Carbon Steel, Alloy Steel, Stainless Steel, and Nickel Base Alloy Castings for Use in the Petroleum and Natural Gas Industry

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1 Scope

1.1 General

This specification identifies requirements for the foundry qualification, production, design, marking and documentation of carbon steel, alloy steel, stainless steel and nickel base alloy castings used in the petroleum and natural gas industries when referenced by an applicable API product standard or otherwise specified as a requirement for compliance.

This specification applies to castings used in the manufacture of pressure containing, pressure controlling and primary load bearing components. Castings manufactured in accordance with this API Standard may be produced using any industry standard casting method.

This specification provides manufacturers with a fixed methodology to examine a qualification casting and to compare the results of that examination to a defined set of acceptance criteria. The results of the qualification testing by material grouping are then used to establish a baseline Casting Specification Level (CSL) for subsequently produced castings.

This specification also provides manufacturers with a fixed production testing methodology to determine if subsequently produced castings conform to the minimum requirements for the intended CSL. The intent is that the production castings meet the minimum CSL requirements established during qualification testing by material grouping and/or the minimum CSL specified by the purchaser.

If product is supplied bearing the API Monogram and manufactured at a facility licensed by API, the requirements of Annex A apply.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies.

For undated references, the latest edition of the referenced document (including any amendments) applies, except that new editions may be used on issue and shall become mandatory upon the effective date specified by the publisher or 6 months from the date of the revision (where no effective date is specified).

API Specification Q1, Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry

API Standard 20H, Heat Treatment Services – Batch Type for Equipment Used in the Petroleum and Natural Gas Industry

ASME Boiler and Pressure Vessel Code (BPVC) \(^1\), Section VIII, Division 1, Pressure Vessels ASME Boiler and Pressure Vessel Code (BPVC), Section IX, Welding and Brazing Qualifications

ASME Boiler and Pressure Vessel Code (BPVC), Section V, Nondestructive Examination

\(^1\) ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org,
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ASNT SNT-TC-1A\textsuperscript{2}, Recommended Practice No. SNT-TC-1A—Personnel Qualification and Certification in Non-Destructive Testing

ASTM A370\textsuperscript{3}, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM A488/A488M, Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

ASTM A609, Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

ASTM E8, Standard Test Methods for Tension Testing of Metallic Materials

ASTM E10, Standard Test Method for Brinell Hardness Test of Metallic Materials

ASTM E18, Standard Test Method for Rockwell Hardness Test of Metallic Materials

ASTM E94, Standard Guide for Radiographic Examination

ASTM E110, Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers

ASTM E112, Standard Test Method for Determining Average Grain Size

ASTM E165, Standard Practice for Liquid Penetrant Examination for General Industry

ASTM E186, Standard Reference Radiographs for Heavy-Walled (2 to 4\textsuperscript{1/2} in. (50.8 to 114-mm)) Steel Castings

ASTM E280, Standard Reference Radiographs for Heavy-Walled (4\textsuperscript{1/2} to 12-in. (114 to 305-mm)) Steel Castings


ASTM E428, Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing

ASTM E446, Standard Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness


ASTM E709, Standard Guide for Magnetic Particle Testing

ASTM E747, Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

ASTM G48, Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

AWS D1.1\textsuperscript{4}, Structural Welding Code—Steel

EN-10204\textsuperscript{5}, Metallic products. Types of inspection documents

\textsuperscript{2} American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

\textsuperscript{3} ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.


\textsuperscript{5} European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.
ISO 148-1, Metallic materials—Charpy pendulum impact test—Part 1: Test method

ISO 6506-1, Metallic materials - Brinell hardness test - Part 1: Test method

ISO 6508-1, Metallic materials - Rockwell hardness test - Part 1: Test method

ISO 6892-1, Metallic materials - Tensile testing - Part 1 Method of test at room temperature

ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories

ISO 17655, Destructive tests on welds in metallic materials - Method for taking samples for delta ferrite measurement

MSS SP-557, Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components—Visual Method for Evaluation of Surface Irregularities

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For purposes of this specification, the following terms and definitions apply.

3.1.1 acceptance criteria
Defined limits placed on characteristics of materials, processes, products or services.

3.1.2 as-cast weight range
The finish weight of a casting after all processing, removal of all gates, raiser, feeds and finished cleaning prior to any machining.

3.1.3 calibration
Comparison and adjustment to a standard of known accuracy.

3.1.4 carbon steel
Alloy of carbon and iron containing a maximum of 2 % mass fraction carbon, 1.65 % mass fraction manganese, and residual quantities of other elements, except those intentionally added in specific quantities for deoxidation (usually silicon and/or aluminum).

3.1.5 casting practice
General method for producing a casting.

NOTE This includes the molding practice. Examples of molding practice include, but are not limited to, sand, centrifugal, investment, shell, permanent mold, die or lost foam casting.

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3.1.6 corrosion-resistant alloy
CRA
Nonferrous-based alloy in which any one or the sum of the specified amount of the elements titanium, nickel, cobalt, chromium, and molybdenum exceeds 50 % mass fraction.

NOTE 1. This definition is different from that in NACE MR0175/ISO 15156 (See Clause 2).
NOTE 2. This definition is the same as that in API Spec 6A.

3.1.7 cosmetic grinding
Grinding meant to remove small surface discontinuities but not to exceed minimum wall conditions and to be blended or feathered with remaining surfaces.

3.1.8 duplex stainless steel
Stainless steels with a high chromium mass fraction (19 % to 33 %) with or without molybdenum additions up to 5 %, and a nickel mass fraction intermediate to those of ferritic and austenitic stainless steels.

NOTE Other elements may be added to secure special properties

3.1.9 equivalent round
Standard for comparing various shaped sections to round bars, in determining the response to hardening characteristics when heat-treating low-alloy and martensitic corrosion-resistant steel.

3.1.10 heat
Material originating from a final melt, or for re-melted alloys, the raw material originating from a single re-melted ingot.

NOTE Different heats of the same material can vary in chemical composition within prescribed limits. Stock from a single heat will have a consistent analysis and more uniform properties.

3.1.11 heat lot
Cast material of the same wall thickness manufactured for one single heat of material and heat treatment batch.

3.1.12 heat treating
Specified, timed sequence of controlled heating and cooling of materials for the purpose of changing physical or mechanical properties.

3.1.13 linear indication
Surface NDE indication whose length is equal to or greater than three times its width.

3.1.14 low-alloy steel
Steel containing less than 5 % mass fraction total alloying elements, or steels with less than 11 % mass fraction chromium, but more than that specified for carbon steel.

3.1.15 major weld repair
Any cavity prepared for repair welding that exceeds 20 % of the part wall thickness or 1 inch (25mm) depth, whichever is smaller or surface areas greater than 10 in² (65 cm²).
3.1.16 melt practice
Procedure and equipment used to create a heat of metal.
NOTE Includes the type of melting furnace used such as AIM, EAF, and the refining process used, such as AOD, when applicable.

3.1.17 on-site
Activity performed at the foundry.

3.1.18 out-source
Function or process that is performed by an external supplier approved by the foundry.

3.1.19 pattern
The wood, metal, wax, foam, or plastic replica of the final product to be made.
NOTE Patterns usually include gating systems.

3.1.20 rigging
Gates, risers, loose pieces, etc., needed on the pattern to produce a sound casting.

3.1.21 sample casting
Casting(s) made and tested as part of the initiation and development of the production method.
NOTE The first casting(s) from a new pattern using the identical foundry practice, i.e. risering, gating, chilling, coring and molding as the production castings it is intended to represent.

3.1.22 stainless steel
Steel containing more than 11 % - 20 % mass fraction chromium to render the steel corrosion-resistant.
NOTE Other elements may be added to secure special properties.

3.1.23 thickness
$T$
Maximum section thickness of the casting.

3.1.24 traceability
The ability to verify the history, location or application of an item by means of documented recorded identification.
3.2 Abbreviations

For purposes of this specification, the following abbreviations apply.

AIM  air induction melting
AOD  argon oxygen de-carburization
EAF  electric arc furnace
ER   equivalent round
CSL  casting specification level
CRA  corrosion resistant alloy
MPS  manufacturing process specification
NDE  nondestructive examination
PWHT post-weld heat treatment
QMS  quality management system

4 Foundry Qualification

4.1 General

This specification gives the requirements for four casting specification levels (CSL). The CSLs are numbered in increasing levels of severity from 1 to 4 in order to reflect increasing technical, quality and qualification criteria. The following subparagraphs describe the conditions which, when met, allow the casting to receive the appropriate CSL classification level.

4.2 Quality Management System (QMS)

The foundry shall establish, document, implement and maintain at all times a QMS conforming to API Specification Q1. In addition, the foundry shall be responsible for conforming to all of the applicable requirements of this specification.

4.3 Qualification Casting

4.3.1 A qualification casting shall be produced, tested, and evaluated by the casting supplier in order to establish qualification for a range of products listed in Table 1. Castings shall be produced in accordance with a manufacturing process specification, as specified in 5.2. The material group of the qualification casting shall be in accordance with Table 2. Qualification castings are to be in their completed cast form, with the addition of any specified rough machining and full heat treatment to establish the final mechanical properties required of the finished product. Qualification castings shall be produced in accordance with the requirements of Table 1, Table 2, Table 3 and the acceptance criteria of Tables 5, 6 and 4.5.2.2. One or more qualification test coupons conforming to Figure 1, Figure 2, Figure 3, Figure 4, and Figure 5, as appropriate, shall be poured at the same time and from the same heat as the qualification casting.

4.3.2 A qualification casting shall be qualified by one of the following methods:

The qualification test shall be carried out at independent test laboratories. Test laboratories shall be accredited in accordance with ISO/IEC 17025 for the applicable processes. The laboratories should hold a national accreditation or;

— Qualification test may be performed at the foundry’s in-house laboratory and the laboratory shall issue qualification records to meet EN-10204-Type 3.2 inspection certificate. The inspection certificate shall be endorsed by a noted body.
4.3.3 A casting qualified to a higher casting specification level within the same material group is also qualified for lower casting specification levels (e.g. CSL-3 is qualified for CSL-2 and CSL-1).

4.3.4 Repair welding on the qualification casting shall not exceed the limits in Table 3. Cosmetic grinding to remove defects is permitted, but cosmetic grinding shall be kept to a minimum. Permissible cosmetic grinding other than rigging areas shall be no greater than 5% of total surface area. Excessive surface grinding may be cause for rejection of the qualification casting. Repair welding shall be performed in accordance with 5.6.5 and casting qualification testing shall include at least the deepest repair (weld metal and HAZ).

<table>
<thead>
<tr>
<th>CSL Level</th>
<th>As-Cast Weight in Pounds (kilogram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSL-1</td>
<td>1-499 (2.2-1100)</td>
</tr>
<tr>
<td>CSL-2</td>
<td>500-2499 (1102-5508)</td>
</tr>
<tr>
<td>CSL-3</td>
<td>2500-9999 (5510-22,038)</td>
</tr>
<tr>
<td>CSL-4</td>
<td>10,000+ (22,040+)</td>
</tr>
</tbody>
</table>

### Table 1 — As-Cast Weight Range

<table>
<thead>
<tr>
<th>CSL Level</th>
<th>% Surface Area</th>
<th>% Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSL-1</td>
<td>50 %</td>
<td>50 %</td>
</tr>
<tr>
<td>CSL-2</td>
<td>25 %</td>
<td>25 %</td>
</tr>
<tr>
<td>CSL-3</td>
<td>20 %</td>
<td>20 %</td>
</tr>
<tr>
<td>CSL-4</td>
<td>10 %</td>
<td>10 %</td>
</tr>
</tbody>
</table>

4.4 Qualification Test Coupon (QTC)

4.4.1 General

4.4.1.1 Qualification test coupons shall either be integral with the components they represent, separate from the components or be taken from sacrificed production part(s). In all cases, test coupons shall be from the same heat as the components they qualify and shall be heat-treated together with the components.
4.4.1.2 Test specimens shall be removed from integral or separate qualification casting or its qualification test coupon so that their longitudinal centerline axis is entirely within the center core 1/4-thickness envelope for a solid test coupon, or within 0.125 in (3 mm) of the mid-thickness of the thickest section of a hollow test coupon. The gauge length of a tensile specimen or the notch of an impact specimen shall be at least 1/4-thickness from the ends of the test coupon.

4.4.1.3 Test specimens taken from sacrificial production parts shall be removed from the center core 1/4-thickness envelope location of the thickest section of the part.

4.4.2 Size and Shape of Qualification Test Coupon

Determine the size of the qualification test coupon for a part using the equivalent-round method. Figure 1 and Figure 2 illustrate the basic models for determining the equivalent round of simple solid and hollow parts. Any of the shapes shown may be used for the qualification test coupon. Figure 3 describes the steps for determining the governing equivalent-round for more complex sections. Determine the equivalent round of a part using the actual dimensions of the part in the “as-heat-treated” condition. The equivalent round of the qualification test coupon shall be equal to or greater than the equivalent-round dimensions of the part it qualifies, except that the equivalent round is not required to exceed 5 in. (125 mm) for CSL-1 and CSL-2 castings. For CSL-3 castings the equivalent round of the test coupon shall be the same as the part it qualifies. Figure 4 and Figure 5 illustrate the procedure for determining the required dimensions of a keel block.

![Figure 1 — Equivalent Round Models — Solids of length L](image)

- **ER = T**
  - a) Round
- **ER = 1.1T**
  - b) Hexagon
- **ER = 1.25T**
  - c) Square
- **ER = 1.5T**
  - d) Rectangle or plate

**NOTE** If \( L \) is less than \( T \), consider section as a plate of thickness \( L \).

![Figure 2 — Equivalent Round Models — Tube (Any Section)](image)

- **ER = 2T**
  - a) Open at Both Ends

**NOTE** If \( L \) is less than \( D \), consider as a plate of thickness, \( T \).
If \( L \) is less than \( T \), consider as a plate of thickness, \( L \).

- **ER = 2.5T if \( D \) is less than or equal to 63.5 mm (2.5 in).**
- **ER = 3.5T if \( D \) is greater than 63.5 mm (2.5 in).**

**NOTE** Use maximum thickness, \( T \), in the calculation.

b) Restricted or Closed at One or Both Ends
NOTE The following steps should be used in determining the governing equivalent-round (ER), for complex sections:

a) reduce the component to simple sections a);

b) convert each simple section to an equivalent-round b);

c) calculate the diagonal through the circle that would circumscribe the intersection of the ER values c);

d) Use the maximum ER value, whether for a single section or an intersection as the ER of the complex section.

4.5 Casting Qualification Testing

4.5.1 Examination Procedure

All examinations and testing described in this section and summarized in Table 4 shall apply to the qualification casting and its QTC(s), as applicable.
4.5.2 Visual Examination

4.5.2.1 All surfaces of the qualification casting shall be visually inspected in accordance with MSS SP-55. No internal chills or permanent metal chaplets are allowed. Chaplets or core supports made of molding media are allowed. In the instance where these molding media chaplets are used, the hole remaining in the casting wall will need to be welded. This weld shall not be considered as a weld repair but as part of the casting production process. Photographs shall be taken of the qualification casting in the “as-received” condition to document surface finish and general appearance.

![Figure 4—Equivalent Round Models—Keel Block Configuration](image)

**NOTE** Shaded area, $A$, indicates $\frac{1}{4}A$ envelope for test specimen removal.

### Table 4—Guidance for Qualification Examination/Testing Requirements

<table>
<thead>
<tr>
<th>CSL</th>
<th>Section References</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSL-1</td>
<td>Chemistry 4.4.8, Mechanical 4.4.6, Micro-Structure —, Visual 4.4.2, Dimensional 4.4.3, Hardness 4.4.4, Surface NDE —, Volumetric NDE —, Sacrificial Casting —, Additional Testing 4.4.9.3 Group D</td>
</tr>
<tr>
<td>CSL-2</td>
<td>Chemistry 4.4.8, Mechanical 4.4.6, Micro-Structure —, Visual 4.4.2, Dimensional 4.4.3, Hardness 4.4.4, Surface NDE 4.4.5.1, Volumetric NDE 4.4.5.2, Sacrificial Casting —, Additional Testing 4.4.9.3 Group D</td>
</tr>
<tr>
<td>CSL-3</td>
<td>Chemistry 4.4.8, Mechanical 4.4.6, Micro-Structure 4.4.7, Visual 4.4.2, Dimensional 4.4.3, Hardness 4.4.4, Surface NDE 4.4.5.1, Volumetric NDE 4.4.5.2, Sacrificial Casting 4.4.5.3, Additional Testing 4.4.9.3 Group D</td>
</tr>
<tr>
<td>CSL-4</td>
<td>Chemistry 4.4.8, Mechanical 4.4.6, Micro-Structure 4.4.7, Visual 4.4.2, Dimensional 4.4.3, Hardness 4.4.4, Surface NDE 4.4.5.1, Volumetric NDE 4.4.5.2, Sacrificial Casting 4.4.5.3, Additional Testing 4.4.9.2 Group D</td>
</tr>
</tbody>
</table>
4.5.2.2 Reference photographs in MSS SP-55 shall be used to determine acceptability of castings. Acceptance criteria shall be in accordance with the following:

a) Type 1—unacceptable;

b) Type 2-12—A and B are acceptable;

c) all others are unacceptable.

Results shall be documented.

4.5.3 Casting Quality Inspection

The casting supplier shall specify and verify critical areas or features in the MPS. Acceptance criteria for critical areas or features shall be as required by the casting supplier’s written specification. Results shall be documented.

4.5.4 Hardness Testing

Brinell and/or Rockwell hardness testing in accordance with ASTM E10, ISO 6506-1, ASTM E110, ASTM E18 or ISO 6508-1 shall be performed on external surfaces of each qualification casting within the CSL, weight range and material group to ensure the casting is within the specified limits for the finished product. A minimum of three (3) indentations per casting is required and shall be averaged. The casting supplier shall specify in the MPS the number and location for the tests. Results shall be documented.
4.5.5 Nondestructive Examination

4.5.5.1 Magnetic Particle Examination

All accessible surfaces of each Group A and Group B ferromagnetic casting shall be magnetic particle inspected per ASTM E709. The acceptance criteria shall be as specified in Table 5. Results shall be recorded.

4.5.5.2 Liquid Penetrant Examination

All accessible surfaces of each non-ferromagnetic casting shall be liquid penetrant inspected in accordance with ASTM E165. The acceptance criteria shall be as specified in Table 5. Results shall be recorded.

4.5.5.3 Volumetric Examination

4.5.5.3.1 General

As far as practical, the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after heat treatment for mechanical properties and prior to machining operations that limit effective interpretation of the results of the examination.

For quench-and-tempered products, the volumetric inspection shall be performed after heat treatment for mechanical properties exclusive of stress-relief treatments or re-tempering to reduce hardness.

4.5.5.3.2 Radiographic Examination

Radiographic examinations shall be performed in accordance with procedures specified in ASTM E94, to a minimum equivalent sensitivity of 2 % and a 2-2T quality level. Both X-ray and gamma-ray radiation sources are acceptable within the inherent thickness range limitation of each. Digital radiographic imaging and recording/enhancement methods may be used if the casting supplier has documented proof that these methods result in a minimum equivalent sensitivity of 2 % and a 2-2T quality level. Wire-type image quality indicators are acceptable for use in accordance with ASTM E747. Acceptance criteria shall be in accordance with Table 6.

NOTE The first number of the quality level designation refers to the image quality indicator or penetrometer thickness expressed as a percentage of the specimen thickness; the second number refers to the diameter of the image quality indicator hole that it is necessary to be able to see on the radiograph, expressed as a multiple of penetrometer thickness.

4.5.5.3.3 Ultrasonic Examination

Ultrasonic examination of castings shall be performed in accordance with the flat-bottom hole procedures specified in ASTM A609 (except immersion method may be used) and ASTM E428.

For calibration, the distance amplitude curve (DAC) shall be based on 1/16 in. (1.6 mm) flat-bottom hole for metal thicknesses through 1 1/2 in. (38 mm), on 1/8 in. (3.2 mm) flat-bottom hole for metal thicknesses from 1 1/2 in. (38 mm) through 6 in. (150 mm), and on 1/4 in. (6.4 mm) flat-bottom hole for metal thicknesses exceeding 6 in. (150 mm). Acceptance shall be in accordance with Table 6.

4.5.5.3.4 Examination Results

All volumetric examination results shall be recorded.

4.5.6 Mechanical Testing

4.5.6.1 The mechanical tests required by this specification shall be performed on the qualification casting or its qualification test coupons representing the heat and heat treatment lot used in the manufacture of the casting. For the purposes of material qualification testing, stress relief following welding is not considered heat treatment, provided that the PWHT temperature is below that which changes the heat-treated condition of the base material.
Weld repair is not permitted on test coupons. If a sacrificial casting is being tested, all testing shall be performed after any weld repair is completed.

4.5.6.2 Tensile test specimens shall be tested in accordance with ASTM A370, ASTM E8, ISO 6892-1 or equivalent national standards, using material in the final heat treated condition. Mechanical properties shall be in accordance with the material specification used. The results shall be reported.

4.5.6.3 Charpy (CVN) impact specimens shall be tested in accordance with ASTM A370 or ISO 148-1, using material in the final heat treated condition. When using ISO 148-1, a striker with a radius of 8 mm shall be used. *NOTE: Refer to ISO 148-1 for further details.*

4.5.6.4 The results shall be reported. CVN test temperature and acceptance criteria shall be in accordance with the material specification used. At the option of the casting supplier, Charpy (CVN) tests may be performed on material not requiring impact testing. Test specimen removal shall in accordance with 4.3.1.

4.5.7 Microstructure Examination

4.5.7.1 Prepare a micro-specimen from the grip end of one of the tensile specimens by making a transverse cut through the center of the grip end of one of the tensile specimens.

4.5.7.2 Provide a photomicrograph of the as-polished, un-etched specimen at 100X for carbon, and alloy steel. For stainless steel, duplex steel and CRA, provide a photomicrograph taken at 400X or greater magnification. Results shall be documented.

4.5.7.3 Etch the specimen using the appropriate reagent. Provide a photomicrograph of the etched specimen at 100X showing the typical microstructure. For stainless steel and duplex steel, provide a photomicrograph taken at 400X or greater magnification showing the typical microstructure. Any unusual anomalies such as intermetallic and/or heavy precipitates or carbides in the grain boundaries, inhomogeneous structure or un-tempered structure, shall be reported. Results shall be documented.

4.5.7.4 Grain size shall be determined in accordance with ASTM E112 for the sample following etching with a suitable reagent. Photomicrographs of grain size shall be taken. Results shall be documented and reported as informational only.

4.5.8 Chemical Analysis

4.5.8.1 The casting supplier shall specify the nominal chemical composition, including composition tolerances, of the material used for the qualification casting.

4.5.8.2 Material composition shall be determined on a heat basis (or on a remelt-ingot basis for remelt-grade materials) in accordance with a nationally or internationally recognized standard.

4.5.8.3 An analysis of each heat shall be made by the foundry in accordance with ASTM A703, to determine the percentages of the specified elements. The analysis shall be made from a test sample, preferably taken during the pouring of the ladle. When drillings are used, they shall be taken not less than ¼ in. (6.4 mm) beneath the surface. The chemical composition thus determined shall be reported and shall conform to the requirements in the individual specification for the grade being poured.

4.5.9 Additional Testing

4.5.9.1 General

The additional testing in this section is mandatory and shall be performed in addition to the requirements of 4.5.1 through 4.5.8.
4.5.9.2 Sacrificial Casting—CSL-4

A casting produced in accordance with 4.3 shall serve as the test piece for the following.

a) Section the casting into four approximately equally sized quadrants.

b) Visually inspect all surfaces of each quadrant for cracks, voids, porosity, or other anomalies. Photograph all anomalies of each surface.

c) Liquid penetrant examine the cut surface of each quadrant per ASTM E165 and report results.

d) Macro-etch one quadrant in accordance with ASTM E340 (an appropriate etchant shall be used) to show the grain structure and internal quality. The surface closest to the centerline shall be used. Photographs shall be taken with a scale visible to provide size reference. Any indications noted shall be clearly marked for later evaluation.

e) A set of hardness traverses shall be made across the cut surface of one quadrant taken 90 degrees to each other. The hardness and specific locations shall be recorded. A photograph shall also be taken.

f) Group D & E, (Duplex Alloys and Ni Based Alloys), castings shall have an integral cast test coupon equal to or greater than the equivalent-round dimensions of the part it qualifies. See Figure 4 for test specimen removal location from integral test coupon. For section size smaller than 2 in (50mm), the test coupon shall be removed at T/2.

4.5.9.3 Group D—Duplex Material Testing

4.5.9.3.1 General

The Group D tests specified in the following shall be performed on a casting produced in accordance with 4.3.

a) The qualification casting and its qualification test coupon (QTC), after the final heat treatment cycle, shall be corrosion tested in accordance with ASTM G48, Method A.

b) If the QTC is a solid block, one ASTM G48 sample shall be taken from the center of the block.

c) If the QTC has a hole, two ASTM G48 samples shall be taken. One shall be taken adjacent to the inside surface and one from the center of the thickest cross-section. The specimen surface shall be parallel to the internal surface.

d) Sides of the test specimen shall be ground to a 120-grit finish (or better) with the edges rounded.

e) For 22 Cr duplex stainless steels, the temperature shall be 77 ± 2 °F (25 ±1 °C) and for 25 Cr super duplex stainless steels, the test temperature shall be 122 ± 2 °F (50 ±1 °C). For both duplex stainless steel grades, the exposure time shall be 24 hours.

f) The acceptance criteria shall be that the test material shall show no evidence of pitting after 24 hours immersion in the test solution when examined with a low power magnification (20X) and the maximum weight loss shall be less than 1 g/m² for products in the solution annealed condition or shall be less than 4.0 g/m² for welds in the as welded condition.
4.5.9.3.2 Ferrite Testing

4.5.9.3.2.1 The micrographic examination shall be carried out on a sample taken from the qualification casting and its qualification test coupon at the same location as specimens taken for mechanical testing. The ferrite content shall be tested in accordance with ASTM E562. The ferrite content shall be in the range of 35 % to 65 % (volume fraction). Samples shall be electrolytically etched in either NaOH or KOH, and in such a manner as to provide maximum contrast for austenite and ferrite phase discrimination. A minimum of 15 fields and 16 points per field shall be used.

4.5.9.3.2.2 Acceptance criteria shall be as follows:

The ferrite content, in percentage by surface/volume fraction, shall be as stated below for all duplex grades:
- 35 % to 60 % in base material;
- 35 % to 65 % in solution heat treated weld metals;
- 30 % to 70 % for welds in the as welded condition.

4.5.9.3.2.3 For the stainless steel Type 22 and 25 Cr duplex, the ferrite content in the weld metal root and in the last bead of the weld cap shall be determined in accordance with ASTM E 562 and shall be in the range of 30 % to 70 %.

4.5.9.3.2.4 A portable ferrite meter shall be used to test the casting at (5) five locations on the casting surface randomly selected and exhibit ferrite content between 35 % to 65 %. The portable ferrite meter shall also be used to test ferrite content at all locations.

4.5.9.3.3 Impact Testing

Duplex materials shall be impact tested in accordance with the method specified in ASTM A370 or ISO 148-1 using the Charpy V-notch technique at -50 °F (-46 °C). When using ISO 148-1, a striker with a radius of 8 mm shall be used.

NOTE: Refer to ISO 148-1 for further details.

Acceptance criteria shall be as follows:

a) average of three specimens: 33 ft. lbs. (45 J) minimum;

b) No single specimen less than 26 ft. lbs. (35 J).

4.6 Acceptance of the Qualification Casting

4.6.1 Results of the examinations specified in Table 4 shall comply with the acceptance criteria specified in 4.5.2.2, Table 5 and Table 6, and the casting supplier’s written specification. Results shall be documented.

4.6.2 Qualification castings failing to meet the acceptance criteria shall be cause for re-evaluation of foundry practice and the casting design. Requalification is required. Results shall be documented.
Table 5—Surface Examination Acceptance

<table>
<thead>
<tr>
<th>Relevant Indication</th>
<th>Surface-rupture NDE indication with major dimensions greater than 1/16 in (1.6 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Relevant Indication</td>
<td>Inherent indications not associated with a surface rupture (i.e., magnetic permeability non-metallic stringers).</td>
</tr>
<tr>
<td>Linear Indication</td>
<td>Any indication in which the length is equal to or greater than three (3) times its width.</td>
</tr>
<tr>
<td>Rounded Indication</td>
<td>Any indication which is circular or elliptical with its length less than three (3) times the width.</td>
</tr>
</tbody>
</table>

**Magnetic Particle Testing**

a) sampling:
All accessible wetted surfaces and all accessible sealing surfaces of each finished part shall be liquid-penetrant inspected after final heat treatment and final machining operations.

If any indications are believed to be non-relevant on the basis that they are not associated with a surface rupture (i.e. magnetic permeability variations, non-metallic stringers), they shall be examined by liquid-penetrant surface NDE methods, or removed and re-inspected, to confirm their non-relevancy.

b) test method:
All ferromagnetic materials shall be examined in accordance with procedures specified in ASTM E709 (MT) or ASTM E165 (PT). Prods are not permitted on well-fluid surfaces or sealing surfaces.

c) acceptance criteria:
The following acceptance criteria apply:
- no relevant indication with a major dimension equal to or greater than 3/16 in (5 mm);
- no more than ten relevant indications in any continuous 6 in² (40 cm²) area;
- four or more relevant indications in a line separated by less than 1/16 in (1.6 mm) (edge to edge) are unacceptable;
- no relevant indications in pressure contact sealing surfaces.

**Liquid Penetrant**

a) sampling:
All accessible wetted surfaces and all accessible sealing surfaces of each finished part shall be liquid-penetrant inspected after final heat treatment and final machining operations.

b) test method:
All non-ferromagnetic materials shall be examined in accordance with procedures specified in ASTM E165.

c) acceptance criteria:
The following acceptance criteria apply:
- no relevant linear indication;
- no relevant rounded indication with a major dimension equal to or greater than 3/16 in (5 mm);
- four or more relevant rounded indications in a line separated by less than 1/16 in (1.6 mm) (edge to edge) are unacceptable;
- no relevant indication in pressure-contact sealing surfaces.
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Table 6—Volumetric Examination Acceptance Criteria

<table>
<thead>
<tr>
<th>Radiography</th>
<th>Maximum Defect Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) sampling: As far as practical, the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after heat treatment for mechanical properties and prior to machining operations that limit effective interpretation of the results of the examination. For quench-and-tempered products, the volumetric inspection shall be performed after heat treatment for mechanical properties exclusive of stress-relief treatments or re-tempering to reduce hardness.</td>
<td></td>
</tr>
<tr>
<td>b) test method: Radiographic examinations shall be performed in accordance with the procedures specified in ASME Section V, Article 2 with a minimum sensitivity of 2T hole on a plaque type image quality indicator. Both x-ray and gamma ray sources are acceptable within the inherent thickness range limitation of each. Real time imaging and recording/enhancement methods may be used provided the designated hole image quality indicator or essential wire is displayed as required by ASME Section V, Article 2.</td>
<td></td>
</tr>
<tr>
<td>c) acceptance criteria:</td>
<td>Maximum Defect Class</td>
</tr>
<tr>
<td>ASTM E186, Standard Reference Radiographs for Heavy-Walled (2 to 4½ in.) Steel Castings.</td>
<td></td>
</tr>
<tr>
<td>ASTM E280, Standard Reference Radiographs for Heavy-Walled (4½ to 12 in.) Steel Castings.</td>
<td></td>
</tr>
<tr>
<td>ASTM E446, Standard Reference Radiographs for Steel Castings Up to 2 in. in Thickness.</td>
<td></td>
</tr>
</tbody>
</table>

Maximum defect classification as follows:

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Maximum Defect Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>2 (All types)</td>
</tr>
<tr>
<td>D</td>
<td>None acceptable</td>
</tr>
<tr>
<td>E</td>
<td>None acceptable</td>
</tr>
<tr>
<td>F</td>
<td>None acceptable</td>
</tr>
<tr>
<td>G</td>
<td>None acceptable</td>
</tr>
</tbody>
</table>

Ultrasonic

| a) sampling: As far as practical, the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after heat treatment for mechanical properties and prior to machining operations that limit effective interpretation of the results of the examination. For quench-and-tempered products, the volumetric inspection shall be performed after heat treatment for mechanical properties exclusive of stress-relief treatments or re-tempering to reduce hardness. |  |
| b) test method: Ultrasonic examinations of castings shall be performed in accordance with the flat bottom hole procedures specified in ASTM A609 (except immersion method may be used) and ASTM E428. |  |
| c) calibration: The distance amplitude curve (DAC) shall be based on 1/16 in (1.6 mm) flat-bottom hole for metal thicknesses through 1 ½ in, (38 mm), on 1/8 in (3.2 mm) flat-bottom hole for metal thicknesses from 1 ½ in (38 mm) through 6 in (150 mm), and on1/4 in (6.4 mm) flat-bottom hole for metal thicknesses exceeding 6 in (150 mm). |  |
| d) acceptance criteria: | Maximum Defect Class |
| no single indication exceeding reference distance amplitude curve; |  |
| no multiple indications exceeding 50 % of reference distance amplitude curve. Multiple indications are defined as two or more indications (each exceeding 50 % of the reference distance amplitude curve) within ½ in (13 mm) of each other in any direction. |  |
4.7 Records of Qualification

The following records shall be required, as a minimum, to document qualification of the casting.

a) Heat/heat lot number, material specification, and actual chemistry with minimum and maximum tolerances, cleanliness, if applicable.

b) Casting parameters such as molding media, wash type if applicable, melt practice, ladle refining if applicable, and tap temperature, pouring temperature.

c) Heat treatment parameters such as specification, ramp rate, temperature, time at temperature, cooling rate and/or cooling media, time to quench if applicable, heat treat equipment used, actual heat treatment chart.

d) Test records: records of the examinations (NDE), mechanical testing, metallographic evaluations, as described in Section 4.

4.8 Limits of Casting Qualifications

Table 7 provides detailed information on limits by CSL that will require requalification of qualification castings.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ref.</th>
<th>CSL 1</th>
<th>CSL 2</th>
<th>CSL 3</th>
<th>CSL-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM keel block</td>
<td>Figure 4, Figure 5</td>
<td>X</td>
<td>X</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Equivalent round or integral test specimen</td>
<td>Figure 3, Figure 5</td>
<td>—</td>
<td>—</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>Sacrificial casting</td>
<td>4.5.9.2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Change in material group</td>
<td>4.8.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>As-cast thickness and weight range class</td>
<td>4.8.2</td>
<td>—</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Change in melt practice</td>
<td>4.8.3</td>
<td>—</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Material specification/grade</td>
<td>4.8.4</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
</tbody>
</table>

NOTE This table provides a matrix of requirements and should be used as a reference only since it may not include all requirements.

4.8.1 CSL-1

4.8.1.1 A change in material group as shown in Table 2 from the casting that was previously qualified requires requalification.

4.8.2 CSL-2

4.8.2.1 Qualification requirements specified for CSL-1 are required for CSL-2.

4.8.2.2 A change in the as-cast weight range class as shown in Table 1 from the casting that was previously qualified requires requalification.

4.8.3 CSL-3

4.8.3.1 Qualification requirements specified for CSL-2 are required for CSL-3.

4.8.3.2 When metal refining steps, such as AOD or ladle refining, are used to produce the qualification casting, the elimination of any of these steps from the melting/casting practice shall require requalification.
4.8.4 CSL-4

4.8.4.1 Qualification requirements specified for CSL-3 are required for CSL-4.

4.8.4.2 A change in the specific material specification/grade from the casting that was previously qualified requires requalification of the casting.

5 Production Castings

5.1 General

Castings, including sample castings, shall be produced in accordance with the manufacturing process specification (MPS) specified in 5.2 and conform to the limits specified in Table 8.

5.2 Manufacturing Process Specification

The casting supplier shall prepare a (MPS) to include, as minimum, allowable levels for all casting parameters including the process control variables listed in 5.3.1 and the heat treatment parameters listed in 5.3.2. As part of the MPS, pattern equipment and rigging shall be documented and made available for review.

5.3 Process Control Variables

5.3.1 General Variables

The following are general process control variables for the production of qualified castings:

a) acceptable pattern equipment for production;

b) acceptable core equipment for production;

c) acceptable sand control;

d) mold/core equipment maintenance;

e) rigging design documented;

f) molding parameters defined, such as sand and wash type, dipping sequence for investment;

g) melt practice;

h) cleaning room practices;

i) weld repair, if required, including PWHT;

j) NDE and inspection procedures;

k) material traceability system;

l) qualification casting and its qualification test coupon per heat;

m) chemical analysis;

n) mechanical properties;
5.3.2 Heat Treating Parameters

The following are heat treat parameters, as applicable:

a) furnace loading diagram and orientation of production parts;

b) temperatures and times for all individual heat treating cycles;

c) casting configuration and dimensions at time of heat treatment;

d) quenching medium and type of agitation (water/polymer, forced, horizontal; or vertical quench, ID/OD, etc.);

e) loading temperature;

f) heating rate;

g) holding temperature;

h) holding time;

i) cooling medium;

j) time to quench;

k) furnace chart(s);

l) maximum quench media temperature at the start and end of quenching.

5.4 Sample Casting

5.4.1 General

The casting supplier shall produce a sample casting(s) and obtain approval from the purchaser. The casting supplier shall perform all required tests and examinations and certify that the sample casting(s) meets the requirements of this specification.

At the discretion of the purchaser, the first production order of castings may be considered the sample. In this case, at least one of the castings shall be processed as a sample by the casting supplier.

5.4.2 Definition of a Sample Casting

A casting shall be deemed a “sample” when one or more of the following events take place:

a) first use of a pattern on a new order;

b) a pattern is re-rigged;

c) a new pattern is made;
d) a pattern is revised;
e) a change in processing (i.e. core making, sand control, melt practice);
f) a pattern is sent to another foundry;
g) rejection of a sample;
h) upon identification of a recurring defect in a casting released for production.

5.4.3 Evaluation of Sample Castings

5.4.3.1 Dimensional inspection shall be performed in accordance with the purchaser's drawings.

5.4.3.2 Visual examination shall be performed in accordance with the purchaser's specification, if provided. No internal chills or permanent metal chaplets are allowed. Chaplets or core supports made of molding media are allowed as agreed upon between the supplier and purchaser. In the instance where these molding media chaplets are used, the hole remaining in the casting wall would need to be welded. If the purchaser does not provide requirements for visual examination; visual examination shall be performed as specified in 4.5.2.

5.4.3.3 Magnetic particle examination of ferromagnetic castings shall be performed in accordance with the purchaser's specification, if provided. If the purchaser does not provide requirements for magnetic particle examination, magnetic particle examination shall be performed as specified in 4.5.5.1.

5.4.3.4 Liquid penetrant particle examination of non-ferromagnetic castings shall be performed in accordance with the purchaser's specification, if provided. If the purchaser does not provide requirements for liquid penetrant examination, liquid penetrant examination shall be performed as specified in 4.5.5.2.

5.4.3.5 Volumetric examination shall be performed in accordance with the purchaser's specification, if provided. If the purchaser does not provide requirements for volumetric examination, the examination shall be performed as specified in 4.5.5.3.

5.4.3.6 Brinell and/or Rockwell hardness testing shall be performed in accordance with ASTM E10, ASTM E110 or ASTM E18. Hardness test locations shall be as specified in the purchaser's specification. If the purchaser does not provide hardness test locations, testing shall be as specified in 4.5.4.

5.4.3.7 Mechanical testing shall be performed as specified in 4.5.6.

5.4.3.8 Chemical analysis shall be performed as specified in 4.5.8.

5.4.3.9 Material testing for Group D material shall be performed as specified in 4.5.9.3.

5.4.4 Sample Casting Acceptance

Upon completion of all required examinations and tests, results shall be sent to the purchaser for approval. Subsequent castings shall not be made until the sample is approved by the purchaser.

5.5 Design and Maintenance of Pattern Equipment

5.5.1 Design

5.5.1.1 The foundry shall use casting simulation software in developing the rigging and gating system to enhance the casting quality. Records of the simulation analysis and revisions shall be maintained as objective evidence the casting design was validated.
5.5.1.2 Design of patterns and cores used to produce castings in accordance with this specification shall include documentation of those designs. This documentation as related to patterns shall include, as applicable:

- design requirements;
- assumptions;
- analysis methods;
- comparison with previous designs or operating history of similar products;
- calculations;
- manufacturing drawings and specifications;
- design reviews; and/or
- physical testing results (such as design validation testing).

5.5.1.3 Design documentation for patterns shall be reviewed by a qualified person.

5.5.1.4 Design documents and data for patterns, shall be maintained for five years after the date of last manufacture of that casting.

5.5.2 Maintenance

Maintenance of patterns and related equipment shall be conducted in accordance with documented procedures. Records of maintenance shall be kept.

5.5.3 Allowable Design Changes

Design changes shall be documented and reviewed by the casting supplier against the design documents to determine if the change is a substantive change.

All substantive design changes shall be documented reviewed and approved by a qualified person before their implementation and shall continue to meet the applicable requirements of this specification. When required by purchase order, all substantive design changes shall be approved by the purchaser.

5.6 Inspection, Quality Control, Marking and Documentation

5.6.1 Calibration

Equipment used to inspect, test, or examine material or other equipment used for acceptance shall be identified, controlled, calibrated, and adjusted at specified intervals in accordance with documented foundry instructions, and consistent with nationally or internationally recognized standards specified by the manufacturer, to maintain the accuracy required by this specification.

5.6.2 Furnace Calibration

Heat treatment furnaces shall have a temperature uniformity survey performed in accordance with API Standard 20H - HSL 1. Furnace instrumentation shall be calibrated at least once every 3 months. Records of furnace calibration shall be maintained in accordance with API Standard 20H.
5.6.3 Nondestructive Examination (NDE)

5.6.3.1 Production castings shall be capable of meeting the NDE requirements of the applicable API product specification.

5.6.3.2 NDE shall be performed as specified in the purchasing documents.

5.6.3.3 NDE personnel shall be qualified in accordance with the manufacturer’s documented training program that is based on and meets the minimum requirements specified in ASNT SNT-TC-1A or ASNT Central Certification Program (ACCP) or ISO 9712, Level 2, minimum for evaluation and interpretation.

NOTE: Alternative standards are acceptable provided they meet the minimum requirements of ASNT SNT-TC-1A.

5.6.3.4 NDE procedures shall be detailed regarding the requirements of this specification and those of all applicable nationally or internationally recognized standards specified herein. All NDE procedures shall be approved by a qualified level III examiner in accordance with ASNT SNT-TC-1A or ASNT Central Certification Program (ACCP) or ISO 9712.

5.6.4 Dimensional Inspection

Dimensional inspection shall be performed on products produced to this specification. Sampling shall be in accordance with ISO 2859-1, Level II, 1.5 AQL. The casting supplier shall verify critical dimensions. Critical dimensions and acceptance criteria shall be as required by the purchaser’s specification.

5.6.5 Repair Welding

5.6.5.1 Where defect removal results in a wall thickness below an acceptable value as specified in purchasing documents, the resultant cavity may be repaired by welding, provided that all of the following requirements are satisfied.

a) Welding shall be performed using weld procedures and personnel qualified in accordance with:

   — CSL-1 and CSL-2 - ASME BPVC, Section IX, ISO 15614-1, ISO 9606-1, AWS D1.1, ASTM A488 or equivalent standards;

   — CSL-3 and CSL-4 - ASME BPVC, Section IX, ISO 15614-1 or ISO 9606-1.

b) Welding shall only be performed by welders or welding operators qualified in accordance with specifications listed in item a).

c) Welding consumables shall conform to the consumable-manufacturer’s specifications. The casting supplier shall have a written procedure for the storage and control of welding consumables.

d) Materials of low-hydrogen type shall be stored and used as recommended by the welding consumable manufacturer to retain their original low-hydrogen properties.

e) Weld repairs shall be heat treated in accordance with the post-weld heat treatment requirements of the ASME BPVC, Section VIII, Division 1.

f) Post-weld heat treatment (solution treatment) of repair welds in austenitic stainless steels is neither required nor prohibited except when required by the material specification.

g) The area shall be re-examined by the NDE method that originally disclosed the defect. The re-examination by magnetic particle or liquid penetrant methods of a repaired area originally disclosed by magnetic particle or liquid penetrant examination shall be performed after post-weld heat treatment when post-weld heat treatment is performed. The re-examination by radiography or ultrasonic methods of a repaired area originally disclosed by radiography or ultrasonic examination maybe performed either before or after post-weld heat treatment. The acceptance standards shall be as in the original examination.
h) Weld repairs made as a result of radiographic examination shall be radiographed after welding. The acceptance standards for porosity and slag inclusion in welds shall be in accordance with the ASME BPVC, Section VIII, Division 1, UW-51.

i) Repair welding on duplex stainless steel is allowed provided that the ferrite content (volume fraction) is maintained between 35 % minimum and 65 % maximum as part of the WPS/PQR in either the as-welded or solution treated condition.

j) Allowable weld repair limited shall be in accordance with Table 3.

k) Major weld repairs shall be documented.

5.6.6 Ferrite Inspection on Group D Material

5.6.6.1 A portable ferrite meter shall be used to test the casting at 5 (five) randomly selected locations on the casting surface and exhibit a ferrite content of 35% to 65%.

5.6.6.2 The portable ferrite meter shall also be used to test ferrite content at all locations where minor or major welding is carried out, and values shall be within 35% to 65%.

5.7 Limits on the Qualification of Production Castings by CSL

Table 8 provides detailed information on limits of a CSL that will require requalification of production castings.
Table 8—Limits of CSL Production Casting Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ref.</th>
<th>CSL 1</th>
<th>CSL 2</th>
<th>CSL 3</th>
<th>CSL 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM keel block</td>
<td></td>
<td>X</td>
<td>X</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Equivalent round or integral test specimen</td>
<td></td>
<td>—</td>
<td>—</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>Sacrificial casting</td>
<td>4.5.9.2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Change in material group</td>
<td>5.7.1.1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Revision or new pattern</td>
<td>5.7.1.2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pattern is re-rigged</td>
<td>5.7.1.3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Change in risers or padding</td>
<td>5.7.1.3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>Change in external chills</td>
<td>5.7.1.3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>—</td>
</tr>
<tr>
<td>As-cast weight range class</td>
<td>5.7.2.2</td>
<td>—</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Casting practice</td>
<td>5.7.2.3</td>
<td>—</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chemistry tolerance outside the UNS range by greater than 15%</td>
<td>5.7.3.2</td>
<td>—</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Change in melt practice</td>
<td>5.7.3.3</td>
<td>—</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Material specification/grade</td>
<td>5.7.4.2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
</tbody>
</table>

NOTE: This table provides a matrix of requirements and should be used as a reference only since it may not include all requirements.

5.7.1 CSL-1

5.7.1.1 A change in material group as shown in Table 1 from the qualification casting requires requalification.

5.7.1.2 Requalification is required when the pattern of the production casting is revised or a new pattern made.

5.7.1.3 Requalification is required when the pattern of the production casting is re-rigged including padding, riser and external chills.

5.7.2 CSL-2

5.7.2.1 Qualification requirements specified for CSL-1 are required for CSL-2.

5.7.2.2 A change in the as-cast weight range class as shown in Table 1 from the qualification casting requires requalification.

5.7.2.3 Requalification is required when the general casting practice is changed from the qualification casting practice, such as changing from an investment casting to a sand casting.

5.7.3 CSL-3

5.7.3.1 Qualification requirements specified for CSL-2 are required for CSL-3.

5.7.3.2 Requalification is required when within a Material Group (Table 2), there is a change in the material type where a specified element’s tolerance changes by 15%.

Example, if a qualification casting is made from ASTM A351 – Grade CF3 with a 0.50 maximum molybdenum and a production casting is to be made from ASTM A351 – CF3M with a molybdenum range of 2.0% to 3.0%, requalification is required.
5.7.3.3 When metal refining steps, such as AOD or ladle refining, are used to produce the qualification casting, the elimination of any of these steps from the melting/casting practice used for production castings shall require requalification.

5.7.4 CSL-4

5.7.4.1 Qualification requirements specified for CSL-3 are required for CSL-4.

5.7.4.2 A change in the specific material specification/grade from the qualification casting requires requalification.

5.8 Traceability

5.8.1 Full traceability of castings shall be maintained with respect to material heat, manufacturing procedure specification, and heat treatment loads.

5.8.2 Casting qualification records shall be traceable to the Manufacturing Process Specification (MPS).

Castings produced to this specification shall be traceable to the applicable casting qualification record.

5.9 Marking

5.9.1 Each casting shall be marked with the following:

— casting supplier's name mark or symbol;
— pattern number or part number;
— material grade;
— API 20A, CSL Number and Material Group;
— Heat, heat-lot or traceability number.

See Table 9 for an example of required marking.

<table>
<thead>
<tr>
<th>Casting Mark</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting Supplier's Name Mark or Symbol</td>
<td>ABC</td>
</tr>
<tr>
<td>Pattern Number or Part Number</td>
<td>21179-01</td>
</tr>
<tr>
<td>Material Grade</td>
<td>A995-6A</td>
</tr>
<tr>
<td>API 20A, CSL Number and Material Group</td>
<td>20A-2-D</td>
</tr>
<tr>
<td>Heat, Heat Lot or Traceability Number</td>
<td>L424</td>
</tr>
</tbody>
</table>

5.9.2 Manufacturing drawings shall identify where stamping is appropriate. The above marking listed in 5.9.1 shall be applied using cast-on or low-stress (dot, vibration, or rounded V) stamps or cast-on lettering. Conventional sharp V-stamping is acceptable in low-stress areas, such as raised pads designed for stamping. Sharp V-stamping is not permitted in high stress areas unless subsequently stress-relieved at 1100° F (590 °C) minimum.
5.9.3 Cast lettering shall be placed on the drag side of the pattern. All cast marking shall be of a size in relationship to the size of the casting. If cast markings are not 100% legible, they shall be ground smooth and reapplied using low stress steel stamping.

5.10 Record Retention

The casting supplier shall establish and maintain documented procedures to control all documents and data required by this specification. Records required by this specification shall be maintained for 10 years from date of manufacture. Documents and data may be in any type of media (hard copy or electronic) and shall be:

— maintained to demonstrate conformance to specified requirements;
— legible;
— retained and readily retrievable;
— stored in an environment to prevent damage, deterioration, or loss;
— available and auditable by the user/purchaser.

5.11 Documentation Provided with the Castings

As a minimum, a certificate of conformance to this specification shall be supplied by the foundry. The certificate(s) shall identify the product specification number, CSL, material group, part number/pattern number, quantity and a statement that castings is/are in full conformance with this product specification edition and all addenda. Also the foundry shall furnish the following.

— Material test report (MTR) in accordance with EN-10204 Type 3.1 to include as a minimum melting practice, chemical analysis, heat treatment, mechanical properties, hardness and microstructure results as applicable.
— NDE reports as required by section 5 of this specification.

5.12 Handling, Storage, and Shipping

Castings shall be packaged for storage or transit in accordance with the written specifications of the casting supplier.

5.13 Minimum Facility Requirements for the Foundry

The foundry shall have on-site equipment and personnel to perform the required processes needed to produce the products under the scope of this specification, as identified in Table 10.

Note: Definition for On-site and Out-source are found in 3.17 and 3.18.
Table - 10—Minimum Facility Requirements

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ACTIVITY</th>
<th>WHERE PERFORMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pattern design including mounting &amp; rigging</td>
<td>On-site or Out-source</td>
</tr>
<tr>
<td>2</td>
<td>Core making, molding</td>
<td>On-site or Out-source</td>
</tr>
<tr>
<td>3</td>
<td>Melting &amp; pouring</td>
<td>On-site</td>
</tr>
<tr>
<td>4</td>
<td>Chemical testing</td>
<td>On-site</td>
</tr>
<tr>
<td>5</td>
<td>Fettling-Cleaning</td>
<td>On-site</td>
</tr>
<tr>
<td>6</td>
<td>Heat treatment</td>
<td>On-site or Out-source</td>
</tr>
<tr>
<td>7</td>
<td>Mechanical testing</td>
<td>On-site or Out-source</td>
</tr>
<tr>
<td>8</td>
<td>NDE</td>
<td>On-site or Out-source</td>
</tr>
<tr>
<td>9</td>
<td>Welding repair</td>
<td>On-site</td>
</tr>
<tr>
<td>10</td>
<td>Product marking</td>
<td>On-site</td>
</tr>
<tr>
<td>11</td>
<td>Final inspection/release</td>
<td>On-site</td>
</tr>
</tbody>
</table>
Annex A
(informative)

Add API monogram annex text here
Bibliography


