Manufacture of Structural Steel Castings for Primary Offshore Applications

API SPECIFICATION 2SC
FIRST EDITION, SEPTEMBER 2009

EFFECTIVE DATE: MARCH 1, 2010

REAFFIRMED, JUNE 2015

AMERICAN PETROLEUM INSTITUTE

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Upstream Segment

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Foreword

This specification is based on the experience acquired during the design, construction, operation and maintenance of offshore processing units and permanent facilities, as supplemented with the experience of operating companies with topsides, fixed platforms, floating structures (e.g. TLPs, spars, and the like), and their tendons and risers. Castings in these applications tend to be limited production components, with relatively few replications, and receive more intense scrutiny than routine mass production runs.

Where appropriate, this specification is based on, or reference is made to, international, regional, national and industry standards.

This is a manufacturing specification for the casting itself. It is anticipated that geometric design for both service requirements and casting feasibility will have been agreed collectively between the contractor, manufacturer, and purchaser before this specification is invoked. Attendant issues regarding system reliability, geometric design, incorporation into the overall construction, operation, and maintenance are not addressed here. Those electing to use this specification as a reference for their needed level of performance quality should carefully consider all these attendant issues.

When contractors or manufacturers/suppliers use this specification they should be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the purchaser will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in their best production. If in doubt, the contractor or manufacturer/ supplier should, without detracting from his own responsibility, consult the purchaser or its technical advisor.

The purchaser may then negotiate with the authorities concerned with the object of obtaining agreement to follow this specification as closely as possible.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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Introduction

This specification defines the minimum requirements for manufacture, testing, and inspection of carbon and low-alloy steel castings Grades 345 to 586 N/mm^2 (50 ksi to 85 ksi) for use in primary steel applications in the fabrication of offshore structures, manufacture of marine mechanical, or riser, tendon, or other equipment intended for application on permanent offshore structures, or for components thereof.

Service categories (A, B, and C), as defined in 4.4, reflect casting geometry and method of incorporation into the overall system. They may also be designated by the user (purchaser) to reflect moderately different but standardized levels of performance.

Manufacture of Structural Steel Castings for Primary Offshore Applications

1 Scope

Castings manufactured to this specification are intended for use in the fabrication of offshore structures, manufacture of critical marine or mechanical or other system components intended for application on permanent offshore structures, or for components used in the construction of offshore tendons, risers and pipelines.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this specification the contractor shall determine which of the requirements are more stringent and which combination of requirements will be acceptable with respect to safety, environmental, economic, and legal aspects. In all cases, the contractor shall inform the purchaser of any deviation from the requirements of this specification which is considered to be necessary in order to comply with national and/or local regulations.

2 Normative References

The following referenced documents are indispensable in the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASME *Boiler and Pressure Vessel Code* (*BPVC*) [1], *Section V: Nondestructive Examination; Section VIII: Pressure Vessels; Section IX: Welding and Brazing Qualifications*

ASNT SNT-TC-1A [2], *Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing*

ASTM A609:1991 [3], *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

ASTM A703:2008, *Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts*

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

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E92, *Standard Test Method for Vickers Hardness of Metallic Materials*

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

AWS A4.3 [4], *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

AWS A5.01, *Filler Metal Procurement Guidelines*

AWS D1.1:2008, *Structural Welding Code—Steel*

BSI BS 2M 54 [5], *Specification for Temperature Control in the Heat Treatment of Metals*

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1 ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.
2 American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.
3 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
4 American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.
5 British Standards Institution, Chiswick High Road, London, W4 4AL, United Kingdom, www.bsi-global.com.

BSI BS 7363, *Methods for Bead-on-plate (BOP) Test for Welds*

BSI BS EN 1043-1, *Destructive Tests On Welds In Metallic Materials—Hardness Testing—Part 1: Hardness Test on Arc Welded Joints*

ISO 3690 [6], *Welding and allied processes—Determination of hydrogen content in ferritic steel arc weld metal*

ISO 6507-1, *Metallic materials—Vickers hardness test—Part 1: Test method*

ISO 10474, *Steel and steel products—Inspection documents*

MIL-STD-1684 [7], *Control of Heat Treatment*

MSS SP-53 [8], *Quality Standard for Steel Castings and Forgings for Valves, Flanges and Fittings and Other Piping Components—Magnetic Particle Examination Method*

MSS SP-54, *Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Radiographic Examination Method*

MSS SP-55, *Quality Standard for Steel Castings for Valves, Flanges, Fittings and Other Piping Components—Visual Method for Evaluation of Surface Irregularities*

3 Terms, Definitions, and Acronyms

3.1 Term and Definitions

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

3.1.1
contractor
The party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility.

NOTE The purchaser may undertake all or part of the duties of the contractor.

3.1.2
critical region for NDT
As defined or approved by the purchaser in contract documents or drawings, where additional or more stringent requirements are needed based on design considerations.

3.1.3
critical section for mechanical properties
As defined or approved by the purchaser in contract documents or drawings, and used to determine effective casting thickness.

3.1.4
grade
Minimum yield strength in N/mm^2.

6 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.
7 U.S. Department of Defense, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, Pennsylvania 19111-5094, http://assist.daps.dla.mil.
8 Manufacturers Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street, N.E., Vienna, Virginia 22180-4602, www.mss-hq.com.

3.1.5
major weld repair
Repair weld whose depth of the cavity required for welding exceeds 20 % of the actual wall thickness or 25 mm (1 in.), whichever is smaller; or weld repairs for which the area of the cavity required for welding exceeds approximately 65 cm^2 (10 $in.^2$).

3.1.6
manufacturer
The party that manufactures components, materials, equipment and services to perform the duties specified by the contractor.

3.1.7
purchaser
The party that acquires the components.

NOTE The purchaser will specify the technical requirements. The purchaser may utilize an agent or consultant to act for, and on behalf of, the purchaser.

3.1.8
quality heat treatment
QHT
The collective sequence of heat treatments performed to achieve final properties.

3.2 Acronyms

AFC	approved for construction
AOD	argon oxygen decarburization
Ar3	the temperature at which austenite begins to transform to ferrite during cooling
B	steel designation suffix indicating “primary” steel
BOP	bead on plate
C	steel designation prefix indicating the component is a casting
CEV	carbon equivalent value
CVN	Charpy V-notch impact test
DWT	drop-weight or Pellini test
FCAW	flux-cored arc welding process
GTAW	gas tungsten arc welding process
HAZ	weld heat-affected zone
LAST	lowest anticipated service temperature
MPS	manufacturing procedure specification
MT	magnetic particle examination
MTR	material test report, or mill certificate
NCR	nonconformance
NDT	nondestructive testing
Pcm	composition parameter
PQR	welding procedure qualification record
PQT	weld procedure qualification test
PT	liquid dye penetrant examination
PWHT	postweld heat treatment
QP	quality plan
QHT	quality heat treatment
QTS	qualification test sample
RT	radiographic examination
SCA	Service Category A (see 4.4.1)
SCB	Service Category B

SCC	Service Category C
SMAW	shielded metal arc welding process
UT	ultrasonic examination
VD	vacuum degassing
VT	visual examination
WPS	welding procedure specification

4 Quality Requirements, Quality Plan (QP), and Manufacturing Procedure Specification (MPS)

4.1 General

The casting producer shall submit a QP and MPS to the purchaser for approval, prior to commencement of production. The quality management system shall include Inspection and test requirements and provide verification of third-party inspection approvals at hold points.

4.2 Procurement Specification

This specification may be used for procurement or, at the contractor's option, the contractor may prepare a detailed procurement specification which is compatible with the contractor's document format and quality system. As a minimum, the contractor's procurement specification shall incorporate all requirements contained herein and shall require approval by the purchaser. The casting manufacturer/supplier and manufacturing facilities, as identified in the MPS, shall require approval by the purchaser and contractor, if applicable. Any subcontracted chemical analysis or mechanical testing laboratories shall be approved by the purchaser and contractor, if applicable.

4.3 Lowest Anticipated Service Temperature (LAST)

The default LAST is –10 °C (14 °F) unless otherwise specified in project documents or on approved for construction (AFC) drawings, except that for permanently-submerged components and other components permanently submerged in service the default LAST is 4 °C (40 °F).

4.4 Service Categories

4.4.1 Service Categories are defined as follows.

a) Service Category A (SCA) castings are those castings, other than bar-shaped castings, not intended to contain, or form part of, structural fabrication weldments, other than repair welds to the casting itself.

b) Service Category B (SCB) castings are those castings, other than bar-shaped castings, intended to contain, or form part of, structural fabrication weldments.

c) Service Category C (SCC) castings are bar-shaped castings. Impact toughness requirements for SCC components are based on round bar geometry.

4.4.2 Casting service category (i.e. SCA, SCB, or SCC) shall be specified in project documents or on AFC drawings. Chemical and mechanical properties requirements for SCA, SCB, and SCC are provided in this specification.

4.4.3 Applicable casting service category (i.e. SCA, SCB, or SCC) shall be as specified in contract documents or on AFC drawings. Chemical and mechanical properties for SCA, SCB, and SCC are provided in 5.2 and Section 8, respectively. Preapproved foundry-proprietary chemical compositions may also be nominated by the purchaser.

4.5 Critical Sections

Critical sections for mechanical properties, critical regions for nondestructive testing (NDT) and structural weld thickness will be identified by the purchaser in contract documents and drawings.

4.6 Underlying Industry Standard Specification

Castings shall be manufactured and tested in accordance with the general requirements of ASTM A703, with the exception that hydrostatic testing as required by ASTM A703, Paragraph 11, is not required unless specified in project documents or on AFC drawings. Additionally, although the product marking requirements of ASTM A703, Paragraph 17, shall be applied, a raised pad is not required. Modifications to ASTM A703 and specific deletions or identifications of nonapplicable parts are given herein. Unless specifically deleted/waived by this specification, all provisions of ASTM A703 shall apply. Some statements and/or required values in ASTM A703 are repeated in this specification for clarity or special emphasis.

4.7 Traceability

The casting manufacturer shall prepare and submit for approval by the purchaser a written materials traceability plan. Each casting shall be given a unique serial number. The serial number shall be traceable to the heat number and heat treat batch number. Reference to the traceability plan shall be included in the MPS.

4.8 Information to be Supplied to the Casting Manufacturer

Information to be supplied to the casting manufacturer includes the following:

a) grade (N/mm^2);

b) LAST, if different from default of –10 °C (14 °F);

c) the requirement for compliance to the ASME *BPVC*;

d) service category (SCA, SCB, or SCC);

e) critical sections for mechanical properties, critical regions for NDT, and structural weld thicknesses for casting edges which will be fabricated (welded) by entities other than the casting manufacturer/supplier;

f) hydrostatic testing requirements (if any);

g) casting dimensions and tolerances;

h) quantities;

i) surface finish requirements (if different from MSS SP-55);

j) procedure qualification test (PQT) plate or spool quantities and sizes, (if any) to be used by organizations other than the casting manufacturer for qualification of field welding procedures;

k) postweld heat treatment (PWHT) requirements or limitations;

l) acceptance of test weld prior to sectioning of test welds for mechanical testing (see 9.8.2.1).

4.9 Document Requiring Approval by the Purchaser and Contractor

The manufacturer shall submit the documents identified in this specification for approval by the purchaser. Table 1 provides a summary of required document submittals.

Table 1—Document Submittals Requiring Approval by the Purchase

Manufacturer and Manufacturer Location of Material [a]	Required Timing of Document Submittal [b]
Casting manufacturer's QP	
Casting manufacturer's MPS	
Contractor's procurement specification, if applicable	
Materials traceability plan	
Configuration of the prototype casting, if required	
Chemical composition including allowable elemental ranges and aim (target) values	
Composition parameter (Pcm) maximums for Grade C552B-SCB and Grade 586B-SCB, if applicable	
Qualification test sample (QTS) configuration and dimensions	
Locations for Brinell hardness determinations for production castings	
Repair welding procedure specifications (WPSs) and welding procedure qualification records (PQRs)	
Welding consumable storage and handling plan	
Third-party inspector	
Any subcontracted testing laboratories for mechanical properties and welding PQT	
Test report justifying alternative atmospheric exposure time periods for welding consumables, if applicable	
All NDT procedures	
NDT operator qualifying body and qualification level	
Ultrasonic examination (UT) scan plans for each casting configuration and size to be examined	
Magnetic particle examination (MT) technique sheets for each casting configuration and size	
Dimensional inspection and gauging procedure	
Any concession waivers (concession requests) for nonconforming product	
PWHT	

[a] These documents shall be approved by the purchaser prior to the commencement of casting manufacture.

[b] After contract award, the purchaser shall complete this column with the requirements that are deemed necessary to meet project schedule.

4.10 Preproduction Meeting

If required by the purchaser, a preproduction meeting shall be held at the casting manufacturer/supplier's manufacturing facility prior to commencement of manufacture in order to discuss and assure common understanding of the QP and MPS in relation to the order. This preproduction meeting shall be a designated hold point in the QP.

4.11 Post-job Production Histograms

If required by the purchaser, a summary report of results as required in the QP and MPS, shall be supplied by the casting manufacturer at the completion of the order.

4.12 Certificates

Inspection certificates shall conform to ASTM A703, Paragraph 16, or ISO 10474, Test Report Type 3.2.

5 Process of Manufacture and Chemical Composition

5.1 General

Steel shall be made by a practice which is followed by either vacuum degassing (VD) or argon oxygen decarburization (AOD), unless a production deviation permit is granted by the purchaser and contractor, if applicable. In order to obtain relief from the VD or AOD requirement, the manufacturer/supplier shall produce a prototype casting, prior to full production, using the proposed steelmaking method and process of manufacture. The configuration of the prototype casting shall be approved by the purchaser and contractor, if applicable. The prototype casting shall be tested for full compliance with all aspects of this specification. Such testing shall include sectioning of the casting in critical regions for confirmation of specified mechanical properties. If results are approved by the purchaser and contractor, if applicable, then relief from the VD or AOD requirement shall be indicated in the MPS. In either case, the steelmaking and refining practice shall be described in the MPS and on the material test report, or mill certificate (MTR) for each heat of castings.

5.2 Chemical Composition

5.2.1 General

5.2.1.1 In the event that the purchaser does not specify the composition of the grade to be supplied, then the manufacturer may determine the composition of grade that will meet the specification requirements. The manufacturer shall submit the proposed chemical composition ranges for approval by the purchaser. The limits on composition shall comply with the requirements of Table 2.

The following grades have chemical compositions suitable for Category A and Category C; ASTM A487 Grade 4, Grade 6, Grade 8, Grade 9, Grade 10, Grade 11, Grade 12, or Grade 13 and NAVSEA T9074-BD-GIB-010/0300, Grade HY-80.

5.2.1.2 Any element specifically limited by the chemical composition specification or intentionally added, shall be reported as specified in 4.12. In addition, nitrogen, and titanium and any element that is listed in the carbon equivalent value (CEV) and Pcm shall be reported.

5.2.1.3 Unless different or more restrictive ranges are required by the chemical composition specified in the MPS by the purchaser, the elemental limits shown in Table 2 shall apply to the heat analysis.

5.2.2 Pcm and CEV Limits

The Pcm, based on final heat analysis, shall be $\leq$ 0.23 wt % for Grade C345B-SCB, $\leq$ 0.25 wt % for Grade C414B-SCB, and $\leq$ 0.27 wt % for Grade C483B-SCB. Pcm limits for Grades C552B-SCB and C586B-SCB shall be submitted

Table 2—Elemental Limits

Element	wt % (max)
Carbon (C)	0.220
Manganese (Mn)	1.600
Silicon (Si)	0.600
Sulfur (S)	0.010
Phosphorus (P)	0.015
Titanium (Ti)	0.020
Copper (Cu)	0.350
Chromium (Cr)	1.650
Nickel (Ni)	3.250
Vanadium (V)	0.050
Molybdenum (Mo)	0.60
Niobium (Nb or Cb)	0.050
Nb + V	0.050
Nitrogen (N)	0.012
Aluminum (Al, total residual)	0.070
Boron (B)	0.0005
Arsenic (As)	0.010
Antimony (Sb)	0.010
Tin (Sn)	0.010
P + As + Sb + Sn	0.035

by the casting manufacturer for approval by the purchaser. CEV shall not exceed 0.45 wt % for C345B-SCB nor 0.48 wt % for C414B-SCB and C483B-SCB.

NOTE 1 Pcm = C + (Si/30) + (Mn + Cu + Cr)/20 + (Ni/60)+(Mo/15) + (V/10)+(5B), all elements in wt %.

NOTE 2 (CEV) = C + (Mn/6) + (Cr + Mo + V)/5 + (Ni + Cu)/15, with all elements in wt %.

5.2.3 Chemical Properties and Tests

The final heat analysis and a product analysis taken from one QTS for each heat of steel, in accordance with ASTM A703 Paragraph 5, and Supplementary Requirement S1, shall be included in the MTR. Pcm and CEV shall be calculated for the final heat analysis of steels for use in SCB and shall be reported in the MTR for each heat.

NOTE The MTR will include results of chemical analyses, mechanical properties tests, visual and nondestructive tests and dimensional inspections.

6 Heat Treatment

6.1 Heat Treatment Process Control Requirements

6.1.1 General

6.1.1.1 Heat treatment process control requirements for quality heat treatment (QHT) and PWHT shall be fulfilled by the selection and adherence to either 4.1.1 or 4.1.2.

6.1.1.2 QHT and PWHT of castings and QTSs shall be conducted in the qualified working zone of furnaces meeting the requirements of SAE AMS 2750, MIL-STD-1684, or BSI BS 2M 54, or equivalent, as approved by the purchaser. The furnace uniformity tolerance for austenitizing shall be limited to ±14 °C (±25 °F) and furnace uniformity tolerance for tempering, ageing or PWHT shall be limited to ±8 °C (±15 °F).

6.1.1.3 QHT and PWHT of castings and QTSs shall be conducted in furnaces with load thermocouples attached to all castings and QTSs. The location and method of attachment of load thermocouples shall be clearly described in the MPS. QTS temperature shall be within ±14 °C (±25 °F) for austenitizing and within ±8 °C (±15 °F) for tempering, ageing, and PWHT of all castings to be qualified by the QTS.

6.2 Quenching

6.2.1 General

6.2.1.1 If quenching is required by the MPS, quenching equipment location and handling facilities shall be sufficient to prevent castings and QTSs from dropping below the Ar3 temperature for the alloy prior to immersion in the quench medium. Quenching facilities shall have sufficient agitation and be of sufficient volume such that the requirements of 4.2.1 and 4.2.2 are met.

6.2.1.2 If water or water-based (i.e. polymer) quenching is required by the MPS, then the temperature of the water or water-based quench medium shall not exceed 38 °C (100 °F) at the start of the quench, nor exceed 49 °C (120 °F) at any time during the quench. Additionally, castings and QTSs shall not be removed from the quench medium until they have cooled to below 204 °C (400 °F), unless otherwise specified in the MPS.

6.2.1.3 If oil-based quenching is required by the MPS, then the temperature of the oil-based quench medium shall be 16 °C to 71 °C (60 °F to 160 °F) at the start of the quench and shall not exceed 93 °C (200 °F) at any time during the quench. Additionally, castings and QTSs shall not be removed from the quench medium until they have cooled to below 204 °C (400 °F), unless otherwise specified in the MPS.

6.3 Heat-treatment Furnace Records or Charts, Temperatures and Cycle Times

Heat-treatment furnace records or charts shall be maintained showing time and temperature for all heat-treatment operations, including PWHT, per ASTM A703, Supplementary Requirement S21. In addition, a record of heat-treatment temperature and cycle times, as well as a description of the methods of cooling, shall be included in the MTR for each heat and heat treat lot for all heat treatment cycles, including PWHT of castings and simulation PWHT of QTSs, in compliance with ASTM A703, Supplementary Requirement S25.

7 Qualification Test Sample (QTS)

7.1 Castings Represented by QTS

A QTS shall be utilized to qualify the mechanical properties of all castings on a heat and heat treat lot basis which have been heat treated (and quenched, if applicable) together in the same lot or batch. Each transfer from austenitizing furnace to quenching bath, individual item or same pallet, shall be considered as a separate heat treat lot.

7.2 QTS Dimensional Requirements

7.2.1 QTSs shall be cast in the same mould and gated to the castings they represent in such a way that molten metal flows through the casting (mould cavity) into the QTS. QTSs shall be of sufficient size to extract all required test Specimens, with sufficient additional material to allow for retests should these be required.

7.2.2 The size of QTSs shall not be limited to the 375 mm × 375 mm × 125 mm (15 in. × 15 in. × 5 in.) block as described in ASTM A703, Paragraph S26.3.3. As an alternative, QTS size may have minimum dimensions of $T \times T \times [2T$ + 50.8 mm (2 in.)].

7.2.3 The casting thickness, T, as described in ASTM A703, Paragraph S26.2, upon which the dimensions of the QTS are based, shall be defined as the diameter of the largest circle that can be inscribed within the critical section for mechanical properties or the structural weld thickness, as applicable, at QHT. The critical section for mechanical properties will be determined by the purchaser.

7.2.4 If more than one critical section for mechanical properties has been identified then the thickest (largest) critical section for mechanical properties shall be used as the basis for defining QTS size requirements.

7.2.5 If more than one structural weld thickness has been identified, then the thickest structural weld thickness shall be used as the basis for defining QTS size requirements.

7.2.6 If both critical sections for mechanical properties and structural weld thicknesses have been identified, one of the following options shall be adhered to.

a) Option 1—One QTS based on the maximum thickness determined above.

b) Option 2—Two QTSs, one with a thickness based on the maximum critical section for mechanical properties and one with a thickness based on the maximum structural weld thickness.

c) Option 3—A stepped QTS containing thicknesses based on both the maximum critical section for mechanical properties and the maximum structural weld thickness.

7.2.7 QTS configuration and dimensions shall be approved by the purchaser, and fully described in the MPS and in the MTR.

7.3 QTS Heat Treatment

QTSs shall be heat treated and quenched with the castings they represent and are to qualify in conformance with ASTM A703, Supplementary Requirement S22.1, except that QTSs are not required to accompany the castings they represent through PWHT or stress relief thermal cycles. If PWHT or stress relief is to be performed on the castings by either the casting manufacturer or a subsequent fabricator, then a simulation PWHT or stress relief shall be performed on the QTS in accordance with ASTM A703, Supplementary Requirement S22.2, at a temperature within ±8 °C (±15 °F) of the actual PWHT or stress relief temperature of the castings to be qualified.

7.4 Partial Severing of Quality Test Samples

For QTSs cast integral to castings, partial severing shall be employed as necessary so that final removal subsequent to quality heat treat is by mechanical means only.

8 Mechanical Properties and Tests

8.1 Tensile Tests

8.1.1 Tensile test requirements shall be as described in ASTM A703, Paragraph 7, and ASTM A703, Supplementary Requirements S14, S22 and S26.

8.1.2 Test results shall comply with the requirements of Table 3 for the applicable grade. For grades not listed in Table 3, but within the ranges given, linear interpolation is acceptable for the determination of minimum and maximum yield strength and minimum ultimate tensile strength requirements. Retests and any reheat treatment shall conform to ASTM A703, Section 13. Retest specimens shall be extracted from equally representative material.

8.1.3 Results from all tensile tests, including failures and failure histories, shall be reported in the MTR.

Table 3—Tensile Properties and Hardness Requirements

Tensile Property	Grade				
	C345	C414	C483	C552	C586
Minimum yield strength 0.2 % offset kg/mm^2 (ksi)	345 (50)	414 (60)	483 (70)	552 (80)	586 (85)
Maximum yield strength 0.2 % offset kg/mm^2 (ksi)	483 (70)	552 (80)	621 (90)	690 (100)	724 (105)
Minimum tensile strength kg/mm^2 (ksi)	448 (65)	517 (75)	586 (85)	621 (90)	655 (95)
Minimum % elongation in 50.8 mm (2 in.) gauge length	17	17	17	17	17
Minimum % reduction in area	35	35	35	35	35
Brinell hardness range HB	140 to 197	167 to 223	187 to 235	207 to 248	217 to 262

8.2 Hardness Tests

8.2.1 As per ASTM A703, Supplementary Requirement S13, Brinell hardness determinations in accordance with ASTM E10 shall be made as near as practicable to the center of at least three of the original cast surfaces of QTSs and at locations approved by the purchaser for the production castings after QHT and PWHT or stress relief, if applicable. If Brinell hardness testing in accordance with ASTM E10 is impracticable, portable Brinell hardness testing in accordance with ASTM E110 or other portable hardness measurement methods as approved by the purchaser and contractor, may be substituted if applicable. The specific method and procedure for hardness testing shall be described in the MPS. The average Brinell hardness of QTSs shall be within 15 Brinell hardness units of the average Brinell hardness of each casting they are to represent.

8.2.2 Each Brinell hardness determined in 8.2.1 on castings shall comply with the range specified in Table 3 for the applicable grade. For grades not listed in Table 3 but within the ranges given, linear interpolation is acceptable for the determination of minimum and maximum Brinell hardness requirements. In the event that a production casting does not exhibit the required minimum hardness level, the casting may be considered to have an acceptable hardness if the measured value equals or exceeds the value given by the following equation:

$$HB_{\text{cast}} = (UTS_{\text{req}}/UTSQTS) \times HBQTS$$

where

HB_{cast} is the minimum acceptable Brinell hardness for production castings;

UTS_{req} is the minimum required ultimate tensile strength for the applicable grade;

UTSQTS is the average ultimate tensile strength determined by tensile specimens extracted and tested from the QTS;

HBQTS is the average Brinell hardness determined on the QTS surface as discussed in 6.2.1.

8.2.3 If PWHT has been employed after repair welding, castings shall be retested for compliance with Brinell hardness criteria at the original locations specified. Brinell hardness thus determined shall comply with Table 3 for the applicable grade, or the equation given in 8.2.2.

8.2.4 Results of all hardness determinations shall be reported in the MTR.

8.3 Charpy V-notch Impact Tests (CVN Tests)

8.3.1 CVN testing of three specimens shall be conducted in accordance with ASTM A703, Supplementary Requirement S8, S22, and S26, with the exception that testing shall be required on a heat and heat-treat lot basis. Specimen extraction locations within the QTS shall comply with the same requirements as the tensile specimens as specified in ASTM A703, Supplementary Requirement S26. Test temperature for the CVN tests shall be ≤ LAST – 20 °C (LAST – 36 °F).

EXAMPLE If the LAST has been designated to be –10 °C, the test temperature is $T \leq -10 - 20 = -30$ °C.

8.3.2 Unless otherwise specified, all three test results shall meet the minimum requirements of Table 4 or Table 5, as applicable, for the specified grade, service category, and critical section for mechanical properties thickness, structural weld thickness or shackle/bar diameter.

8.3.3 For SCB where both critical sections for mechanical properties and structural weld thicknesses have been identified, but only one QTS has been produced (see 7.2.6, Option 1), the largest of the dimensions shall be used to define CVN requirements.

8.3.4 For SCB where two QTSs (see 7.2.6, Option 2) or stepped QTSs (see 7.2.6, Option 3) have been used to represent critical sections for mechanical properties and structural weld thicknesses, the CVN requirements for the QTS, or portion of the QTS, corresponding to the critical section for mechanical properties shall be determined from Table 4 for the critical section for mechanical properties, and CVN requirements for the QTS, or portion of the QTS, corresponding to the structural weld thickness shall be determined from Table 4 for the structural weld thickness.

8.3.5 Linear interpolation is acceptable for the determination of the minimum absorbed energy requirements for grades, thicknesses or shackle/bar diameters not listed in Table 4 or Table 5, as applicable, but within the values given.

8.3.6 In addition to the absorbed energy requirements given in Table 4 and Table 5, CVN specimens shall display greater than or equal to 50 % ductile fracture (i.e. 50 % shear) appearance.

8.3.7 All CVN absorbed energy and fracture appearance results, including failures and failure history, shall be provided in the MTR.

8.4 Drop-weight or Pellini Test (DWT)

8.4.1 DWT testing in accordance with ASTM A703, Supplementary Requirement S9, S22, and S26, is required. Specimen extraction locations within the QTS shall comply with the same requirements as the tensile specimens as specified in ASTM A703, Supplementary Requirement S26. Test temperature shall be equal to or less than LAST. For example, if the LAST has been designated to be –10°C, then the test temperature shall be equal to or less than –10 °C. If only one of the two specimens exhibits “break” performance, then two additional specimens may be extracted from material immediately adjacent to the failed specimen, but still fulfilling the specified specimen extraction location requirements, and retested as above. Both retest specimens shall exhibit “no break” performance for acceptance.

Table 4—CVN Absorbed Energy Requirements—SCA and SCB

Critical Section for Mechanical Properties or Structural Weld Thickness	Grade				
	C345	C414	C483	C552	C586
$T \leq$ 76.2 mm (3 in.)	50 J (37 ft-lb)	60 J (45 ft-lb)	70 J (52 ft-lb)	81 J (60 ft-lb)	91 J (67 ft-lb)
76.2 mm (3 in.) < $T \leq$ 101.6 mm (4 in.)	64 J (47 ft-lb)	75 J (55 ft-lb)	92 J (68 ft-lb)	104 J (77ft-lb)	115 J (85 ft-lb)
$T >$ 101.6 mm (4 in.)	[a]	[a]	[a]	[a]	[a]
NOTE 1 Test temperature shall be ≤ LAST – 20 °C (LAST – 36 °F). For example, if the LAST has been designated to be –10 °C (i.e. the default value), then the test temperature shall be $T \leq$ –10 °C – 20 °C = –30 °C.					
NOTE 2 In addition to the absorbed energy requirement, percent shear fracture appearance shall be ≥ 50 %.					
[a] These values will be specified by the purchaser and contractor, if applicable, on a case-by-case basis.					

Table 5—CVN Absorbed Energy Requirements—SCC

Shackle or Bar Shaped Casting Diameter	C345	C414	C483	C552	C586
$T \leq$ 76 mm (3 in.)	27 J (20 ft-lb)	31 J (23 ft-lb)	39 J (29 ft-lb)	49 J (36 ft-lb)	51 J (38 ft-lb)
76 mm (3 in.) < $T \leq$ 102 mm (4 in.)	30 J (22 ft-lb)	39 J (29 ft-lb)	49 J (36 ft-lb)	62 J (45 ft-lb)	65 J (48 ft-lb)
102 mm (4 in.) < $T \leq$ 127 mm (5 in.)	35 J (26 ft-lb)	46 J (34 ft-lb)	59 J (43 ft-lb)	73 J (54 ft-lb)	77 J (57 ft-lb)
127 mm (5 in.) < $T \leq$ 152 mm (6 in.)	41 J (30 ft-lb)	54 J (40 ft-lb)	68 J (50 ft-lb)	85 J (63 ft-lb)	89 J (66 ft-lb)
$T >$ 152 mm (6 in.)	[a]	[a]	[a]	[a]	[a]
NOTE 1 Test temperature shall be ≤ LAST – 20 °C (LAST – 36 °F). For example, if the LAST has been designated to be –10 °C (i.e. the default value), then the test temperature shall be $T \leq$ –10 °C – 20 °C = –30 °C.					
NOTE 2 In addition to the absorbed energy requirement, percent shear fracture appearance shall be ≥ 50 %.					
[a] These values will be specified by the purchaser and contractor, if applicable, on a case-by-case basis.					

DWT testing is not required if the percentage shear fracture results from all CVN tests performed in 6.3 are ≥ 90 %.

8.4.2 Results of all DWT tests, including failures and failure history, shall be included in the MTR.

9 Repair Welding of Castings

9.1 Approval of Repair Welding WPSs and PQRs and Code Compliance

All repair welding WPSs and PQRs shall be approved by the purchaser. All repair welding of castings and qualification of repair welding procedures, welders, and operators shall be in compliance with AWS D1.1, with modifications, clarifications, deletions, or exceptions as given herein. All applicable requirements of AWS D1.1 shall be applied.

9.2 Allowable Welding Processes

Repair welding processes shall be limited to shielded metal arc welding process (SMAW), gas tungsten arc welding process (GTAW), or flux-cored arc welding process—gas-shielded only (FCAW-G).

9.3 PWHT of Major Weld Repairs

PWHT is required for all major weld repairs or an accumulated area of minor repairs greater than 20 $in.^2$. For SCB castings, a separate WPS (without PWHT) may be used for weld repairs.

9.4 Identification

9.4.1 A system of identification for each welder and welding operator shall be established. The identification shall be unique to an individual and shall not be transferred for the duration of the work. The identification system shall provide assurance that each welder and welding operator is qualified to perform the particular repair welding operation to which he is assigned. The identification system shall be referenced in the MPS.

9.4.2 Each welder and welding operator shall present his identification to the purchaser's representative, the contractor's representative, or the third-party inspector upon request.

9.5 Records of Welder and Welding Operator Qualification Test Results

Records of welder and welding operator qualification test results shall be submitted for review by the purchaser's representative, the contractor's representative, or the third-party inspector upon request.

9.6 Welding Consumables

9.6.1 Hydrogen Requirements for Welding Consumables

Welding electrodes and electrode/flux combinations shall be certified by the electrode manufacturer as having no more than 4 mL of diffusible hydrogen per 100 g of deposited weld metal in accordance with AWS A4.3 or ISO 3690 (see 9.6.3).

9.6.2 Definition of Welding Consumable Production Lots

A production lot of welding consumables shall be defined in accordance with AWS A5.01 as follows:

a) SMAW electrodes—Class C4,

b) FCAW-G electrodes—Class T3,

c) GTAW consumables—Class S2.

9.6.3 Consumable Production Lot Testing Requirements

The mechanical properties and average diffusible hydrogen level for each production lot of welding consumables shall be determined and reported. Testing shall be performed in accordance with AWS A5.01, Test Schedule I, and the applicable AWS filler metal specification. Mechanical properties and chemical composition shall be determined in accordance with the applicable AWS filler metal specification. Deposited weld-metal diffusible hydrogen level shall be determined and reported as the average of four tests in accordance with AWS A4.3 or ISO 3690.

9.6.4 Consumable Storage and Handling Plan

The casting manufacturer shall submit a welding consumable storage and handling plan for approval by the purchaser, which will ensure that the extra low hydrogen characteristics specified for consumables will be maintained. Consumable storage and handling practices may be audited for compliance with the approved plan at any time. This audit may include sampling of consumables and testing for compliance with deposited weld-metal diffusible hydrogen level requirements.

9.7 Welding Procedure Specification (WPS)

9.7.1 General

Conditions under which repair welding is to be performed shall be limited to those described in a WPS, which shall include written documentation of allowable ranges for all welding parameters and shall cover all essential variables for the welding process.

9.7.2 Joint Details for Repair Welds

Joint details for repair welds, including minimum and maximum depth, minimum root radius, and minimum length for excavated cavities, shall be shown on the WPS.

9.7.3 WPSs with Multiple Supporting PQRs

Multiple process WPSs for repair welding shall not be written based on individual PQRs for the separate processes.

9.7.4 WPS Availability

WPSs shall be posted at each applicable work location where repair welding is to be performed and shall be readily available to each welder, welding operator, the purchaser's representative, and the third-party inspector.

9.7.5 Essential Variables

9.7.5.1 General

Essential variables for welding procedure qualification shall be as specified in AWS D1.1 and modified/augmented herein. Changes to essential variables outside the ranges allowed by this section and AWS D1.1 shall require requalification of the welding procedure.

9.7.5.2 Materials

9.7.5.2.1 The base metal used for the WPS tests shall conform to the casting specification being used in production. The proprietary steel name for special nonstandard chemical compositions shall be considered an essential variable to be included on the WPS.

9.7.5.2.2 The Pcm and CEV of the base metal for which the welding procedure qualification results remain valid shall be limited to no more than 0.025 wt % above those which were successfully tested in the procedure qualification.

9.7.5.2.3 Consumable (electrodes), manufacturer/supplier, trade name, and manufacturing facility (location) shall be considered as essential variables.

9.7.5.2.4 Weld deposit individual bead thickness limits of ASME *BPVC*, Section IX, shall apply.

9.7.5.2.5 The backing material (if any) shall be of the casting material specification.

9.7.5.3 Preheat/Interpass Temperature

9.7.5.3.1 Minimum preheat and interpass temperatures shall be established to develop the specified properties in the weldment, but shall not be less than those recommended by the consumable manufacturer/supplier or AWS D1.1, Annex I, Method 2. When using AWS D1.1, Annex I, for determination of minimum preheat and interpass temperature, all repair welds shall be classified as high restraint level and the applicable susceptibility index grouping shall be determined in accordance with AWS D1.1, Annex I, Table I-1.

9.7.5.3.2 The maximum allowable interpass temperature for production repair welding shall be no higher than 14 °C (25 °F) above that which was sustained during welding of the PQT weld, on a per pass basis.

9.7.5.4 Welding Parameters

Weld procedure qualification, relative to CVN testing requirements, is limited to a +10 % or –25 % variation in heat input per pass. Voltage and current shall be determined with calibrated meters and recorded for each pass during PQT welding. Travel speed shall also be recorded for each pass. Heat input shall be calculated as (volts × amps × 60)/1000 (kJ/in.). These data shall be included in the PQR documentation. A wider tolerance on qualified heat input range may be achieved by successfully testing PQT welds which have been made at both the highest and lowest heat inputs to be allowed for production welding, as governed by the WPS.

9.7.5.5 PWHT

Procedure qualification is limited to a ±14 °C (±25 °F) tolerance on PWHT temperature relative to the temperature actually utilized during PWHT of the PQT weld(s).

9.7.5.6 Repair Weld Excavated Cavity Dimensions

In addition to the essential variable requirements placed by ASME *BPVC*, Section IX, on base metal and weld deposit thickness and by AWS D1.1 on groove dimensions, excavated cavity dimensions shall have a length which is equal to or greater than the bead-on-plate (BOP) test weld required by 9.8.5.3. Repair weld excavated cavities shall be sufficiently deep to allow deposition of a minimum of two weld passes below the surface of the base metal. In the case where PQT plates have been prepared with either a single U-groove or an excavated cavity, the minimum root radius for production repair welds shall be equal to or greater than that of the PQT weld. The maximum repair weld cavity depth shall be limited to that which is supported by the CVN results achieved during PQT (see 9.8.4.4).

9.8 Repair Weld Procedure Qualification Requirements

9.8.1 General

9.8.1.1 NDT and Mechanical Testing

Repair welding procedures shall be qualified by NDT and mechanical testing as specified in AWS D1.1 and as modified or augmented in this specification.

9.8.1.2 Witnessing Requirements

Procedure qualification welding, NDT of PQT welds, and specimen layout for mechanical properties tests shall be witnessed by the purchaser's representative or a third-party inspector approved by the purchaser. Any subcontracted mechanical testing laboratories shall be approved by the purchaser.

9.8.1.3 PQR Documentation

The results of testing, original photomacrographs, and copies of certificates for base-metals and consumables shall be included in the PQR documentation. The documentation shall include the names of the personnel, ID, witness signatures.

9.8.1.4 Qualification Test Material

Test plates for repair weld PQT shall be samples of the cast material, and at least 38.1 mm (1.5 in.) in thickness and grooves for repair weld procedure qualification shall be either single V-groove or single U-groove, either with or without a backweld, or may be an actual excavated cavity. Test plates for repair weld PQT shall comply with all aspects of this specification and their entire volume shall be treated as critical for NDT and mechanical properties.

9.8.1.5 PWHT

If PWHT is to be specified in the WPS or if castings have been stipulated to receive PWHT after fabrication welding by an entity other than the casting manufacturer in project documents or on AFC drawings, then the qualification test weld(s) shall be either:

a) cycled through two distinct PWHT treatments, or

b) held at the required PWHT temperature for 3 to 3.5 times the required minimum hold time.

In the case of subsequent fabrication welding and PWHT by an entity other than the casting manufacturer, ranges for PWHT temperature and time will be stipulated in project documents or on AFC drawings. Hold temperature and time and method of heat-up and cool-down shall be recorded and included in the PQR documentation. PWHT temperature shall be 14 °C to 28 °C (25 °F to 50 °F) below previous final tempering or ageing temperatures for the base metal.

9.8.2 NDT of Procedure Qualification Welds

9.8.2.1 Visual Examination (VT) of PQT Welds

PQT welds shall receive VT over 100 % of the length of weld surfaces except that 50 mm (2 in.) at the beginning and end of each test weld may be disregarded. At the purchaser's option, acceptance shall be required prior to sectioning of test welds for mechanical testing. Test welds shall meet the same requirements for weld profiles and VT as that specified for production repair welding.

9.8.2.2 NDT of PQT Welds

9.8.2.2.1 PQT welds shall be examined by the NDT methods given below with 100 % coverage except that 50 mm (2 in.) at the beginning and end of each test weld may be disregarded. NDT shall be performed after PWHT or a minimum waiting period of 48 hours for test welds to be left in the as-welded condition. Test weld NDT results shall be accepted prior to sectioning of test welds for mechanical testing. Repair welding of test welds is not permitted.

9.8.2.2.2 Test welds shall be subjected to either radiographic examination (RT) or UT, selected at the casting supplier's option unless stipulated otherwise in the contract documents.

9.8.2.2.3 All test welds in the PWHT condition shall be examined by UT.

9.8.2.2.4 The finished surface of test welds shall be examined by either the liquid dye penetrant examination (PT) or MT methods selected at the contractor's option unless stipulated otherwise in the contract documents.

9.8.2.2.5 Acceptance criteria for NDT of test welds shall be the same as that specified for production repair welds.

9.8.3 Tensile Tests of Procedure Qualification Welds

9.8.3.1 All-weld-metal Tensile Test

9.8.3.1.1 An all-weld-metal tensile test in accordance with AWS D1.1, Figure 4.18, shall be extracted and tested from the PQT weld for each combination of base-metal and welding consumables. The longitudinal axis of the tensile test specimen shall coincide with the PQT weld axis. The tensile specimen size and location within the PQT weld wall thickness shall be such that a minimal amount of heat-affected zone (HAZ) and base-metal is included in the specimen gage length; however, the largest tensile specimen per AWS D1.1, Figure 4.18, that fulfills this criterion shall be utilized.

9.8.3.1.2 Results of the all-weld-metal tensile test shall meet all requirements specified for the base-metal.

9.8.3.2 Reduced-section Tensile Tests

Reduced-section tensile test results shall meet all of the requirements specified for the base-metal.

9.8.4 CVN Testing of Procedure Qualification Welds

9.8.4.1 Test locations for CVN Specimens shall be as specified in Table 6. Three standard Type A CVN specimens shall be machined and tested in accordance with ASTM E23 from each of the locations.

Table 6—Test Locations for CVN Specimens

Weld Location	CVN Test Location
Weld Metal Root Location A	Center of notch in root area weld metal Center of notch at centerline of weld metal
HAZ Root Location B	Center of notch in root area HAZ Center of notch 0.4 mm (0.016 in.) into HAZ from fusion line
HAZ Surface Location C	Center of notch in HAZ 6.4 mm (0.25 in.) from outer surface where cap passes were applied Center of notch 2 mm (0.08 in.) into HAZ from fusion line
HAZ Surface Location D	Center of notch in HAZ 6.4 mm (0.25 in.) from outer surface where cap passes were applied Center of notch 5 mm (0.2 in.) into HAZ from fusion line
Weld Metal Surface Location E	Required only for test plate thickness > 13 mm (0.5 in.) Center of notch 6.4 mm (0.25 in.) from outer surface where cap passes were applied Center of notch at centerline of weld metal

9.8.4.2 The longitudinal centerline of each specimen shall be transverse to the weld axis. The base of the notch shall be perpendicular (normal) to the test piece surfaces.

9.8.4.3 The scribing of CVN specimen blanks for machining of V-notches shall be accomplished by the following.

a) Machining over-length specimen blanks out of the test weld at the specified depths from the test piece surfaces.

b) Etching the specimen blanks with a 5 % to 10 % nital solution to reveal the location of the weld-metal, fusion line, and HAZ.

c) Scribing the notch centerline by using the fusion line, as shown on the plane of the specimen perpendicular to the axis of the weld and the test piece surfaces, as a reference.

d) Photographing the etched specimen with scribe lines. Alternatively, at the option of the purchaser, scribing of CVN specimen blanks for machining of V-notches shall be witnessed by the purchaser's representative or a third-party inspector approved by the purchaser.

9.8.4.4 CVN test temperature, acceptance requirements, and retest provisions shall be the same as that specified for the base-metal in 6.3.

9.8.5 Macrosection, Microhardness Survey, and BOP Tests of Procedure Qualification Welds

9.8.5.1 Macrosection Evaluation

9.8.5.1.1 One macrosection shall be extracted from the middle of the PQT weld. Macrosections shall be polished to a metallographic finish and etched in a 5 % to 10 % nital solution. Evaluation of the macrosection shall show full fusion at the root, no cracks, and thorough fusion between adjacent layers of weld-metal and between weld-metal and base-metal. Photomacrographs of macrosections at approximately 3× magnification shall be included in the PQR documentation.

9.8.5.1.2 For procedure qualification welds in the PWHT condition, macrosection evaluation shall include metallographic examination at a minimum of 200X magnification of the HAZ and weld-metal for any stress-relief cracking. Representative photomicrographs shall be included in the PQR documentation.

9.8.5.2 Macrosection Microhardness Survey

A Vickers microhardness survey utilizing an applied load of 10 kgf (i.e. HV 10) shall be performed on a macrosection from the test weld in accordance with ASTM E92 or ISO 6507-1. Hardness test indention locations shall be as recommended by BSI BS EN 1043-1.

9.8.5.3 BOP Test

9.8.5.3.1 A BOP weld pass and Vickers microhardness survey shall be made on each base-metal with each consumable to be permitted by the WPS in accordance with BSI BS 7363, Type 2. The length of the deposited bead shall not exceed the minimum permissible bead length for repair welds. This pass shall be made with the lowest permissible heat input and preheat temperature applicable to the repair welding procedure being qualified.

9.8.5.3.2 Location of hardness readings shall be as shown in Figure 9 of BSI BS 7363 except that an additional all-weld-metal hardness reading shall be obtained. Hardness measurements shall be HV 10.

9.8.5.4 Acceptable Microhardness

The maximum acceptable microhardness for the hardness traverses required by 9.8.5.2 and 9.8.5.3 shall be 350 HV 10.

9.9 Repair Weld Workmanship and Technique

9.9.1 Preheat and Interpass Temperatures

Preheat and interpass temperatures shall be as required by the repair WPS.

9.9.2 Location of Preheat Temperature Measurement

Preheat temperature shall be measured at a minimum of 76 mm (3 in.) from the edge of the weld bevel on both sides of the weld joint if applicable. The interpass temperature shall be measured within 25 mm (1 in.) of the center of the weld groove. Interpass temperature measurement shall be made adjacent to the weld-start location of the subsequent pass within two minutes prior to commencement of welding. Temperature indicating crayons shall not be marked on weld bevels, weld beads or surfaces to be welded.

9.9.3 Extent of Preheat

Preheat shall be applied to establish and maintain the required temperatures for a distance equal to the thickness of the casting at the location to be repair welded, but not less than 76 mm (3 in.) in all directions (including through-thickness) from the point of welding.

9.9.4 Electrode and Flux Moisture Control

Electrode and flux moisture control (baking, storage ovens, exposure times, etc.) shall be in accordance with Section 5.3 of AWS D1.1, as applicable, and 9.6.4.

9.9.5 Removal of Slag and Spatter

The use of manual slag hammers, chisels, and lightweight vibrating tools for the removal of slag and spatter is permitted and is not considered peening, except that excessive mechanical working of the surface that may mask surface defects or otherwise inhibit a proper visual inspection is prohibited.

9.9.6 Arc Strikes

Arc strikes outside of the weld groove shall not be permitted. Repair of inadvertent arc strikes shall be carried out by grinding followed by VT and MT or PT examination. A written report recording the results of these examinations shall be prepared.

9.9.7 Removal of Weld-metal or Portions of Base-metal

The removal of weld-metal or portions of base-metal may be accomplished by machining, grinding, chipping, or air-arc gouging. Oxyfuel gouging shall not be permitted.

9.9.8 Backgouging

The root side of complete penetration repair welds shall be backgouged, using grinding, air-arc gouging, chipping or machining, to sound metal before weld metal is deposited on the backside. The groove shall be prepared by grinding to provide the proper shape and bevel for the welding procedure. Oxyfuel gouging shall not be permitted.

9.9.9 Surfaces Showing Carbon Deposits

Surfaces produced by carbon-arc gouging or cutting, or surfaces showing carbon deposits due to oxyfuel heating including carbon and oxide residue shall be removed by blasting, grinding, brushing.

9.9.10 Excavated Cavities and Local Grinding of Surface Defects—Not Repair Welded

Excavated cavities in regions not designated as critical for NDT or mechanical properties are not required to be repair welded as long as their depth does not exceed 6.4 mm (0.25 in.) and as long as dimensions and remaining casting thickness comply with tolerances stipulated in project documents or on AFC drawings. Any cavities left unwelded shall be blended smoothly into surrounding base-metal with a transition into surrounding base metal no steeper than 1 in 4 (i.e. 15° slope) and reinspected by VT and MT or PT. Local grinding to remove nonconforming surface defects is permitted provided dimensions and remaining casting thickness comply with tolerances stipulated in project documents or AFC drawings. Ground regions shall be blended smoothly into surrounding base-metal with a transition into surrounding base metal no steeper than 1 in 4 (i.e. 15° slope) and reinspected by VT and MT or PT.

9.9.11 Excavated Cavities—Repair Welded

All excavated cavities which will subsequently be repair welded shall be deep enough to allow Deposition of a minimum of two weld passes below the surface of the base metal.

9.10 NDT of Repair Welds Made During Production

9.10.1 VT of Repair Welds

9.10.1.1 Repair weld areas shall be blended with the surrounding base-metal to conform to the surface requirements stipulated in project documents or on AFC drawings.

9.10.1.2 Completed repair welds shall receive VT in accordance with 8.1. Acceptance criteria shall be the same as that specified for base-metal in the same region of the casting and the applicable criteria of AWS D1.1. For welds

receiving PWHT, VT may be carried out upon cooling to ambient temperature after PWHT. For welds not receiving PWHT, VT shall not be carried out until a period of 48 h has elapsed after welding.

9.10.2 NDT of Repair Welds for Surface Defects

9.10.2.1 Excavated regions for repair welding shall be examined for surface defects in accordance with ASTM A703, Supplementary Requirement S10.

9.10.2.2 Completed repair welds shall be examined for surface defects in accordance with 10.2 herein. Acceptance criteria shall be the same as that Specified for base-metal in the same region of the casting and the applicable criteria of AWS D1.1. For welds receiving PWHT, NDT for surface defects may occur immediately upon cooling to ambient temperature after PWHT. For welds not receiving PWHT, NDT for surface defects shall not occur until a period of 48 h has passed after welding.

9.10.3 NDT of Repair Welds for Subsurface Defects

Completed repair welds shall be examined by UT for subsurface defects in accordance with 8.3. Acceptance criteria shall be the same as that specified for base-metal in the same region of the casting and the applicable criteria of AWS D1.1. For welds receiving PWHT, NDT for subsurface defects may occur immediately upon cooling to ambient temperature after PWHT. For welds not receiving PWHT, NDT for subsurface defects shall not occur until a period of 48 h has elapsed after welding and cooling to ambient temperature.

9.11 Repair Weld Charts and Maximum Allowable Repair Weld Volume and Surface Area

Repair weld charts in compliance with ASTM A703, Supplementary Requirement S20, documenting length, width and depth of all major repair welds and any repair welds in regions designated as critical for NDT shall be prepared for each casting and included in the MTR. The total excavated cavity volume for major repair welds shall not exceed 5 % of the casting volume. The total surface area of all repair welds shall not exceed 20 % of the total surface area for the casting.

10 NDT of Castings

10.1 General

Final NDT shall be performed only after a minimum of 48 hours has elapsed since heat treatment or weld repair.

All NDT procedures shall be written and submitted to the purchaser for approval.

Personnel performing and interpreting NDT shall meet the requirements of ASNT SNT-TC-1A, Level II. Personnel approving the NDT procedure shall meet the requirements of ASNT SNT-TC-1A, Level III.

10.2 VT of Castings

10.2.1 Procedure

VT with 100 % coverage of each casting shall be conducted in compliance with ASME *BPVC*, Section V, Article 9.

10.2.2 Acceptance Criteria

10.2.2.1 General

Surface indications which will be removed by subsequent machining need not be subjected to the acceptance criteria stated herein. There shall be no porosity on surfaces designated for painting or coating. Local grinding to remove

nonconforming surface defects is permitted provided dimensions and remaining casting thickness comply with tolerances stipulated in project documents or AFC drawings. Ground regions shall be blended smoothly into surrounding base-metal with a transition into surrounding base metal no steeper than 1 in 4 (i.e. 15° slope) and reinspected by VT and MT or PT.

10.2.2.2 Critical Regions for NDT and Weld Edges

Regions designated as critical for NDT, edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer shall be subjected to the surface indication acceptance criteria stated in 10.3.2 for MT and PT.

10.2.2.3 All Other Regions

VT acceptance criteria shall be in accordance with MSS SP-55, unless otherwise agreed upon by the purchaser and manufacturer.

10.3 NDT of Castings for Surface Defects

10.3.1 Procedure

10.3.1.1 General

Where specified each casting shall be examined in the critical areas by either MT or PT. Coverage shall be 100 % of the critical area. Final examination shall occur after final QHT. Prods shall not be used after final QHT unless followed by a stress relief or tempering thermal cycle approved by the purchaser. MT of parts with $L/D < 2$ shall be accomplished using an electromagnetic yoke. Separate written MT technique instructions are required for each casting configuration and size to be examined that convey information necessary to augment the MT procedure in regards to part-specific magnetizing plan, sequence, direction and level. The acceptance criteria shall be approved by the purchaser, prior to MT of production parts. Parts shall be demagnetized as necessary after MT examination such that maximum remnant magnetic field strength shall not exceed 5 gauss.

10.3.1.2 Critical Regions for NDT and Weld Edges

The following are the requirements for PT or MT procedures.

MT or PT procedures for regions designated as critical for NDT and edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer shall be in accordance with either ASTM A703, Supplementary Requirements S4 or S6, respectively, or with ASME *BPVC*, Section VIII, Appendix 7.

Final MT shall utilize the wet continuous technique.

10.3.1.3 All Other Regions

MT and PT procedures shall be as specified in ASTM A703, Supplementary Requirements S4 and S6, respectively, or shall be in accordance with 8.2.1.2.

10.3.2 Acceptance Criteria

10.3.2.1 General

There shall be no indications of porosity, whether they are single pores or clusters, on surfaces designated for painting or coating. Local grinding to remove nonconforming surface defects is permitted provided dimensions and remaining casting thickness comply with tolerances stipulated in project documents or AFC drawings. Ground regions

shall be blended smoothly into surrounding base-metal with a transition into surrounding base metal no steeper than 1 in 4 (i.e. 15° slope) and reinspected by VT and MT or PT.

10.3.2.2 Critical Regions for NDT and Weld Edges

Regions designated as critical for NDT, and edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer, shall be subject to the acceptance standards of ASME *BPVC*, Section VIII, Appendix 7.

10.3.2.3 All Other Regions

MT and PT acceptance criteria shall be in accordance with either MSS SP-53 or 10.3.2.2.

10.4 NDT of Castings for Subsurface Indications

10.4.1 Procedure

10.4.1.1 General

Each casting shall be examined for internal (subsurface) indications by RT or UT. Coverage requirements outside the critical area (as specified in 4.5) shall be agreed by the purchaser and manufacturer.

UT examination of edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer is required. UT indications less than 25 mm (1 in.) apart shall be evaluated as one discontinuity. For RT, separate written RT setup/shot plans are required for each casting configuration and size to be examined. For UT, separate written UT scan plans are required for each casting configuration and size to be examined that show the test configuration at the time of examination, thickness of excess material over finished dimensions, ultrasonic beam paths, coverage, transducer details (manufacturer/supplier and transducer designation, size, beam angle, frequency, near field length, etc.), acceptance criteria and any special calibration standards required. RT setup/shot plans and UT scan plans shall be approved by the purchaser, prior to RT or UT on production parts.

10.4.1.2 Critical Regions for NDT and Weld Edges

The following are critical regions for NDT and weld edges.

a) RT procedures for castings which have been stipulated to be in compliance with the ASME *BPVC*, Section VIII, shall comply with ASME *BPVC*, Section VIII, Appendix 7.

b) RT procedures for regions designated as critical for NDT shall comply with either ASTM A703, Supplementary Requirement S5, or ASME *BPVC,* Section VIII, Appendix 7.

c) UT procedures for castings which have been stipulated to be in compliance with the ASME *BPVC*, Section VIII, shall be in accordance with the requirements of ASME *BPVC*, Section V, Article 5, Section T541.4.

d) UT examination of regions designated as critical for NDT shall be performed in accordance with either ASTM A609 or ASME *BPVC*, Section V, Article 5, Section T-541.4.

e) UT examination of edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer shall be performed in accordance with ASME *BPVC*, Section VIII, Appendix 12.

f) UT shall be performed such that 100 % volumetric coverage over 100 % of the external surface from three mutually orthogonal directions is achieved utilizing longitudinal (straight) beam if possible; otherwise, angle-beam examination may be used, as necessary, to effect 100 % coverage.

g) Angle-beam examination of critical regions for NDT properties, other than edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer/supplier and castings which have been stipulated to be in compliance with the ASME *BPVC*, Section VIII, shall be in accordance with either ASTM A609, Supplementary Requirement S1, or ASME *BPVC*, Section V, Article 5, Section T-541.4.

10.4.1.3 All Other Regions

UT shall be performed in accordance with ASTM A609 as a minimum requirement for the entire casting.

10.4.2 Acceptance Criteria

10.4.2.1 RT Acceptance Criteria

10.4.2.1.1 Critical Regions for NDT, Weld Edges and ASME *BPVC*, Section VIII Castings

RT acceptance criteria for regions designated as critical for NDT, edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer, and castings for which compliance with the ASME *BPVC*, Section VIII, has been stipulated shall be in accordance with ASME *BPVC*, Section VIII, Appendix 7.

10.4.2.1.2 All Other Regions

RT acceptance criteria shall be in compliance with MSS SP-54 for all imperfection categories.

10.4.2.2 UT Acceptance Criteria

10.4.2.2.1 Critical Regions for NDT, Weld Edges and ASME *BPVC*, Section VIII Castings

10.4.2.2.1.1 UT acceptance criteria for castings which have been stipulated to be in compliance with the ASME *BPVC*, Section VIII, shall comply with ASME *BPVC*, Section VIII, Appendix 7.

10.4.2.2.1.2 UT acceptance criteria for regions designated as critical for NDT shall be no planar discontinuities plus ASTM A609 Quality Level 1 to a depth of $^1/_4\ T$ from the surface and Quality Level 2 for the remainder of the wall thickness. The UT acceptance criteria shall be based on Paragraphs 10.2.1, 10.2.2, and 10.2.3 of ASTM A609.

10.4.2.2.1.3 UT acceptance criteria for edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the casting manufacturer/supplier shall be in accordance with ASME *BPVC*, Section VIII, Appendix 12.

10.4.2.2.2 All Other Regions

UT acceptance criteria shall be in accordance with ASTM A609 Quality Level 3 plus no planar discontinuities. The UT acceptance criteria shall be based on Paragraphs 10.2.1, 10.2.2, and 10.2.3 of ASTM A609.

10.5 Documentation of NDT results

Results of all NDT shall be included in the MTR.

11 Dimensional Inspection

The casting manufacturer shall submit a detailed dimensional inspection and gauging procedure for approval by the purchaser which verifies all specified dimensions and tolerances and surface finish requirements stipulated in project documents or on AFC drawings.

12 MTR

The completed MTR shall include a stamp or signature of a third-party inspector approved by the purchaser signifying complete conformance to this specification and that all nonconformances (NCRs) have either been rectified or that a proper concession waiver (concession request) has been approved by the purchaser. The MTR shall include copies of all approved concession waivers.

Unless otherwise allowed in project documents, the MTR shall be electronically scanned into multipage .tif or .pdf image files and stored on digital media or transmitted electronically, as approved by the purchaser. Digital media file structure shall be such that each casting serial number is represented by one multipage .tif or .pdf image file, with the name of the file corresponding to the casting serial number. Number of hard (paper) copies and CD-ROMs and distribution to the purchaser, shall be as specified in project documents or on AFC drawings.

Annex A
(informative)

Use of the API Monogram by Licensees

A.1 Scope

The API Monogram Program allows an API Licensee to apply the API Monogram to products. The API Monogram Program delivers significant value to the international oil and gas industry by linking the verification of an organization's quality management system with the demonstrated ability to meet specific product specification requirements. The use of the Monogram on products constitutes a representation and warranty by the Licensee to purchasers of the products that, on the date indicated, the products were produced in accordance with a verified quality management system and in accordance with an API product specification.

When used in conjunction with the requirements of the API License Agreement, API Q1, in its entirety, defines the requirements for those organizations who wish to voluntarily obtain an API license to provide API monogrammed products in accordance with an API product specification.

API Monogram Program licenses are issued only after an on-site audit has verified that the Licensee conforms to the requirements described in API Q1 in total, and the requirements of an API product specification. Customers/ users are requested to report to API all problems with API monogrammed products. The effectiveness of the API Monogram Program can be strengthened by customers/users reporting problems encountered with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at https://ncr.api.org. API solicits information on new product that is found to be nonconforming with API-specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification deficiencies or nonconformities with API-specified requirements.

This annex sets forth the API Monogram Program requirements necessary for a supplier to consistently produce products in accordance with API-specified requirements. For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, NW, Washington, DC 20005 or call 202-962-4791 or by email at certification@api.org.

A.2 References

In addition to the referenced standards listed earlier in this document, this annex references the following standard:

API Specification Q1.

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

A.3 API Monogram Program: Licensee Responsibilities

A.3.1 Maintaining a License to Use the API Monogram

For all organizations desiring to acquire and maintain a license to use the API Monogram, conformance with the following shall be required at all times:

a) the quality management system requirements of API Q1;

b) the API Monogram Program requirements of API Q1, Annex A;

c) the requirements contained in the API product specification(s) for which the organization desires to be licensed;

the requirements contained in the API Monogram Program License Agreement.

A.3.2 Monogrammed Product—Conformance with API Q1

When an API-licensed organization is providing an API monogrammed product, conformance with API-specified requirements, described in API Q1, including Annex A, is required.

A.3.3 Application of the API Monogram

Each Licensee shall control the application of the API Monogram in accordance with the following.

a) Each Licensee shall develop and maintain an API Monogram marking procedure that documents the marking/ monogramming requirements specified by the API product specification to be used for application of the API Monogram by the Licensee. The marking procedure shall define the location(s) where the Licensee shall apply the API Monogram and require that the Licensee's license number and date of manufacture be marked on monogrammed products in conjunction with the API Monogram. At a minimum, the date of manufacture shall be two digits representing the month and two digits representing the year (e.g. 05-07 for May 2007) unless otherwise stipulated in the applicable API product specification. Where there are no API product specification marking requirements, the Licensee shall define the location(s) where this information is applied.

b) 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 nonconforming with API-specified requirements. Products that do not conform to API-specified requirements shall not bear the API Monogram.

c) Only an API Licensee may apply the API Monogram and its license number to API monogrammable products. For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. The current API requirements for Monogram marking are detailed in the API Policy Document, Monogram Marking Requirements, available on the API Monogram Program website at http://www.api.org/ certifications/monogram/.

d) The API Monogram shall be applied at the licensed facility.

e) The authority responsible for applying and removing the API Monogram shall be defined in the Licensee’s API Monogram marking procedure.

A.3.4 Records

Records required by API product specifications shall be retained for a minimum of five years or for the period of time specified within the product specification if greater than five years. Records specified to demonstrate achievement of the effective operation of the quality system shall be maintained for a minimum of five years.

A.3.5 Quality Program Changes

Any proposed change to the Licensee’s quality program to a degree requiring changes to the quality manual shall be submitted to API for acceptance prior to incorporation into the Licensee's quality program.

A.3.6 Use of the API Monogram in Advertising

Licensee shall not use the API Monogram on letterheads or in any advertising (including company-sponsored web sites) without an express statement of fact describing the scope of Licensee’s authorization (license number). The Licensee should contact API for guidance on the use of the API Monogram other than on products.

A.4 Marking Requirements for Products

A.4.1 General

These marking requirements apply only to those API Licensees wishing to mark their products with the API Monogram.

A.4.2 Product Specification Identification

Manufacturers shall mark equipment on the nameplate with the information identified in 4.6, as a minimum, including "API Spec 2SC."

A.4.3 Units

As a minimum, equipment should be marked with U.S. customary (USC) units. Use of dual units [metric (SI) units and USC units] is acceptable.

A.4.4 License Number

The API Monogram license number shall not be used unless it is marked in conjunction with the API Monogram.

A.5 API Monogram Program: API Responsibilities

The API shall maintain records of reported problems encountered with API monogrammed products. Documented cases of nonconformity with API-specified requirements may be reason for an audit of the Licensee involved, (also known as audit for "cause").

Documented cases of specification deficiencies shall be reported, without reference to Licensees, customers or users, to API Subcommittee 18 (Quality) and to the applicable API Standards Subcommittee for corrective actions.

Bibliography

[1] ASTM A487 [9], *Standard Specification for Steel Castings Suitable for Pressure Service*

[1] ISO 9000 [10], *Quality management systems—Fundamentals and vocabulary*

[2] ISO 9001, *Quality management systems—Requirements*

[3] NACE MR 0175 [11], *Petroleum and Natural Gas Industries—Materials for Use in H_2S-containing Environments in Oil and Gas Production—Parts 1, 2 and 3*

[4] NAVSEA T9074-BD-GIB-010/0300 [12], *Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100*

[5] SAE AMS 2750 [13], *Pyrometry*

[9] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
[10] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.
[11] NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.
[12] Naval Sea Systems Command, SEA 05M2, 1333 Isaac Hull Ave SE Stop 5160, Washington, DC 20376, www.navsea.navy.mil.
[13] Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.

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