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

API SPECIFICATION 20A SECOND EDITION, AUGUST 2017

EFFECTIVE DATE: FEBRUARY 1, 2018



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

# 1 Scope

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 six 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 Specification 6A, Specification for Wellhead and Christmas Tree Equipment

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

ANSI/NACE MR0175<sup>1</sup>/ISO 15156, Materials for use in H2S-containing environments in oil and gas production

ASME Boiler and Pressure Vessel Code (BPVC)<sup>2</sup>, 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

<sup>&</sup>lt;sup>1</sup> NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas

<sup>77084-4906,</sup> www.nace.org.

<sup>&</sup>lt;sup>2</sup> ASME International, 2 Park Avenue, New York, New York 10016-5990, <u>www.asme.org</u>.

ASNT SNT-TC-1A<sup>3</sup>, Recommended Practice No. SNT-TC-1A—Personnel Qualification and Certification in Non-Destructive Testing

ASTM A370<sup>4</sup>, 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 A703, Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

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

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

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

ASTM E23, Standard Test Methods for Notched Bar Impact Testing 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 Methods 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 <sup>1</sup>/<sub>2</sub>-in. (50.8 to 114-mm)) Steel Castings

ASTM E280, Standard Reference Radiographs for Heavy-Walled (4<sup>1</sup>/<sub>2</sub> to 12-in. (114 to 305-mm)) Steel Castings

ASTM E340, Standard Test Method for Macroetching Metals and Alloys

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 E562, Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count

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<sup>5</sup>, Structural Welding Code—Steel

EN-10204<sup>6</sup>, Metallic products—Types of inspection documents

<sup>&</sup>lt;sup>3</sup> American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, Ohio 43228, www.asnt.org.

<sup>&</sup>lt;sup>4</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

<sup>&</sup>lt;sup>5</sup> American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.

ISO 148-1<sup>7</sup>, Metallic materials—Charpy pendulum impact test—Part 1: Test method

IS0 2859-1, Sampling procedures for inspection by attributes—Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

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 9001, Quality management systems—Requirements

ISO 9606-1, Qualification testing of welders—Fusion welding—Part 1: Steels

ISO 9712, Non-destructive testing—Qualification and certification of NDT personnel

ISO 15614-1, Specification and qualification of welding procedures for metallic materials—Welding procedure test— Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys

ISO/IEC 17020, Conformity assessment—Requirements for the operation of various types of bodies performing inspection

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-55<sup>8</sup>, Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components— Visual Method for Evaluation of Surface Irregularities

SAE AMS 2750°, Pyrometry

#### Terms, Definitions, and Abbreviations 3

#### 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 finished weight of a casting after all processing, removal of all gates, risers, feeds and finished cleaning prior to any machining.

<sup>&</sup>lt;sup>6</sup> European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.

<sup>&</sup>lt;sup>7</sup> International Organization for Standardization, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org. <sup>8</sup> Manufacturers Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street, NE, Vienna, Virginia 22180- 4602,

www.mss-hq.com.

<sup>&</sup>lt;sup>9</sup> SAE International, 400 Commonwealth Drive, Warrendale, PA 15096, www.sae.org.

### 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.

### 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 the 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 from re-melted alloys. The raw material originating from a single remelted 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 from one single heat of material and heat treatment batch.

#### 3.1.12

#### heat-treat lot

(batch furnaces) Material from the same melt or remelt ingot processed together using the same procedures. The same hot/cold work processing and heat treated in the same furnace load including the same quenching practice.

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### 3.1.13

#### heat-treat lot

(continuous furnaces) Group of pieces of material with the same nominal size that is moved sequentially through the heat treatment process using the same process parameters.

#### 3.1.14

#### heat treating

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

#### 3.1.15

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.

#### 3.1.16

#### major weld repair

Weld repair of an excavated cavity that exceeds 20 % of the part wall thickness or 1 in. (25 mm) depth, whichever is smaller, or surface areas greater than 10 in.<sup>2</sup> (65 cm<sup>2</sup>).

#### 3.1.17

#### 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.

### 3.1.18

#### on-site

Activity performed at the foundry, by foundry personnel.

#### 3.1.19

#### outsource

Function or process that is performed by an external supplier approved by the foundry.

#### 3.1.20

#### pattern

The wood, metal, wax, foam, or plastic replica of the final product to be made.

NOTE Patterns usually include gating systems.

#### 3.1.21

#### rigging

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

#### 3.1.22

#### 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.

#### 3.1.23

#### stainless steel

Steel containing 11 % or higher, mass fraction of chromium to render the steel corrosion-resistant.

NOTE Other elements may be added to secure special properties.

### 3.1.24

### thickness

Maximum section thickness of the casting.

### 3.1.25

### 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		
CVN	Charpy V-Notch		
MPS	manufacturing process specification		
NDE	nondestructive examination		
PQR	procedure qualification record		
PWHT	post-weld heat treatment		
QMS	quality management system		
WPS	welding procedure specification		

### 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 sections describe the conditions that, 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 or ISO 9001. In addition, the foundry shall be responsible for conforming to all of the applicable requirements of this specification.

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### 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 Table 5, Table 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 conform to ISO/IEC 17025 for the applicable processes.
- The 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 an independent third party conforming to ISO/IEC 17020.

**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.

	As-cast Weight in Pounds (kilogram)					
CSL	1-499	500-2,499	2,500-9,999	10,000+		
CSL-1	1 Qualification					
CSL-2	1	Qualification	1 Qualification	1		
CSL-3	1 Qualification	1 Qualification	1 Qualification	1 Qualification		
CSL-4	Weights are not applicable for CSL 4. Each casting shall be individually qualified.					

#### Table 1—As-cast Weight Range

NOTE: Any one (1) weight range in CSL 1 qualifies all weight ranges per each specific material group. Any two (2) weight ranges in CSL 2 qualifies all weight ranges per each specific material group. All four (4) weight ranges in CSL 3 qualifies all weight ranges per each specific material group.

#### Table 2—Material Groups

Material Group	Description
Group A	Carbon steels
Group B	Low alloy steels
Group C	Stainless steels (other than duplex)
Group D	Duplex stainless steels
Group E	CRA

CSL	% Surface Area	% Wall Thickness
CSL-1	50 %	50 %
CSL-2	25 %	25 %
CSL-3	20 %	20 %
CSL-4	10 %	10 %

### Table 3—Casting Weld Repair Limitations

### 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. Shapes shown in Figures 1, 2, 3, and 4 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. An equivalent round is not required to exceed 5 in. (125 mm) for CSL-1, CSL-2, and CSL-3 material groups A, B, and C castings.

For CSL-3 castings in groups D and E, the test coupon thickness shall be the same as the part it qualifies and the properties compliant with the standard specification.

Figure 4 and Figure 5 illustrate the procedure for determining the required dimensions of a keel block.



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

#### Figure 1—Equivalent Round Models—Solids of Length L





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.

#### a) Open at Both Ends



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

NOTE Use maximum thickness, T, in the calculation.

#### b) Restricted or Closed at One or Both Ends

#### Figure 2—Equivalent Round Models—Tube (Any Section)



NOTE The following steps should be used in determining the governing equivalent-round (ER), for complex sections:

- a) reduce the component to simple sections;
- b) convert each simple section to an ER;
- c) calculate the diagonal through the circle that would circumscribe the intersection of the ER values;
- d) use the maximum ER value, whether for a single section or an intersection as the ER of the complex section.



a = Bodies with screwed and open ends.

When all internal and external surfaces during heat treatment are within 1/2 in. (13 mm) of the final surfaces, ER = 1 1/4 *T*. When all internal and external surfaces during heat treatment are not within 1/2 in. (13 mm) of the final surfaces, ER = 2*T*. On multi-flanged components, *T* shall be the thickness of the thickest flange.

Where T is the thickness when the component is heat-treated as in T (2), use the larger of the two indicated dimensions.

#### Figure 3—Equivalent Round Models—Complex Shapes

### 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 shall be welded and the requirements for repair welding shall apply.

Photographs shall be taken of the qualification casting in the "as-received" condition to document surface finish and general appearance.



#### ER = 2.3 R

NOTE Shaded area, A, indicates <sup>1</sup>/4 T envelope for test specimen removal.

### Figure 4—Equivalent Round Models—Keel Block Configuration

CSL	Section References									
	Visual	Inspection	Hardness	Surface	Volumetric NDE	Mechanical	Micro- structure	Sacrificial Casting	Chemistry	Additional Testing
CSL-1	4.5.2	4.5.3	4.5.4		_	4.5.6	Ι	_	4.5.8	4.5.9.3 Group D
CSL-2	4.5.2	4.5.3	4.5.4	4.5.5.1 4.5.5.2	_	4.5.6	_	_	4.5.8	4.5.9.3 Group D
CSL-3	4.5.2	4.5.3	4.5.4	4.5.5.1 4.5.5.2	4.5.5.3	4.5.6	4.5.7	_	4.5.8	4.5.9.3 Group D
CSL-4	4.5.2	4.5.3	4.5.4	4.5.5.1 4.5.5.2	4.5.5.3	4.5.6	4.5.7	4.5.9.2	4.5.8	4.5.9.3 Group D

Table 4—Guidance f	or Qualification	<b>Examination/Tes</b>	ting Requirements
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**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.



To develop a keel block for ER = 4.5 in. (115 mm), see footnotes:

- <sup>a</sup> Noting from Figure 3 that ER = 2.3 R, then R = ER/2.3 = 2 in. (50 mm).
- <sup>b</sup> Construct keel block as illustrated in Figure C using multiples of *R*.

° Diameter D

#### Figure 5—Example of Development of Keel Block Dimensions

### 4.5.3 Casting Quality Inspection

The purchaser and casting supplier shall specify critical dimensions, critical areas or features, and the acceptance criteria for each. These shall all be identified in the casting supplier's MPS. 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 the 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. When NACE MR0175 / ISO 15156 is specified, the restrictions for averaging hardness values shall apply. The casting supplier shall specify the number and location for the tests in the MPS. Results shall be documented.

### 4.5.5 Nondestructive Examination

### 4.5.5.1 Magnetic Particle Examination

All accessible surfaces of each ferromagnetic casting shall be magnetic particle inspected per Table 5. 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 nonferromagnetic casting shall be liquid penetrant inspected per Table 5. 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 final heat treatment 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 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 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 or ISO 6892-1, 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, ASTM E23 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** 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 be in accordance with 4.4. The results shall be reported.

### 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 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. 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 <sup>1</sup>/<sub>4</sub> 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 examination of the cut surface of each quadrant per ASTM E165 and report results.
- d) Macro-etch one quadrant in accordance with ASTM E340 to show the grain structure and internal quality. The surface closest to the centerline shall be used. Photographs shall be taken with a measurement 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) Groups D and 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 5 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) After the final heat treatment cycle, the qualification casting or its qualification test coupon (QTC) shall be corrosion tested in accordance with ASTM G48, Method A.
- b) If the QTC is a solid block, one sample in accordance with ASTM G48 shall be taken from the center of the block.
- c) If the QTC has a hole, two samples in accordance with ASTM G48 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 of immersion in the test solution when examined with a low-power magnification (20X) and the maximum weight loss shall be less than 4 g/m2 for products in the solution annealed 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 or 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 listed per 4.5.9.3.2.2. 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 all major weld repair locations shall exhibit ferrite content between 35 % to 65 %.

### 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) or lower. 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.

Relevant Indication Surface-rupture NDE indication with major dimensions greater than <sup>1</sup> / <sub>16</sub> in. (1.6 mm)	
Nonrelevant Indication	Inherent indications not associated with a surface rupture (i.e. magnetic permeability nonmetallic stringers)
Linear Indication	Any indication in which the length is equal to or greater than three (3) times the width
Rounded Indication	Any indication that is circular or elliptical with its length less than three (3) times the width
Magnetic Particle Examination	<ul> <li>a) sampling:</li> <li>All accessible surfaces of each part shall be magnetic-particle inspected after final heat treatment.</li> <li>If any indications are determined to be nonrelevant on the basis that they are not associated with a surface rupture (i.e. magnetic permeability variations, nonmetallic stringers), they shall be examined by liquid-penetrant surface NDE methods, or removed and reinspected, to confirm their nonrelevancy.</li> <li>b) test method:</li> <li>Magnetic particle examinations shall be per ASME BPVC Sec VIII-Div.1, Appendix 6.</li> <li>c) acceptance criteria:</li> <li>Acceptance standards shall be as given in ASME BPVC Sec VIII-Div. 1, Appendix 7.</li> </ul>
Liquid Penetrant Examination	<ul> <li>a) sampling:</li> <li>All accessible surfaces of each part shall be liquid-penetrant inspected after final heat treatment.</li> <li>b) test method:</li> <li>Liquid-penetrant examinations shall be per ASME BPVC Sec. VIII,Div.1 Appendix 8.</li> <li>c) acceptance criteria:</li> <li>Acceptance standards shall be as given in ASME BPVC Sec VIII-Div. 1, Appendix 7.</li> </ul>

#### Table 5—Surface Examination Acceptance

# Table 6—Volumetric Examination Acceptance Criteria

	<b>Sampling:</b> As far as practical, the entire volume of (radiography or ultrasonic) after heat treatment.	f each part shall be volumetrically inspected					
	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:</b> Radiographic examinations shall be performed in accordance with the procedures specified in ASME Section V, Article 2, with a minimum sensitivity of 2 % (2-2 T).						
	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.						
	Acceptance criteria:						
Radiography	ASTM E186, Standard Reference Radiographs fo Steel Castings	r Heavy-Walled (2 to 4 <sup>1</sup> /2 in. (50.8 to 114 mm))					
	ASTM E280, Standard Reference Radiographs fo Steel Castings	r Heavy-Walled (4 <sup>1</sup> /2 to 12 in. (114 to 305 mm))					
	ASTM E446, Standard Reference Radiographs fo	r Steel Castings Up to 2 in. (50.8 mm) in Thickness					
	Maximum defect classification as follows:						
	Defect Type	Maximum Defect Class					
	A	2					
	В	2					
	С	2 (All types)					
	D	None acceptable					
	E	None acceptable					
	F	None acceptable					
	G	None acceptable					
	<b>Sampling:</b> As far as practical, the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after heat treatment.						
	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:</b> 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.						
Ultrasonic	<b>Calibration:</b> The distance amplitude curve (DAC) shall be based on a $^{1}/_{16}$ in. (1.6 mm) flat-bottom hole for metal thicknesses through $1^{1}/_{2}$ in., (38 mm), on a $^{1}/_{8}$ in. (3.2 mm) flat-bottom hole for metal thicknesses from $1^{1}/_{2}$ in. (38 mm) through 6 in. (150 mm), and on a $^{1}/_{4}$ in. (6.4 mm) flat-bottom hole for metal thicknesses exceeding 6 in. (150 mm).						
	Acceptance criteria:						
	<ul> <li>no single indication exceeding reference</li> </ul>	e distance amplitude curve;					
	<ul> <li>no multiple indications exceeding 50 % indications are defined as two or moreference distance amplitude curve) direction.</li> </ul>	of reference distance amplitude curve. Multiple ore indications (each exceeding 50 % of the within $^{1}/_{2}$ in. (13 mm) of each other in any					

### 4.7 Records of Qualification

The following records shall be required, at 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, including PWHT, parameters such as specification, ramp rate, temperature, total 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, and metallographic evaluations, as described in Section 4.
- e) Weld maps for major weld repair.

### 4.8 Limits of Casting Qualifications

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

Requirement	Reference(s)	CSL 1	CSL 2	CSL 3	CSL-4
ASTM keel block	Figure 4, Figure 5	Х	Х	_	_
Equivalent round or integral test specimen	Figure 1, Figure 2, Figure 3	—	_	Х	—
Sacrificial casting	4.5.9.2	_	-	_	Х
Change in material group	4.8.1	Х	Х	Х	Х
As-cast weight range class	4.8.2	_	Х	Х	Х
Change in melt practice	4.8.3	—	_	Х	Х
Material specification/grade	4.8.4	—	_	—	Х
NOTE: This table provides a matrix of requirements and should be used as a reference only, since it may not include all requirements.					

Table 7—Limits of CSL Qualification Summary

#### 4.8.1 CSL-1

A change in the 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 9.

### 5.2 Manufacturing Process Specification (MPS)

The casting supplier shall prepare an MPS, to include, at a 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 and Requirements

The following are process variables and other essential elements of 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) chaplets used to support the mold during metal pouring, and their location;
- h) melt practice, including pouring temperature;
- i) mold preheat (if applicable);
- j) cleaning room practices;
- k) weld repair, if required, including PWHT;
- I) NDE and inspection procedures;
- m) material traceability system;
- n) qualification casting and its qualification test coupon per heat;

- o) chemical analysis;
- p) mechanical properties;
- q) hardness testing;
- r) microstructural examination and additional testing, as applicable.

#### 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);
- I) 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) meet 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;
- 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.

### 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 shall 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 nonferromagnetic 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, ISO 6506-1, ASTM E110, ASTM E18 or ISO 6508-1. 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 that 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;
- 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

#### 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, API 6A, or AMS 2750. Furnace instrumentation shall be calibrated at least once every three 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 meet 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, 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 in accordance with ASNT SNT-TC-1A, 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 ASME BPVC, Section VIII, Division 1.
- f) Post-weld heat treatment (solution treatment) of repair welds in austenitic stainless steels is not mandatory unless required by the material or product 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 shall be performed 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 criteria shall be in accordance with the applicable product specification. The maximum allowable amount of weld repairs shall be in accordance with Table 8.
- i) Repair welding on duplex stainless steel is allowed provided that the ferrite content (volume fraction) is in accordance with section 4.5.9.3.2.2 as part of the WPS and PQR.
- j) Major weld repairs shall be documented.

CSL	% Surface Area	% Wall Thickness
CSL-1	50 %	75 %
CSL-2	25 %	65 %
CSL-3	20 %	50 %

### Table 8—Production Casting Weld Repair Limitations

#### 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 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 major welding is carried out, and values shall be within 35 % and 65 %.

### 5.6.7 Documentation

All documentation and records are required per this standard.

### 5.7 Limits on the Qualification of Production Castings by CSL

Table 9 provides detailed information on the limits of a CSL that shall require requalification of production castings.

Requirement	Ref.	CSL 1	CSL 2	CSL 3	CSL-4
ASTM keel block	Figure 4, Figure 5	Х	Х	—	_
Equivalent round or integral test specimen	Figure 1, Figure 2, Figure 3	Х	Х	Х	_
Sacrificial casting	4.5.9.2	—	—	_	Х
Change in material group	5.7.1.1	Х	Х	Х	Х
Revision or new pattern	5.7.1.2	Х	Х	Х	Х
Pattern is re-rigged	5.7.1.3	Х	Х	Х	Х
Change in risers or padding	5.7.1.3	Х	Х	Х	Х
Change in external chills	5.7.1.3	Х	Х	Х	Х
As-cast weight range class	5.7.2.2	—	Х	Х	Х
Casting practice	5.7.2.3	—	Х	Х	Х
Chemistry tolerance outside the UNS range by greater than 15 %	5.7.4.3	—	_	_	Х
Change in melt practice	5.7.3.2	—	—	х	Х
Material specification/grade	5.7.4.2	—	—	_	Х

Table 9—Limits of CSL Production Casting Summary

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** A new sample casting is required when the pattern of the production casting is revised or a new pattern is made.

**5.7.1.3** A new sample casting 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** 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.

**5.7.4.3** 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 %.

For example, if a qualification casting is made from ASTM A351 – Grade CF3 with 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.

### 5.8 Traceability

**5.8.1** Traceability of castings shall be maintained with respect to material heat, manufacturing procedure specification, and heat lot.

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 10 for an example of the required marking(s).

Casting Mark	Example
Casting supplier's name, mark, or symbol	ABC
Pattern number or part number	21179-01
Material grade	A995-6A
API 20A, CSL number, and material group	20A-2-D
Heat, heat lot, or traceability number	L424

### Table 10—Example: Casting Marking

**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 1,100 °F (590 °C) minimum.

**5.9.3** All cast marking that is required by this specification shall be visually legible in proportion to the size of the casting.

### 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, unless otherwise specified herein, shall be maintained for 10 years from the 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 are in full conformance with this product specification edition and all addenda. Also, the foundry shall furnish the following.

 Material test report (MTR) in conformance with EN-10204 Type 3.1 to include, at 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 conformance 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 11.

NOTE Definition for on-site and outsource are found in 3.1.18 and 3.1.19.

ltem	Activity	Where Performed
1	Pattern design, including mounting and rigging	On-site or outsourced
2	Core making, molding	On-site or outsourced
3	Melting and pouring	On-site
4	Chemical testing	On-site
5	Cleaning	On-site or outsourced
6	Heat treatment	On-site or outsourced
7	Mechanical testing	On-site or outsourced
8	NDE	On-site or outsourced
9	Welding repair	On-site or outsourced
10	Product marking	On-site
11	Final inspection/release	On-site

#### **Table 11—Minimum Facility Requirements**

# Annex A

# (informative)

# API Monogram Program

# Use of the API Monogram by Licensees

# A.1 Scope

The API Monogram<sup>®</sup> is a registered certification mark owned by the American Petroleum Institute (API) and authorized for licensing by the API Board of Directors. Through the API Monogram Program, API licenses product manufacturers to apply the API Monogram to new products which comply with product specifications and have been manufactured under a quality management system that meets the requirements of API Q1. API maintains a complete, searchable list of all Monogram licensees on the API Composite List website (http://compositelist.api.org).

The application of the API Monogram and license number on products constitutes a representation and warranty by the licensee to API and to purchasers of the products that, as of the date indicated, the products were manufactured under a quality management system conforming to the requirements of API Q1 and that the product conforms in every detail with the applicable standard(s) or product specification(s). API Monogram Program licenses are issued only after on-site audits have verified that an organization has implemented and continually maintained a quality management system that meets the requirements of API Q1 and that the resulting products satisfy the requirements of the applicable API product specification(s) and/or standard(s). Although any manufacturer may claim that its products meet API product requirements without monogramming them, only manufacturers with a license from API can apply the API Monogram to their products.

Together with the requirements of the API Monogram license agreement, this annex establishes the requirements for those organizations who wish to voluntarily obtain an API license to provide API monogrammed products that satisfy the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program requirements.

For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, NW, Washington, DC 20005 at certification@api.org.

# A.2 Normative References

For Licensees under the Monogram Program, the latest version of this document shall be used. The requirements identified therein are mandatory.

# A.3 Terms and Definitions

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

# A.3.1

### API monogrammable product

Product that has been newly manufactured by an API Licensee utilizing a fully implemented API Q1 compliant quality management system and that meets all the API-specified requirements of the applicable API product specification(s) and/or standard(s).

# A.3.2

### API product specification

Prescribed set of rules, conditions, or requirements attributed to a specified product that address the definition of terms; classification of components; delineation of procedures; specified dimensions; manufacturing criteria;

material requirements, performance testing, design of activities; and the measurement of quality and quantity with respect to materials; products, processes, services, and/or practices.

### A.3.3

### **API-specified requirements**

Requirements, including performance and Licensee-specified requirements, set forth in API Q1 and the applicable API product specification(s) and/or standard(s).

NOTE Licensee-specified requirements include those activities necessary to satisfy API-specified requirements.

### A.3.4

### Design package

Records and documents required to provide evidence that the applicable product has been designed in accordance with API Q1 and the requirements of the applicable product specification(s) and/or standard(s).

### A.3.5

### Licensee

Organization that has successfully completed the application and audit process, and has been issued a license by API to use the API Monogram Mark.

### A.4 Quality Management System Requirements

An organization applying the API Monogram to products shall develop, maintain, and operate at all times a quality management system conforming to API Q1.

### A.5 Control of the Application and Removal of the API Monogram

Each licensee shall control the application and removal of the API Monogram in accordance with the following:

- a) Products that do not conform to API specified requirements shall not bear the API Monogram.
- b) Each licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by this annex and any applicable API product specification(s) and/or standard(s). The marking procedure shall:
  - 1) define the authority responsible for application and removal of the API Monogram and license number;
  - 2) define the method(s) used to apply the Monogram and license number;
  - 3) identify the location on the product where the API Monogram and license number are to be applied;
  - 4) require the application of the date of manufacture of the product in conjunction with the use of the API Monogram and license number;
  - 5) require that the date of manufacture, at a minimum, be two digits representing the month and two digits representing the year (e.g. 05-12 for May 2012) unless otherwise stipulated in the applicable API product specification(s) or standard(s); and
  - 6) define the application of all other required API product specification(s) and/or standard(s) marking requirements.
- c) Only an API licensee shall apply the API Monogram and its designated license number to API monogrammable products.
- d) The API Monogram and license number, when issued, are site-specific and subsequently the API Monogram shall only be applied at that site specific licensed facility location.

e) The API Monogram may be applied at any time appropriate during the production process but shall be removed in accordance with the licensee's API Monogram marking procedure if the product is subsequently found to be out of conformance with any of the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program.

For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. Requirements for alternative API Monogram marking are detailed in the, *API Alternative Marking Agreement (AMA)*, available on the API Monogram Program website at: <u>http://www.api.org/products-and-services/api-monogram-and-apigr/documents#tab\_certification-documents</u>

### A.6 Design Package Requirements

Each licensee and/or applicant for licensing shall maintain a current design package for all of the applicable products that fall under the scope of each Monogram license. The design package information shall provide objective evidence that the product design meets the requirements of the applicable and most current API product specification(s) and/or standard(s). The design package(s) shall be made available during API audits of the facility.

In specific instances, the exclusion of design activities is allowed under the Monogram Program, as detailed in Advisory # 6, available on API Monogram Program website at <u>http://www.api.org/products-and-services/api-monogram-and-apigr#tab\_advisories</u>.

### A.7 Manufacturing Capability

The API Monogram Program is designed to identify facilities that have demonstrated the ability to manufacture equipment that conforms to API specifications and/or standards. API may refuse initial licensing or suspend current licensing based on a facility's level of manufacturing capability. If API determines that additional review is warranted, API may perform additional audits (at the organization's expense) of any primary subcontractors to ensure their compliance with applicable specifications.

Facilities with capabilities that are limited to the processes or activities defined below do not meet the manufacturing capability requirements to produce new products, and therefore, shall not be licensed or be the basis for licensing under the API Monogram Program:

- Capabilities that are limited to performing final inspection and testing of the product, except for testing agencies as specified in API Spec 14A and/or API Spec 6AV1
- Buying, selling and/or distributing finished products and materials;
- Design and development activities;
- Tearing-down and/or re-assembling of products/components; and,
- Repairing or remanufacturing of existing, used, worn or damaged products.

In all instances where requirements for manufacturing or manufacturing facilities are explicitly identified within the API product specification, those requirements shall take precedence over this advisory.

### A.8 API Monogram Program: Nonconformance Reporting

API solicits information on products that are found to be nonconforming with API specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification and/or standard deficiencies or nonconformities against API specified requirements. Customers are requested to report to API all problems with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at <a href="http://ncr.api.org/ncr.aspx">http://ncr.api.org/ncr.aspx</a>.

# **Bibliography**

- [1] ASTM A352, Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure- containing Parts, Suitable for Low-Temperature Service
- [2] ASTM A1067, Standard Specification for Test Coupons for Steel Castings
- [3] NACE MR0175/ISO 15156, Petroleum and natural gas industries—Materials for use in H2S-containing environments in oil and gas production



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