analysis of filler metal or weld deposits shall be made in accordance with NG-2420 and as required by the following subparagraphs.

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

(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 either the filler metal analysis or the undiluted weld deposit analysis or for 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\textsuperscript{9} 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 NG-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of NG-2431.1(c) do not apply.

(d) The alternative 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 QW-214.2 for the minimum thickness for which the Welding Procedure Specification is qualified.

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Table NG-2432.1-1
Sampling of Welding Materials for Chemical Analysis

<table>
<thead>
<tr>
<th></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>
part or 15 in.\(^2\) (9 700 mm\(^2\)), whichever is less, shall require the same documentation as welds exceeding the minimum depth.

**NG-4200** FORMING, FITTING, AND ALIGNING

**NG-4210** CUTTING, FORMING, AND BENDING

**NG-4211** Cutting

Materials may be cut to shape and size by mechanical means, such as machining, shearing, chopping, or grinding, or by thermal cutting.

**NG-4211.1** Preheating Before Thermal Cutting.

When thermal cutting is performed to prepare weld joints or edges, to remove attachments or defective material, or for any other purpose, consideration shall be given to preheating the material, using preheat schedules, such as suggested in Appendix D.

**NG-4211.2** Material Preparation After Thermal Cutting for P-No. 8 Material.

When metal is to be removed by thermal cutting methods, additional material shall be removed by mechanical means to the extent required in the Design Specifications.

**NG-4212** Forming and Bending Processes

Any process may be used to hot or cold form or bend core support structure material, including weld metal, provided the required dimensions are attained (see NG-4214 and NG-4220), and provided the specified impact properties of the material, when required, are not reduced below the minimum specified values or they are effectively restored by heat treatment following the forming operation. Hot forming is defined as forming with the material temperature higher than 100°C (56°C) below the lower transformation temperature of the material. When required, the process shall be qualified for impact properties as outlined in NG-4213.

**NG-4213** Qualification of Forming Processes for Impact Property Requirements

A procedure qualification test shall be conducted using specimens taken from material of the same specification, grade or class, heat treatment, and with similar impact properties as required for the material in the structure. These specimens shall be subjected to the equivalent forming or bending process and heat treatment as the material in the structure. Applicable tests shall be conducted to determine that the required impact properties of NG-2300 are met after straining.

**NG-4213.1** Exemptions. Procedure qualification tests are not required for materials listed in (a) through (f)

(a) hot formed material, such as forgings, in which the hot forming is completed by the Material Organization prior to removal of the impact test specimens

(b) hot formed material represented by test coupons required in either NG-2211 or NG-4121.2 which has been subjected to heat treatment representing the hot forming procedure and the heat treatments to be applied to the parts

(c) material which does not require impact tests in accordance with NG-2300

(d) material which has a final strain less than 0.5%

(e) material where the final strain is less than that of a previously qualified procedure for that material

(f) material from which the impact testing required by NG-2300 is performed on each heat and lot, as applicable, after forming

**NG-4213.2** Procedure Qualification Test. The procedure qualification test shall be performed in the manner stipulated in (a) through (f).

(a) The tests shall be performed on three different heats of material both before and after straining to establish the effects of the forming and subsequent heat treatment operations.

(b) Specimens shall be taken in accordance with the requirements of NG-2000 and from the tension side of the strained material.

(c) The percent strain shall be established by the following equations:

For cylinders

\[
\% \text{ strain} = 50t/R_f \left[ 1 - \left( R_f/R_o \right)^{1/3} \right]
\]

For spherical or dished surfaces

\[
\% \text{ strain} = 75t/R_f \left[ 1 - \left( R_f/R_o \right)^{1/3} \right]
\]

For pipe

\[
\% \text{ strain} = 100r/R
\]

where

\( R = \) nominal bending radius to the center line of the pipe
\( r = \) nominal radius of the pipe
\( R_f = \) final radius to center line of shell
\( R_o = \) original radius (equal to infinity for a flat part)
\( t = \) nominal thickness

(d) The procedure qualification shall simulate the maximum percent surface strain, employing a bending process similar to that used in the fabrication of the material or by direct tension on the specimen.

(e) Sufficient \( C_P \) specimens shall be taken from each of the three heats of material to establish a transition curve showing both the upper and lower shelves. On each of the three heats, tests consisting of three impact specimens shall be conducted at a minimum of five different temperatures distributed throughout the transition region. The upper and lower shelves may be established by the use of one test specimen each. Depending on the product form, it may be necessary to plot the transition curves using
NG-4311.3 Inertia and Continuous Drive Friction Welding. Inertia and continuous drive friction welding shall not be used for the fabrication of core support structures.

NG-4320 WELDING QUALIFICATIONS, RECORDS, AND IDENTIFYING STAMPS

NG-4321 Required Qualifications

(a) Each Certificate Holder is responsible for the welding done by his organization, and he shall establish the procedure and conduct the tests required by this Article and by Section IX in order to qualify both the welding procedures and the performance of welders and welding operators who apply these procedures.

(b) Procedures, welders, and welding operators used to join permanent or temporary attachments to core support structure parts and to make permanent or temporary tack welds used in such welding shall also meet the qualification requirements of this Article.

(c) When making procedure test plates for butt welds, consideration shall be given to the effect of angular, lateral, and end restraint on the weldment. This applies particularly to material and weld metal of 80.0 ksi (550 MPa) tensile strength or higher and heavy sections of both low and high tensile strength material. The addition of restraint during welding may result in cracking difficulties that otherwise might not occur.

NG-4322 Maintenance and Certification of Records

The Certificate Holder shall maintain a record of their qualified welding procedures and of the welders and welding operators qualified by them, showing the date and results of tests and the identification mark assigned to each welder. These records shall be reviewed, verified, and certified by the Certificate Holder by signature or some other method of control in accordance with the Certificate Holder’s Quality Assurance Program and shall be available to the Authorized Nuclear Inspector.

NG-4322.1 Identification of Joints by Welder or Welding Operator.

(a) Each welder or welding operator shall apply the identification mark assigned to him by the Certificate Holder on or adjacent to all permanent welded joints or series of joints on which he welds. The marking shall be at intervals of 3 ft (1 m) or less and shall be done with either blunted continuous or blunted nose interrupted dot die stamps. As an alternative, the Certificate Holder shall keep a record of permanent welded joints in each item and of the welders and welding operators used in making each of the joints.

(b) When a multiple number of permanent structural attachment welds, nonstructural welds, fillet welds, socket welds, welds of specially designed seals, weld metal cladding, hard surfacing, and tube-to-tubesheet welds are made on an item, the Certificate Holder need not identify the welder or welding operator who welded each individual joint, provided

(1) the Certificate Holder maintains a system that will identify the welders or welding operators that made such welds on each item so that the Inspector can verify that the welders or welding operators were all properly qualified

(2) the welds in each category are all of the same type and configuration and are welded with the same Welding Procedure Specification

(c) The identification of welder or welding operator is not required for tack welds.

NG-4323 Welding Prior to Qualification

No welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with NG-4320 and Section IX shall be used.

NG-4324 Transferring Qualifications

The welding procedure qualifications and the performance qualification tests for welders and welding operators conducted by one Certificate Holder shall not qualify welding procedures and shall not qualify welders or welding operators to weld for any other Certificate Holder except as provided in Section IX, QW-201 and QW-200-2.

NG-4330 GENERAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION TESTS

NG-4331 Conformance to Section IX Requirements

All welding procedure qualification tests shall be in accordance with the requirements of Section IX as supplemented by the requirements of this Article.

NG-4333 Heat Treatment of Qualification Welds for Ferritic Material

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

NG-4334 Preparation of Test Coupons and Specimens

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