API vs MSS

Standardization of Castings Quality

Presented by: Rick Faircloth-Principal Engineer
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Introduction – Casting Quality

This presentation reviews the two newly proposed standards with special emphasis on difference in requirements.
Background - Casting Quality

- ASME B16.34 Standard Class only requires:
  - Visual examination per MSS SP-55
  - Pressure testing at standard pressures
  - Casting quality???

- ASME B16.34 Special Class requires:
  - Radiographic examination Level 3 or better
  - Magnetic Particle or Liquid Penetrant examination
  - Visual examination per MSS SP-55
  - Pressure testing at higher pressures

- Basic visual examination and pressure testing doesn’t reveal everything!
New Approach – Casting Quality

American Petroleum Institute (API) and the Manufacturer’s Standardization Society (MSS) continue to define the requirement of castings quality in the petroleum, chemical, and pipeline industries through development of steel castings quality standards.

Previous attempts (1956 & 1978) were made by the Steel Founder’s Society of America defining casting quality and other considerations.
Newly Proposed Castings Standards

- **API 20A** - Steel, Stainless Steel, and Nickel Base Alloy Castings for Use in the Petroleum and Natural Gas Industry.

API 20A

- Created by Committee 20 “Supply Chain Management”. Created to help provide guidance for supply chain quality & procurement as well as end users

- Part of series of standards:
  - Open Die Forgings - 20B
  - Closed Die Forgings - 20C
  - Heat Treatment - 20G
  - Bolting - 20E
  - NDE-20D

- These API 20 series documents are auditable by API Q1

- Can be applied to any API product standard such as 6A, 6D, 6DSS, 17D, 600, 608, 603, etc.

MSS SP-14X

- Under the auspices of MSS Committee 304 “Quality Standards”
API 20A - Requirements

Scope / Purpose
The standard specifies requirements for the design, foundry qualification, production, 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 equipment standard, or otherwise specified as a requirement for compliance.

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

Casting Specification Levels (CSL)
The standard establishes requirements for four casting specification levels (CSL). These four CSL designations define different levels of cast product technical, quality and qualification requirements.

MSS SP-14X
The purpose of this standard practice is to provide evaluation methods and nondestructive acceptance criteria for non-Special Class, steel valve castings. The document additionally provides procedures for developing and qualifying Standard Class pilot castings.
### API 20A – Qualification Castings Limits of CSL

<table>
<thead>
<tr>
<th>Requirement</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>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Equivalent Round or Integral Test Specimen</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>Sacrificial casting</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>Change in Material Group – change in material group from the casting that was previously qualified requires requalification</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>As-cast Thickness and Weight Range – change in the as-cast thickness and weight range class from the casting that was previously qualified requires requalification</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Change in Melt Practice - 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</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Material Specification / Grade – change in the specific material specification / grade from the casting that was previously qualified requires requalification of the casting</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>

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

Note: There are four pages of coupon/keel block instructions specified in the standard...
- Coupons/keel blocks are to be proportional to finished qualified casting cross-sections.
- Coupons/keel blocks are to be from the same heat as the components they qualify.
- Coupons/keel blocks are to be heat treated together with those same components.
# API 20A – Production Casting Limits of CSL

<table>
<thead>
<tr>
<th>Requirement</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>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Equivalent Round or Integral Test Specimen</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>Sacrificial Casting</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Change in Material Group</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Revised or new-Pattern</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pattern re-Rigging</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Change in Risers or Padding</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Change in External Chills</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>As-cast Thickness and Weight Range Class</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Casting Process</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Chemistry Tolerance greater than 15%</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Change in melting Practice</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Material Specification / Grade</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note: Above matrix of requirements do not include all requirements and are to be used as reference only.
API 20A – Foundry Qualification

The standard specifies four casting specification levels (CSL). The CSL’s are numbered in increasing levels of severity from 1 ~ 4 in order to reflect increasing technical, quality and qualification criteria. The following slides describe the conditions which, when met, allow the casting to receive the appropriate CSL classification level.

Qualification Casting

A qualification casting is to be produced, tested, and evaluated by the casting supplier in order to establish qualification for a range of products. Castings are to be produced in accordance with a manufacturing procedure specification. The material group of the qualification casting shall be in accordance with Table 1.

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 are to be produced in accordance with specified requirements including the acceptance criteria. One or more qualification test coupons conforming to defined figures, as appropriate, are to be poured at the same time and from the same heat as the qualification casting.
### API 20A Material Groups

<table>
<thead>
<tr>
<th>Material Group</th>
<th>Description</th>
<th>Typical Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Carbon Steels</td>
<td>ASTM A216, ASTM A148, ASTM A352, Gr. LCC</td>
</tr>
<tr>
<td>Group B</td>
<td>Low Alloy Steels</td>
<td>ASTM A217, A487 / A487M</td>
</tr>
<tr>
<td>Group C</td>
<td>Stainless Steels other than Duplex</td>
<td>ASTM A351</td>
</tr>
<tr>
<td>Group D</td>
<td>Duplex Stainless Steels</td>
<td>Duplex and Super Duplex Stainless Steels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM A890, ASTM A995</td>
</tr>
<tr>
<td>Group E</td>
<td>Nickel Base Alloys (CRA)</td>
<td>ASTM A494, ASTM A743, ASTM A744</td>
</tr>
</tbody>
</table>

### MSS SP-14X

Materials covered by SP-14X include ASTM A216 Grades WCA, WCB, and WCC; and ASTM A217 Grades WC6, WC9, C5, and C12. SP-14X can also be utilized for other materials such as stainless steel, etc., by agreement between the foundry and the purchaser.
API 20A - Qualification Casting

A casting qualified to higher casting specification level will also qualify for lower casting specification levels (e.g. CSL-4 is qualified for CSL-3, CSL-2 and CSL-1).

Repair welding on the qualification casting is to comply as per Table 2 below. Cosmetic grinding to remove defects is permitted, but is to be kept to a minimum. Excessive surface grinding may be cause for rejection. Repair welds are to be tested to include at least the deepest repair (weld metal and HAZ).

### Qualification Casting - Weld Repair Limitations

<table>
<thead>
<tr>
<th>CSL Level</th>
<th>% Surface Area</th>
<th>% Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSL-1</td>
<td>No Limitation</td>
<td>No Limitation</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>
</tbody>
</table>

### Repair Welding - Procedures, Welders / Welding Operators Qualification

<table>
<thead>
<tr>
<th>CSL Level</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSL-1 &amp; CSL-2</td>
<td>ASME BPVC, Section IX; AWS D1.1; ASTM A488 or equivalent standards</td>
</tr>
<tr>
<td>CSL-3</td>
<td>ASME BPVC, Section IX</td>
</tr>
<tr>
<td>CSL-4</td>
<td>No welding permitted</td>
</tr>
</tbody>
</table>
API 20A - Casting Qualification Testing

Examination Procedure
All examinations and testing summarized in Table below shall apply to the qualification casting and its QTC(s), as applicable.

{Table 3}

<table>
<thead>
<tr>
<th>Type</th>
<th>CSL-1</th>
<th>CSL-2</th>
<th>CSL-3</th>
<th>CSL-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical (tension, toughness)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Micro-Structure (micro-specimen)</td>
<td>-</td>
<td>-</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Visual (MSS SP-55)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Dimensional</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Hardness</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Surface NDE (LP or M, level 2 max.)</td>
<td>-</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Volumetric NDE (RT or UT, level 2 max.)</td>
<td>- (a)</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Sacrificial Casting</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>√</td>
</tr>
<tr>
<td>Corrosion Testing</td>
<td>-</td>
<td>-</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Other Testing (Group D Material)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

(a) required for special class
API 20A – Quality Control

Visual Inspection

- All surfaces of the qualification casting are to be visually inspected in accordance with MSS SP-55. No internal chills or permanent metal chaplets are allowed, however, chaplets or core supports made of molding media are allowed. Where these molding media chaplets are used, the hole remaining in the casting wall will need to be welded. The standard does consider this weld as a weld repair, but as part of the casting production process. Photographs are to be taken of the qualification casting in the “as-received” condition to document surface finish and general appearance.

- Reference photographs in MSS SP-55 are to be used to determine acceptability of castings. Acceptance criteria is to be as follows:
  - Type 1 – unacceptable
  - Type 2-12 – A and B are acceptable
  - All others are unacceptable

- Results are to be documented
API 20A – Quality Control

Dimensional Inspection
The casting supplier has to specify and verify critical dimensions. Acceptance criteria for critical dimensions is to be as required by the casting supplier’s written specification. Results are to be documented.

Hardness Testing
Brinell and/or Rockwell hardness testing is to be performed in accordance with ASTM E10, ASTM E110, or ASTM E18 on external surfaces to ensure the casting is within the specified limits for the finished product. A minimum of three (3) indentations per casting is required. The casting supplier has to specify in the MPS the number and location for the tests. Results are to be documented.
API 20A – Non-destructive Examination

Surface NDE - Magnetic Particle Examination
All accessible surfaces of each Group A and Group B ferromagnetic casting are to be magnetic particle inspected per ASTM E709. The acceptance criteria shall be as specified in the standard. Results are to be recorded.

Surface NDE - Liquid Penetrant Examination
All accessible surfaces of each non-ferromagnetic casting are to be liquid penetrant inspected in accordance with ASTM E165. The acceptance criteria shall be as specified in the standard. Results are to be recorded.
API 20A – Non-destructive Examination

Volumetric NDE
- As practical, the entire volume of each part is to 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 is to be performed after heat treatment for mechanical properties exclusive of stress-relief treatments or re-tempering to reduce hardness.

Volumetric NDE - Radiographic Examination
Radiographic examinations are to 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 penetrameter 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 penetrameter thickness,
API 20A – Non-destructive Examination

Volumetric NDE - Ultrasonic Examination
Ultrasonic examination of castings is to 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) is to be based on 1.6 mm (1/16 in.) flat-bottom hole for metal thicknesses through 38 mm (1 ½ in.), on 3.2 mm (1/8 in.) flat-bottom hole for metal thicknesses from 38 mm (1 ½ in.) through 150 mm (6 in.), and on 6.4 mm (1/4 in.) flat-bottom hole for metal thicknesses exceeding 150 mm (6 in.). Acceptance shall be in accordance with the standard.

Test Results
All volumetric examination test results are to be recorded.
API 20A – Material Testing

Mechanical Testing
The mechanical tests required by this standard are to be performed on the qualification casting and its qualification test coupons representing the heat and heat treatment lot used in the manufacture of the casting. Tests are to be performed in accordance with the requirements of **ASTM A370, or equivalent national standards**, using material in the final heat-treated condition. For the purpose 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
• Tensile test specimens are to be tested in accordance with ASTM A370. Mechanical properties are to be in accordance with the material specification used. Results are to be reported.

• Charpy (CVN) impact specimens are to be tested in accordance with ASTM A370. CVN test temperature and acceptance criteria are to 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. Results are to be reported.
API 20A – Material Testing

Microstructure Examination
- Specimens are to be prepared from the grip end of one of the tensile specimens.

- Photomicrograph is to be provided of the as-polished specimen at 100X showing average and worst-case field (any type). For stainless steel and duplex steel, a micrograph taken at 400X or greater magnification of the best and worst area shall be made.

- Specimen is to be etched using the appropriate reagent. The structure is to be free from casting defects, inclusions, and must be homogenous. Typical microstructure is to be photographed and reported. Any unusual anomalies such as inter-metallic and/or heavy precipitates in the grain boundaries are also to be photographed and reported. Results are to be documented.

- For Group A, B and C materials, steel cleanliness is to be determined in accordance with ASTM E45 as specified in the standard. Photomicrographs are to be taken at 100X magnification showing average and worst-case field views. Results are to be documented.

- Grain size is to be determined in accordance with ASTM E112 for the sample following etching with a suitable reagent. Photomicrographs of grain size are to be taken.
API 20A – Material Testing

Chemical Analysis
The casting supplier has to specify the nominal chemical composition, including composition tolerances, of the material used for the qualification casting.

Material composition is to be determined on a heat basis (or on a re-melt ingot basis for re-melt grade materials) in accordance with a nationally or internationally recognized standard.

Additional Testing
For CSL-4 castings qualification, additional testing for Sacrificial Casting, Group-D (Duplex Material) Testing, Microstructure Controls, Impact Testing is mandatory and is to be performed in addition to the requirements specifies for CSL-2 & CSL-3 castings.
API 20A – Additional Testing

Sacrificial Casting – CSL-4

- Casting is to be sectioned into four (4) approximately equally sized quadrants.

- All surfaces of each quadrant is to be visually inspected for cracks, voids, porosity, or other anomalies. Photograph all anomalies of each surface.

- Liquid penetrant examination is to be performed on the cut surface of each quadrant per ASTM E165 and results ba
  - One quadrant is to be macro-etched in accordance with ASTM E340 (an appropriate etchant shall be used) to show the grain structure and internal quality, using the surface closest to the centerline. Photographs shall be taken with a scale visible to provide size reference. Any indications noted are to be clearly marked for later evaluation.

- A set of hardness traverses are to be made across the cut 3@p$aCe of one quadrant taken 90 degrees to each other. The hardness and specific locations are to be recorded and a photograph taken.
API 20A – Additional Testing

Group D - Duplex Material Testing

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

- If the QTC is a solid block, one ASTM G48 sample is to be taken from the center of the block.

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

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

- For 22 Cr duplex stainless steels, the temperature is to be 25±1°C and for 25 Cr duplex stainless steels, the test temperature is to be 50±1°C. For both duplex stainless steel grades, the exposure time is 24 hours.

- The acceptance criteria is that the test material shows 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 is less than 1 g/m².
API 20A – Additional Testing

Microstructure Controls

The micrographic examination is to 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 is to be tested in accordance with ASTM E562. The ferrite content must be in the range of 35 % – 65 % (volume fraction). Samples are to 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 are to be used.

Impact Testing

Duplex materials are to be impact tested to ASTM A923, method B.
## API 20A - Surface Examination Acceptance Criteria

{Table 5}

<table>
<thead>
<tr>
<th>NDE Method</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic Particle</td>
<td>Indications greater than the following shall be unacceptable: Ref ASTM E125</td>
</tr>
<tr>
<td></td>
<td>Defect Type</td>
</tr>
<tr>
<td>I</td>
<td>Linear</td>
</tr>
<tr>
<td>II</td>
<td>Shrinkage</td>
</tr>
<tr>
<td>III</td>
<td>Inclusions</td>
</tr>
<tr>
<td>IV</td>
<td>Chills &amp; Chaplets</td>
</tr>
<tr>
<td>V</td>
<td>Porosity</td>
</tr>
<tr>
<td>Liquid Penetrant</td>
<td>a) No linear relevant indications greater than 3/16”.</td>
</tr>
<tr>
<td></td>
<td>b) No rounded relevant indications greater than 3/16”.</td>
</tr>
<tr>
<td></td>
<td>Four or more rounded relevant indications greater than 1/16” in a line separated by less than 1/16”, edge to edge, are unacceptable.</td>
</tr>
</tbody>
</table>

**Definitions:**
- Relevant Indication – those indications whose major dimension is greater than 1/16”.
- Non-Relevant Indication – Inherent indications not associated with a surface rupture (i.e., magnetic permeability, non-metallic stringers).
- Linear Indication – any indication in which the length is equal to or greater than three times its width.
- Rounded Indication – any indication which is circular or elliptical with its length less than three times the width.
# API 20A - Volumetric Examination Acceptance Criteria  

## Table 6

<table>
<thead>
<tr>
<th>NDE Method</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
</table>
| Radiography | ASTM E186: Standard reference radiographs for heavy walled (2" ~ 4 ½") steel casting.  
ASTM E280: Standard reference radiographs for heavy walled (4 ½" ~ 12") steel casting.  
ASTM E446: Standard reference radiographs for steel casting up to 2" in thickness.  
Maximum defect classification as follows: |
|            | Type Defect         | Maximum Defect Class |
|            | A                   | 2                    |
|            | B                   | 2                    |
|            | C                   | 2 (all types)        |
|            | D                   | none acceptable      |
|            | E                   | none acceptable      |
|            | F                   | none acceptable      |
|            | G                   | none acceptable      |

| Ultrasonic | Distant amplitude curve (DAC) shall be based on the following:  
Wall Thickness (T) | DAC |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T to 1 ½&quot; inclusive</td>
<td>1/16&quot;</td>
</tr>
<tr>
<td>T from 1 ½&quot; ~ 6&quot; inclusive</td>
<td>1/8&quot;</td>
</tr>
<tr>
<td>T over 6&quot;</td>
<td>¼&quot;</td>
</tr>
</tbody>
</table>

a) No single indication greater than reference DAC.  
b) Two or more indications exceeding 50% DAC within ½" of each other in any direction are unacceptable.
API 20A - Acceptance of the Qualification Casting

- Results of the examinations must comply with the specified acceptance criteria and according to the casting supplier’s written specification. Results are to be documented.

- 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 are to be documented.

Records of Qualification
Records required to document qualification of the casting include:

- Heat number, material specification, actual chemistry with minimum and maximum tolerances, cleanliness, if applicable.
- Casting parameters such as molding media, wash type if applicable, melt practice, ladle refining if applicable, tap temperature, pouring temperature.
- 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.
- Test records of the examinations, mechanical testing, metallographic evaluations, as described in the standard.
## API 20A - Limits of Casting Qualifications

<table>
<thead>
<tr>
<th>CSL Level</th>
<th>As-cast Thickness (inch) and Weight (pound)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;2</td>
</tr>
<tr>
<td></td>
<td>&lt;500</td>
</tr>
<tr>
<td>CSL-1</td>
<td>1 Qualification</td>
</tr>
<tr>
<td>CSL-2</td>
<td>1 Qualification</td>
</tr>
<tr>
<td>CSL-3</td>
<td>1 Qualification</td>
</tr>
<tr>
<td>CSL-4</td>
<td>Weight and thickness are not applicable for CSL-4. Each casting shall be individually qualified.</td>
</tr>
</tbody>
</table>

**CSL-1:** A change in material group from the casting that was previously qualified requires requalification.

**CSL-2:** A change in the as-cast thickness and weight range class from the casting that was previously qualified requires requalification.

**CSL-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 requires requalification.

**CSL-4:** A change in the specific material specification/grade from the casting that was previously qualified requires requalification of the casting.
API 20A - Production Castings

Castings, including sample castings, are to be produced in accordance with the manufacturing procedure specification specified and conform to the limits specified in the standard.

Manufacturing Procedure Specification

The casting supplier has to prepare a manufacturing procedure specification (MPS) to include, as minimum, allowable levels for all casting parameters including the process control variables and the heat treatment parameters listed in the standard. As part of the MPS, pattern equipment and rigging shall be documented and made available for review.
API 20A - Process Control Variables

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

- Acceptable pattern equipment for production;
- Acceptable core equipment for production;
- Acceptable sand control;
- Mold/core equipment maintenance;
- Rigging design documented;
- Molding parameters defined, such as sand and wash type, dipping sequence for investment;
- Melt practice;
- Cleaning room practices;
- Weld repair, if required, including PWHT;
- NDE and inspection procedures;
- Material traceability system;
- Qualification casting and its qualification test coupon per heat;
- Chemical analysis;
- Mechanical properties;
- Hardness test;
- Micro-structural examination and additional testing, as applicable
API 20A - Heat Treating Parameters

The following are heat treat parameters, as applicable:

• Furnace loading diagram and orientation of production parts;
• Temperatures and times for all individual heat treating cycles;
• Casting configuration and dimensions at time of heat treatment;
• Quenching medium and type of agitation (water/polymer, forced, horizontal; or vertical quench, ID/OD, etc.);
• Loading temperature;
• Heating rate;
• Holding temperature;
• Holding time;
• Cooling medium;
• Time to quench;
• Furnace chart(s).
• Maximum quench media temperature at the start and end of quenching.
API 20A - Sample Casting

- Prior to the production of castings, the casting supplier has to produce a sample casting(s) and obtain approval from the purchaser/equipment manufacturer. The casting supplier has to perform all required tests and examinations and certify that the sample casting(s) meets the requirements of this standard.

- At the discretion of the purchaser/equipment manufacturer, the first production run of castings may be considered the sample. In that case, at least one of the castings is required to be processed as a sample.

- A casting is be deemed a "sample" when one or more of the following events take place:
  
  • First use of a pattern on a new order;
  • Pattern is re-rigged;
  • New pattern is made;
  • Pattern is revised;
  • Change in processing (i.e., core making, sand control, melt practice);
  • Pattern is sent to another foundry;
  • Rejection of a sample;
  • Upon identification of a recurring defect in a casting released for production.
MSS SP-14X - Pilot Casting Quality Control

- Visual (MSS SP-55)
- Surface NDE - Magnetic Particle (MSS SP-53) or Penetrant Testing (MSS SP-93) - All accessible internal and external surfaces
- Volumetric NDE - Radiography (MSS SP-54) – critical areas as defined by ASME B16.34
- Evaluated without weld repairs
API 20A - Sample Castings Evaluation

- Dimensional inspection is to be performed in accordance with the purchaser’s drawings.

- Visual examination is to 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, then the visual examination is to be performed as specified in this standard.

- Magnetic particle examination of ferromagnetic castings is to be performed in accordance with the purchaser’s specification, if provided. If the purchaser does not provide requirements for magnetic particle examination, then the magnetic particle examination is to be performed as specified in this standard.

- Liquid penetrant particle examination of non-ferromagnetic castings is to be performed in accordance with the purchaser/equipment manufacturers’ specification, when provided. If the purchaser does not provide requirements for liquid penetrant examination, then the liquid penetrant examination is to be performed as specified in this standard.
API 20A - Sample Castings Evaluation

- Volumetric examination is to be performed in accordance with the purchaser’s specification, if provided. If the purchaser does not provide requirements for volumetric examination, then the volumetric examination is to be performed as specified in this standard.

- 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, then the hardness testing is to be performed as specified in this standard.

- Mechanical testing is to be performed as specified in this standard.

- Chemical analysis is to be performed as specified in this standard.

- Material testing for Group D (duplex steel) material is to be performed as specified in this standard.
API 20A - Sample Casting Acceptance

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

Traceability

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

- Casting qualification records are to be traceable to the casting supplier’s Manufacturing Procedure Specification (MPS).

- Castings produced to this specification are to be traceable to the applicable casting qualification record.
API 20A - Pattern Equipment Design

Design of patterns and cores used to produce castings in accordance with this standard have to include documentation of those designs. This documentation 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).

Design documentation has to be reviewed by a qualified person other than the person who created the original design. Design documents and data are to be maintained for 5 years after the date of last manufacturing of that product.
API 20A - Maintenance of Pattern Equipment

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

Allowable Design Changes

- Design changes are to 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 are to be documented, reviewed and approved by a qualified person before their implementation and continue to meet the applicable requirements of this standard. When required by purchase order, all substantive design changes must be approved by the purchaser/equipment manufacturer.
API 20A - Inspection, Quality Control, Marking, and Documentation

Calibration

Inspection, measuring and testing equipment used for acceptance is to be identified, inspected, calibrated, and adjusted at specific intervals in accordance with NCSL Z540.3 and this standard. Calibration standards must be traceable to the applicable national or international standards agency and shall be no less stringent than the requirements included herein. Inspection, measuring and testing equipment is to be used only within the calibrated range. Calibration intervals are to be established based on repeatability and degree of usage.

Furnace Calibration

Heat treatment furnaces are to be calibrated annually in accordance with a recognized international standard such as API 6A, Annex M or AMS 2750. Records of furnace calibration are to be maintained.

Dimensional inspection

Dimensional inspection is to be performed on products produced to this standard. Sampling is to be in accordance with ISO 2859-1, Level II, 1.5 AQL. The casting supplier has to verify critical dimensions. Critical dimensions and acceptance criteria are to be as required by the purchaser’s specification.
API 20A - Surface NDE

CSL-2 and CSL-3
The casting supplier has to randomly select one casting from each production run of each weight/thickness class (Table 7) and material group (Table 1) for surface examination. Surface examination is be performed in accordance with the methods specified in this standard, as appropriate for the material. Acceptance criteria is to be in accordance with the standard.

CSL-4
Each CSL-4 casting is to be surface-examined in accordance with the methods specified in this standard, as appropriate for the material. Acceptance criteria is to be in accordance with the standard.

Failure to Meet Acceptance Criteria
Failure of a CSL-2 and CSL-3 casting to meet the applicable acceptance criteria will require a “hold” to be placed on the production lot and a surface examination performed on two additional sample castings selected at random from the same production run of castings. If the two additional castings fail, the purchaser and the casting supplier have to specifically agree on the disposition of the production lot.
API 20A - Volumetric NDE

CSL-2 and CSL-3
The casting supplier has to randomly select one casting from each production run of each weight/thickness class (Table 7) and material group (Table 1) for volumetric examination. Volumetric examination shall be performed in accordance with the methods specified in the standard. Acceptance criteria is to be in accordance with this standard for ultrasonic examination and the radiographic quality levels.

CSL-4
Each CSL-4 casting is to be volumetrically examined in accordance with the methods specified in this standard. Acceptance criteria is to be in accordance with this standard for ultrasonic examination and the radiographic quality levels.

Failure to Meet Acceptance Criteria
Failure of a CSL-2 and CSL-3 casting to meet the applicable quality level will require a “hold” to be placed on the production lot and a radiographic examination performed on two additional sample castings selected at random from the same production run of castings. If the two additional castings fail, the purchaser and the casting supplier have to specifically agree on the disposition of the production lot.
API 20A - Wall thickness up to 2” in accordance with ASTM E446

<table>
<thead>
<tr>
<th>Discontinuity Type</th>
<th>Category</th>
<th>Acceptable Comparative Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>A</td>
<td>A3, A2</td>
</tr>
<tr>
<td>Sand</td>
<td>B</td>
<td>B4, B3</td>
</tr>
<tr>
<td>Shrinkage, Type 1</td>
<td>C</td>
<td>CA3, CA2</td>
</tr>
<tr>
<td>Shrinkage, Type 2</td>
<td>C</td>
<td>CB4, CB3</td>
</tr>
<tr>
<td>Shrinkage, Type 3</td>
<td>C</td>
<td>CC4, CC3</td>
</tr>
<tr>
<td>Shrinkage, Type 4</td>
<td>C</td>
<td>CD4, CD3</td>
</tr>
<tr>
<td>Hot Tears &amp; Cracks</td>
<td>D &amp; E</td>
<td>none</td>
</tr>
<tr>
<td>Inserts (Chills &amp; Chaplets)</td>
<td>F</td>
<td>none</td>
</tr>
</tbody>
</table>

MSS SP-14X requirement
## API 20A - Wall thicknesses 2” ~ 4 ½” in accordance with ASTM E186

<table>
<thead>
<tr>
<th>Discontinuity Type</th>
<th>Category</th>
<th>Acceptable Comparative Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CSL-2 &amp; CSL-3</td>
</tr>
<tr>
<td>Gas</td>
<td>A</td>
<td>A3</td>
</tr>
<tr>
<td>Sand</td>
<td>B</td>
<td>B4</td>
</tr>
<tr>
<td>Shrinkage, Type 1</td>
<td>C</td>
<td>CA4</td>
</tr>
<tr>
<td>Shrinkage, Type 2</td>
<td>C</td>
<td>CB4</td>
</tr>
<tr>
<td>Shrinkage, Type 3</td>
<td>C</td>
<td>CC4</td>
</tr>
<tr>
<td>Crack</td>
<td>D</td>
<td>none</td>
</tr>
<tr>
<td>Hot Tear</td>
<td>E</td>
<td>none</td>
</tr>
<tr>
<td>Inserts</td>
<td>F</td>
<td>none</td>
</tr>
</tbody>
</table>

MSS SP-14X requirement
### API 20A - Wall thicknesses 4 ½” ~ 12” in accordance with ASTM E280

<table>
<thead>
<tr>
<th>Discontinuity Type</th>
<th>Category</th>
<th>Acceptable Comparative Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CSL-2 &amp; CSL-3</td>
</tr>
<tr>
<td>Gas</td>
<td>A</td>
<td>A4</td>
</tr>
<tr>
<td>Sand</td>
<td>B</td>
<td>B4</td>
</tr>
<tr>
<td>Shrinkage, Type 1</td>
<td>C</td>
<td>CA4</td>
</tr>
<tr>
<td>Shrinkage, Type 2</td>
<td>C</td>
<td>CB4</td>
</tr>
<tr>
<td>Shrinkage, Type 3</td>
<td>C</td>
<td>CC4</td>
</tr>
<tr>
<td>Crack</td>
<td>D</td>
<td>none</td>
</tr>
<tr>
<td>Hot Tear</td>
<td>E</td>
<td>none</td>
</tr>
<tr>
<td>Inserts</td>
<td>F</td>
<td>none</td>
</tr>
</tbody>
</table>

**MSS SP-14X requirement**
API 20A - Repair welding

When 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:

- Welding is to be performed using weld procedures qualified in accordance with:
  - CSL-1 and CSL-2 – ASME BPVC, Section IX, AWS D1.1, ASTM A488 or equivalent standards;
  - CSL-3 – ASME BPVC, Section IX;
  - CSL-4 – No welding permitted.

- Welding is to be only performed by welders or welding operators qualified in accordance with standards listed in item a).

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

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

- Weld repairs have to be heat treated in accordance with the post-weld heat treatment requirements of the ASME BPVC, Section VIII, Division 1.
API 20A - Repair welding

- 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.

- The weld area has to 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 is to 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 are to be as in the original examination.

- Weld repairs made as a result of radiographic examination are to be radiographed after welding. The acceptance standards for porosity and slag inclusion in welds are to be in accordance with the ASME BPVC, Section VIII, Division 1, UW-51.

- Repair welding is not permitted on duplex stainless steel and CSL-4.

- Weld repair has to be documented.
API 20A - Limits on the Qualification of Production Castings

CSL-1
- A change in material group from the qualification casting requires requalification.
- Requalification is required when the pattern of the production casting is revised or a new pattern made.
- Requalification is required when the pattern of the production casting is re-rigged including padding and external chills.

CSL-2
- Qualification requirements specified for CSL-1 are required for CSL-2.
- A change in the as-cast thickness and weight range class from the qualification casting requires requalification.
- Requalification is required when the general casting process is changed from the qualification casting process, such as changing from an investment casting to a sand casting.
**MSS SP-14X – Production Casting**

- Visual (MSS SP-55) – all external and accessible internal areas
- Standard production, pressure containing castings shall be randomly based on the sampling plan specified in Annex A
- Volumetric NDE - Radiography (MSS SP-54) – meet the radiographic quality levels as listed in Tables 1, 2 & 3, as applicable for critical areas as designated in ASME B16.34

<table>
<thead>
<tr>
<th>NPS</th>
<th>150</th>
<th>300</th>
<th>600</th>
<th>900</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>2” ~ 8”</td>
<td>1%</td>
<td>1%</td>
<td>2%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>10” ~ 16”</td>
<td>1%</td>
<td>1%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>18” ~ 24”</td>
<td>2%</td>
<td>2%</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>&gt;24”</td>
<td>5%</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Recommended Sample Plan – Gate valves
API 20A - Limits on the Qualification of Production Castings

CSL-3
- Qualification requirements specified for CSL-2 are required for CSL-3.
- Requalification is required when there is a change in the material type within a Material Group, where a specified element's tolerance changes by 15%. E.g., if a qualification casting is made from ASTM A352 LCC with a 0.50 maximum nickel and a production casting is to be made from ASTM A352 LC3 with a 3.0% – 4.0% nickel, requalification is required.
- 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 require requalification.

CSL-4
- Qualification requirements specified for CSL-3 are required for CSL-4.
- A change in the specific material specification/grade from the qualification casting requires requalification.
Each casting shall be marked with the following:

- Casting supplier’s name or mark;
- Pattern number;
- Material grade;
- “API Spec 20A”;
- Date of manufacture (month and year);
- Heat or heat treat lot number;
- Traceability number;
- Material group;
- Weight/thickness range; and
- Qualification record.
API 20A - Marking

- Manufacturing drawings have to identify where stamping is appropriate. Marking are to be applied using low-stress (dot, vibration, or rounded V) stamps or by 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 590 °C (1100 °F) minimum.

- Cast lettering is to be placed on the drag side of the pattern. All cast marking is to 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.
API 20A - Record Retention

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

• Maintained to demonstrate conformance to specified requirements;
• Legible;
• Retained and readily retrievable;
• Stored in an environment to prevent damage, deterioration, or loss; and
• Available and auditable by the user/purchaser.

Handling, Storage, and Shipping

Castings are to be packaged for storage or transit in accordance with the written specifications of the casting supplier.
Thank You...