Manufacture of Structural Steel Forgings for Primary Offshore Applications

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Introduction

This specification is based on the experience acquired during the design, construction, operation, and maintenance of offshore processing units and facilities, as supplemented with the experience of operating companies with topsides, fixed platforms, floating structures (e.g. TLPs, spars, etc.), and their tendons and risers. Forgings 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 forging itself. It is anticipated that geometric design for both service requirements and forging 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 in this specification. Those electing to use this specification as a reference for their needed level of performance quality should carefully consider all of these attendant issues.

Manufacture of Structural Steel Forgings for Primary Offshore Applications

1 Scope

Forgings manufactured to this specification are intended for use in the fabrication of offshore structures, marine risers, TLP tendons and pipelines, or other system components intended for application on permanent offshore structures. This specification defines the minimum requirements for manufacture, testing, and inspection of carbon and low-alloy steel forgings, including extrusions and heavy-wall seamless tubular product, grades 345 N/mm^2 to 586 N/mm^2 (50 ksi to 85 ksi) for use in primary steel applications.

Service categories A, B, and C (SCA, SCB, and SCC) reflect forging geometry and method of incorporation into the overall system, rather than levels of criticality. They may also be designated by the user (purchaser) as described in 4.4 to reflect moderately different but standardized levels of performance.

2 Normative References

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

API Recommended Practice 2Z, *Preproduction Qualification for Steel Plates for Offshore Structures*, Fourth Edition

ASME *Boiler and Pressure Vessel Code (BPVC)* [1], *Section V: Nondestructive Examination; Article 9: Visual Examination*, 2007

ASME *Boiler and Pressure Vessel Code (BPVC), Section VIII: Rules for Construction of Pressure Vessels*, 2007

ASTM A275 [2], *Standard Practice for Magnetic Particle Examination of Steel Forgings*

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A751, *Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products*

ASTM A788, *Standard Specification for Steel Forgings, General Requirements*

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

ASTM E2375, *Standard Practice for Ultrasonic Testing of Wrought Products*

ASTM E384, *Standard Test Method for Knoop and Vickers Hardness of Materials*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E1444-12, *Standard Practice for Magnetic Particle Testing*

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1 ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

2 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM E2375, *Standard Practice for Ultrasonic Testing of Wrought Products*

BSI BS 2M 54 [3], *Specification for Temperature Control in the Heat Treatment of Metals*

EN 10204 [4], *Metallic products. Types of inspection documents*

ISO 6507-1 [5], *Metallic materials. Vickers hardness test. Test method*

ISO 9015-1, *Destructive tests on welds in metallic materials. Hardness testing. Part 1: Hardness test on arc welded joints*

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

MIL-STD-1684 [6], *Control of Heat Treatment*

SAE AMS-STD-2154 [7], *Inspection, Ultrasonic, Wrought Metals, Process for*

SAE AMS-STD-2750, *Pyrometry*

3 Terms, Definitions, Abbreviations, and Acronyms

3.1 Terms and Definitions

For the purposes of this document, the following 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 nondestructive examination
The region of the forging 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
The section of the forging defined or approved by the purchaser in contract documents or drawings and used to determine effective forging thickness.

3.1.4
forging
The product of a substantially compressive plastic working operation that consolidates the material and produces the desired shape.

NOTE The plastic working may be performed by a hammer, press, forging machine, or ring rolling machine and must deform the material to produce a wrought structure.

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3 British Standards Institution, Chiswick High Road, London W4 4AL, United Kingdom, www.bsigroup.com.

4 European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.

5 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

6 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.

7 SAE International 4000 Commonwealth Drive, Warrendale, Pennsylvania 15906-0001, www.sae.org.

3.1.5
grade
Minimum yield strength, in N/mm^2.

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

3.1.7
material test report
mill certificate
Document including results of chemical analyses, mechanical properties tests, visual and nondestructive tests, and dimensional inspections.

3.1.8
purchaser
The party that acquires the components.

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

3.1.9
quality heat treatment
QHT
The collective sequence of heat treatments performed to achieve final properties.

3.1.10
Service Category A
SCA
Forgings, other than bar-shaped forgings, not intended to contain, or form part of, structural fabrication weldments.

3.1.11
Service Category B
SCB
Forgings, other than bar-shaped forgings, intended to contain, or form part of, structural fabrication weldments.

3.1.12
Service Category C
SCC
Bar-shaped forgings.

NOTE Impact toughness requirements for SCC components are based on round bar geometry.

3.2 Abbreviations and Acronyms

For the purposes of this document, the following abbreviations and acronyms apply.

AFC approved for construction drawings

Ar3 the temperature at which austenite begins to transform to ferrite during cooling

AOD argon oxygen decarburization

CEV carbon equivalent value, (CEV) = C+(Mn/6)+(Cr+Mo+V)/5+(Ni+Cu)/15, elements wt%

CTOD	crack tip opening displacement test
CVN	Charpy V-notch impact test
HAZ	weld heat-affected zone
LAST	lowest anticipated service temperature
MPS	manufacturing procedure specification
MT	magnetic particle examination
NDE	nondestructive examination
Pcm	composition parameter, Pcm = C+(Si/30)+(Mn+Cu+Cr)/20+(Ni/60)+(Mo/15)+(V/10)+(5B), all elements in wt%
PQT	procedure qualification test
QP	quality plan
QTS	qualification test sample
VAD	vacuum arc degassing
VOD	vacuum oxygen decarburization
VT	visual examination

4 Manufacturing and Quality Requirements

4.1 Quality Plan (QP) and Manufacturing Procedure Specification (MPS)

The forging producer shall submit a QP and an 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.

The QP and MPS should include the following:

a) steel manufacturing, melting, and refining process;

b) chemical composition with target chemistry and allowable ranges for all elements (see 5.2.1); these may vary with thickness in a prescribed manner;

c) forging techniques and hot work ratios at each stage;

d) heat treatment methods. including time-temperature cycles at each stage as well as furnace description, calibration, loading of components, temperature control, temperatures, location of thermocouples, soaking time, and quenching equipment, including quenching media and flow arrangement;

e) cleaning equipment;

f) stress relieving;

g) machining and surface finish;

h) mechanical testing, including details of the prolongation, position of test coupons, and sampling requirements;

i) dimensional control;

j) shipping and handling.

4.2 Manufacturer, Facility, and Subcontractor Approval

4.2.1 This specification may be used directly for procurement, or at the contractor's option, the contractor may prepare a detailed procurement specification that 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.

4.2.2 The forging manufacturer/supplier and manufacturing facilities, as identified in the MPS, shall require approval by the purchaser and contractor, if applicable.

4.2.3 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. Permanently submerged deepwater components and other components permanently submerged in service shall have a default LAST of 4 °C (40 °F).

4.4 Service Categories

The applicable forging service category (i.e. SCA, SCB, or SCC) shall be as specified by the purchaser. Chemical analysis and mechanical properties for SCA, SCB, or SCC shall be as specified in 5.2 and Section 8, respectively. Preapproved forge-proprietary chemical analysis may also be designated by the purchaser.

4.5 Critical Sections

Critical sections for mechanical properties, critical regions for nondestructive examination (NDE), and structural weld thickness shall be as identified by the purchaser in contract documents and drawings.

4.6 Forging Specifications

4.6.1 Manufacturing Specification

Forgings shall be manufactured and tested in accordance with ASTM A788.

4.6.2 Marking

4.6.2.1 Forgings shall be marked with grade symbol. Forgings individually weighing 22.7 kg (50 lb) or more shall be serialized and traceable to each heat in accordance with 4.7.

4.6.2.2 Low-stress stamps shall be used for forgings with impact property requirements. The manufacturer's identification shall be on each forging unless provisions have been made between the manufacturer and the purchaser.

4.6.2.3 Modifications to ASTM A788 and specific deletions or identifications of nonapplicable parts are provided in this specification. Unless specifically deleted/waived by this specification, all provisions of ASTM A788 shall apply.

4.7 Traceability

The forging manufacturer shall prepare and submit for approval by the purchaser a written materials traceability plan. Each forging 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 Supplied to the Forging Manufacturer

Information to be supplied to the forging manufacturer shall include 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*, if applicable;

d) service category: SCA SCB, or SCC;

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

f) specific or proprietary chemical compositions, if required;

g) forging dimensions and tolerances;

h) quantities;

i) surface finish requirements;

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

k) applicable supplemental requirements when specified, for example, S3 additional mechanical tests and S11 preproduction qualification (crack tip opening displacement test [CTOD] in accordance with API 2Z).

4.9 Documents Requiring Approval by Purchaser and Contractor

The manufacturer shall submit the following documents for approval by the purchaser:

a) manufacturer and location;

b) forging manufacturer QP;

c) forging manufacturers MPS;

d) contractor's procurement specification, if applicable;

e) materials traceability plan;

f) configuration of the prototype forging, if required;

g) chemical composition, including allowable elemental ranges and aim (target) values;

h) composition parameter (Pcm) and carbon equivalent value (CEV) maximums for Grades F552B-SCB and F586B-SCB, if applicable;

i) qualification test sample (QTS) configuration and dimensions;

j) locations for Brinell hardness determinations for production forgings;

k) third-party inspector;

l) subcontracted testing laboratories for mechanical properties and weldability qualification testing;

m) NDT procedures;

n) MT technique sheets for each forging configuration and size;

o) NDT operator qualifying body and qualification level;

p) dimensional inspection and gauging procedure;

q) concession waivers (concession requests) for nonconforming product;

r) MTR.

These documents shall be approved by the purchaser prior to the commencement of forging manufacture; however, after the contract award, the purchaser shall determine the required timing of document submittals that are deemed necessary to meet the project schedule.

4.10 Preproduction Meeting

If required by the purchaser, a preproduction meeting shall be held at the forging manufacturer/supplier's manufacturing facility prior to commencement of manufacture 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 forging manufacturer at the completion of the order.

4.12 Certificates

Inspection certificates shall conform to ASTM A788 Section 16, ISO 10474, Test Report Type 3.2, or EN 10204, Test Report Type 3.1.

5 Manufacturing Process and Chemical Composition

5.1 Steel Making and Refining Practice

5.1.1 Steel shall be manufactured by the vacuum arc degassing (VAD), vacuum oxygen decarburization (VOD), or argon oxygen decarburization (AOD) methods unless a production deviation permit is granted by the purchaser and contractor, if applicable.

5.1.2 In order to obtain deviation from the VAD, VOD, or AOD methods, the manufacturer/supplier shall produce a prototype forging, prior to full production, using the proposed steelmaking method and process of manufacture. The configuration of the prototype forging shall be approved by the purchaser and contractor, if applicable.

5.1.3 The prototype forging shall be tested for full compliance with all aspects of this specification. Such testing shall include sectioning of the forging in critical regions for confirmation of specified mechanical properties. If the test results are approved by the purchaser and contractor, if applicable, the deviation from the VAD, VOD, 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 MTR for each forging lot.

5.2 Chemical Composition

5.2.1 General

5.2.1.1 If the purchaser does not specify the composition of the grade to be supplied, 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. Specifications listed in Table 1 may be considered. The limits on composition shall comply with the requirements of Table 2. The elemental limits given in the MPS shall apply to the heat analysis.

Table 1—Industry Standard Chemical Composition Specifications

Specifications for Service Category A and C	Specifications for Service Category B
AISI 4120-4130, 4320-4330, 8620-8630	ASTM A350 Grade LF6, LF787
ASTM A182 Grade F22 [a]	ASTM A707 Grade L5 ASTM A707 Grades other than L5 [a]
ASTM A336 Class F22 [a]	ASTM A859
ASTM A350 Grade LF6, LF787	ASTM A694
ASTM A193 Grade B7, B7M, B16	MSS SP-75
ASTM A508 Class 2, 2a, 3, 3a, 4, 4b, 5, 22B	A707-Modified Grade 1M, 2M, or 3M (see Table 5)
ASTM A541 Class 2, 2a, 3, 3a, 4, 7, 7B, 8, 22B, 22C	AISI 4120-4130 [b], 4320-4330 [b], 8620-8630 [b]
ASTM A707	ASTM A182 Grade F22 [b]
ASTM A739 Grade B22	ASTM A336 Class F22 [b]
ASTM A859	ASTM A508 Class 2 [b], 2a [b], 3 [b], 3a [b], 4 [b], 4b [b], 5 [b], 22B [b]
ASTM A694	ASTM A541 Class 2 [b], 2a [b], 3 [b], 3a [b], 4 [b], 7 [b], 7B [b], 8 [b], 22B [b], 22C [b]
MSS SP-75	ASTM A739 Grade B22 [b]
A707-Modified Grade 1, 2, or 3 (see Table 5)	NAVSEA T9074-BD-GIB-010/0300 Grade HY-80 [b]
NAVSEA T9074-BD-GIB-010/0300 Grade HY-80	
EN 10083-1 Grade 34CrMo4, 42CrMo4, 36CrNiMo4, 34CrNiMo6	
ISO 683-1 Grade 25CrMo4, 34CrMo4, 42CrMo4, 36CrNiMo4, 36CrNiMo6, 31CrNiMo8	

[a] F22 provided chemistry also complies with more restrictive Table 2.

[b] Usage of these alloy compositions for SCB requires special caution in the development of fabrication welding procedures and may require PWHT to achieve specified properties and hardness limitations. Usage of these alloy compositions requires specific approval by the principal and contractor, if applicable on a case-by-case basis.

Table 2—Elemental Limits

Element	Maximum Weight Percent
Carbon (C)	0.22
Manganese (Mn)	1.60
Silicon (Si)	0.35
Sulfur (S)	0.015 (0.010 for SCB)
Phosphorus (P)	0.025 (0.015 for SCB)
Titanium (Ti) [a]	0.040 (0.020 for SCB)
Copper (Cu)	0.35
Chromium (Cr)	1.65
Nickel (Ni)	3.25
Vanadium (V) [a]	0.050
Molybdenum (Mo)	0.60
Niobium (Nb or Cb) [a]	0.060
Nb+V [a]	0.050
Nitrogen (N)	0.012
Aluminum (Al, total residual)	0.070 (0.020 min to 0.070 max SCB)
Boron (B)	0.010 (0.0005 for SCB)
Arsenic (As)	0.010
Antimony (Sb)	0.010
Tin (Sn)	0.010
P+As+Sb+Sn	0.035

[a] Values listed for Ti, V, Nb, and Nb+V are maximum allowables for intentional additions. Residual levels shall be limited to 0.010 wt% maximum each.

5.2.1.2 Any proposed chemical composition shall have a demonstrated history of successful use or be subject to prototype testing and approval of test results by the purchaser before commencing production.

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

Examples of weldable precipitation hardening chemistries are given in Table 3.

5.2.2 Pcm and CEV Limits

The Pcm, based on final heat analysis, shall be ≤ 0.23 wt% for Grade F345B-SCB, ≤ 0.25 wt% for Grade F414B-SCB, and ≤ 0.27 wt% for Grade F483B-SCB. Pcm limits for Grades F552B-SCB and F586B-SCB shall be submitted by the forging manufacturer for approval by the purchaser. CEV shall not exceed 0.45 wt% for F345B-SCB or 0.48 wt% for F414B-SCB and C483B-SCB.

Table 3—A707-modified Chemical Composition

Element	Range (wt%)		
	A707-G1M	**A707-G2M**	**A707-G3M**
C	0.03–0.06	0.03–0.06	0.02–0.06
Mn	1.00–1.50	1.00–1.50	1.00–1.50
Si	0.35 max	0.35 max	0.35 max
Ni	0.88–1.00	1.55–1.85	1.95–2.20
Cu	1.00–1.30	1.00–1.30	1.00–1.30
S	0.015 max	0.015 max	0.015 max
P	0.025 max	0.025 max	0.025 max
Nb	0.040–0.060	0.040–0.060	0.040–0.060
Mo	0.40–0.50	0.35–0.50	0.35–0.50
Cr	0.60–0.80	0.50–0.80	0.50–0.80
Al (Total)	0.02–0.05	0.02–0.05	0.02–0.05
N	0.0120 max	0.0120 max	0.0120 max
Calcium treatment for sulfide shape control is required; however, Ca shall not exceed 0.005 wt%. No other elements shall be intentionally added.			

5.2.3 Chemical Properties and Tests

The final heat analysis and a product analysis taken from each heat of steel shall be included in the MTR. Testing shall be in accordance with ASTM A751 and shall be included in the MTR. Pcm and CEV shall be calculated for the final heat analysis of steels for use in Service Category B and shall be reported in the MTR for each heat.

5.3 Forging Process

Forgings may be produced by open or closed die forging, ring rolling, extrusion, or by seamless tubular processes (e.g. pierce and draw, etc.).

The overall hot work ratio from the ingot or continuous-cast bloom to product shall be equal to or greater than 3 to 1. The overall hot work ratio is defined as the product of the hot work ratio for each separate hot-working or forging operation, not including initial upsetting or any upsetting not followed by drawing or extrusion. A statement of the hot work ratio shall be included in the MTR.

5.4 Repair Welding

Repair welding by the forging manufacturer of SCA and SCC forgings is not permitted, and a statement that no weld repair was performed shall be included in the MTR. By agreement between the purchaser and the manufacturer, and when individually authorized on the purchase order, repair welding of SCB forgings is permitted, with a specific repair welding procedure qualified and approved for that purpose.

NOTE Extensive requirements for repair welding can be found in API 2SC.

6 Heat Treatment

6.1 Heat Treatment Process Control Requirements

All heat treatment shall be as described in the MPS. Heat treatment process control requirements for quality heat treatment (QHT) shall be in accordance with one of the following.

a) QHT (including the QTS) shall be conducted in the qualified working zone of furnaces meeting the requirements of SAE AMS-STD-2750, MIL-STD-1684, or 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 or ageing shall be limited to ±8 °C (±15 °F).

b) QHT (including the QTS) shall be conducted in furnaces with load thermocouples attached to all forgings 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 and ageing to be qualified by the QTS.

6.2 Quenching

If quenching is required by the MPS, quenching equipment location and handling facilities shall be sufficient to prevent forgings 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 in accordance with the following.

a) 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, forgings 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.

b) 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, forgings 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/Charts, Temperatures, and Cycle Times

Heat treatment furnace records or charts shall be maintained showing time and temperature for all heat treatment operations. 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.

7 Qualification Test Sample (QTS)

7.1 Forgings Represented by QTS

A QTS shall be utilized to qualify the mechanical properties of all forgings on a heat and heat treat lot basis that 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 The QTS for material qualification shall be as a physical prolongation of similar geometry having undergone precisely the same forging ratio and heat treatments as the forging they represent. The QTS

shall be of sufficient size to extract all required test specimens, with sufficient additional material to allow for retests should these be required. A QTS trepanned from the forging itself or a sacrificial forging of the same heat and heat treat lot may be used as the QTS.

7.2.2 QTS size shall have minimum dimensions of $T \times T \times [2T + 50.8\text{ mm}\ (2\text{ in.})]$. The forging thickness, T, 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 for SCB parts, as applicable, at QHT. The critical section for mechanical properties shall be as determined by the purchaser.

7.2.3 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. The purchaser may request that the thinnest (smallest) critical section be also tested for mechanical properties.

7.2.4 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.

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

a) *Option 1*—One QTS based on the maximum thickness as determined in 7.2.2.

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.

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

7.2.7 QTS configuration shall enable removal subsequent to final heat treatment by mechanical means only. Partial severing by thermal cutting shall only be permitted prior to final austenitizing.

7.3 Heat Treatment of QTSs

QTSs shall be fully heat treated with the forgings they are to qualify. If stress relief is to be performed on the forgings by a subsequent fabricator, then a simulation stress relief shall be performed on the QTS at a temperature within ±8 °C (±15 °F) of the specified stress relief temperature of the forgings to be qualified.

8 Mechanical Properties and Tests

8.1 Tensile Tests

8.1.1 Tensile test requirements shall be as described in ASTM A788, Section 10, and ASTM A788, Supplementary Requirements S12, S13, S14, and S26 in Annex A. Tensile tests shall be tested in accordance with ASTM A370 and shall be located on the QTS at $T/4$ and centered along the length.

8.1.2 Test results shall comply with the requirements of Table 4 for the applicable grade. For grades not listed, but within the ranges given in Table 4, linear interpolation is acceptable for determining the minimum and maximum yield strength and the minimum ultimate tensile strength requirements. 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 4—Tensile Properties and Hardness Requirements

Property	Grade				
	F345	F414	F483	F552	F586
Minimum yield strength 0.2 % offset N/mm^2 (ksi)	345 (50)	414 (60)	483 (70)	552 (80)	586 (85)
Maximum yield strength 0.2 % offset N/mm^2 (ksi)	483 (70)	552 (80)	621 (90)	690 (100)	724 (105)
Minimum tensile strength N/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 percentage reduction in area	35	35	35	35	35
Brinell hardness range HB	140–197	167–223	187–235	207–248	217–262

8.2 Hardness Tests

8.2.1 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 surfaces of QTSs and at locations approved by the purchaser for the production forgings after QHT 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, if applicable, may be substituted. 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 forging they are to represent.

8.2.2 Each Brinell hardness determined in 8.2.1 on forgings shall comply with the range specified in Table 4 for the applicable grade. For grades not listed in Table 4, but within the ranges given, linear interpolation is acceptable for the determination of minimum and maximum Brinell hardness requirements. With the purchaser's approval, in the event that a production forging does not exhibit the required minimum hardness level, the forging may be considered to have an acceptable hardness if the measured value equals or exceeds the value given by the following equation:

$$\mathrm{HB}_{\mathrm{forge}} = (\mathrm{UTS}_{\mathrm{req}} / \mathrm{UTS}_{\mathrm{QTS}}) \times H_{\mathrm{BQTS}}$$

where

$\mathrm{HB}_{\mathrm{forge}}$ is the minimum acceptable Brinell hardness for production forgings;

$\mathrm{UTS}_{\mathrm{req}}$ is the minimum required ultimate tensile strength for the applicable grade;

$\mathrm{UTS}_{\mathrm{QTS}}$ is the average ultimate tensile strength determined by tensile specimens extracted and tested from the QTS;

H_{BQTS} is the average Brinell hardness determined on the QTS surface as discussed in 8.2.1.

8.2.3 Results of all hardness determinations, including failures, shall be reported in the MTR.

8.3 CVN Tests

8.3.1 CVN testing of three specimens shall be conducted in accordance with ASTM A370, and testing shall be required on a heat and heat treat lot basis. Testing shall be located at $T/4$ and centered along the length. Test temperature for the CVN tests shall be as specified in Table 5 or Table 6.

EXAMPLE If the LAST has been designated to be –10 °C, then the test temperature will be $T \leq -10 - 20 = -30$ °C for SCA or SCB.

8.3.2 Unless otherwise specified, all three test results shall meet the minimum requirements of Table 5 or Table 6, as applicable, for the specified grade, service category, and critical section for mechanical properties thickness, structural weld thickness, or bar diameter.

8.3.3 For Service Category B where both critical sections for mechanical properties and structural weld thicknesses have been identified, but only one QTS has been produced [see 7.2.5 a)], then the largest of the dimensions shall be used to define CVN requirements.

8.3.4 For Service Category B where two QTSs [see 7.2.5 b)] or stepped QTSs [see 7.2.5 c)] have been utilized in order 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 5 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 6 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 5 or Table 6, as applicable, but within the values given.

8.3.6 In addition to the absorbed energy requirements given in Table 5 and Table 6, CVN specimens shall display greater than or equal to 50 % ductile fracture (i.e. 50 % shear) appearance.

8.3.7 If the absorbed energy result from only one specimen from a set fails to meet specified requirements but is no less than 67 % of the required minimum values, or if the ductile fracture appearance from only one specimen from a set fails to meet the 50 % shear criterion but is no less than 35 % shear, then three additional specimens may be extracted from material immediately adjacent to the failed specimen, but still fulfilling the specified specimen extraction location requirements, and retested in accordance with 8.3.1. Test results from all three additional specimens shall meet specified requirements for acceptance.

Table 5—CVN Absorbed Energy Requirements—Service Category A and B [a] [b]

Critical Section for Mechanical Properties or Structural Weld Thickness	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 (77 ft-lb)	115 J (85 ft-lb)
$T >$ 101.6 mm (4 in.)	c	c	c	c	c

[a] 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 will be $T \leq -10 - 20 = -30$ °C.

[b] In addition to the absorbed energy requirement, percent shear fracture appearance shall be ≥ 50 % as determined in accordance with ASTM E23, Annex A6.

[c] These values will be specified by the purchaser and contractor, if applicable, on a case-by-case basis.

Table 6—CVN Absorbed Energy Requirements—Service Category C [a] [b]

Critical Section for Mechanical Properties or Structural Weld Thickness	C345	C414	C483	C552	C586
$T \leq$ 76.2 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)
76.2 mm (3 in.) < $T \leq$ 101.6 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)
101.6 mm (4 in.) < $T \leq$ 127.0 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)
127.0 mm (5 in.) < $T \leq$ 152.4 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)
$T >$ 152.4 mm (6 in.)	c	c	c	c	c

[a] Test temperature shall be ≤ LAST − 10 °C (LAST − 18 °F). For example, if the LAST has been designated to be –10 °C (i.e. the default value), then the test temperature will be $T \leq -10 - 10 = -20$ °C.

[b] In addition to the absorbed energy requirement, percent shear fracture appearance shall be ≥ 50 % as determined in accordance with ASTM E23, Annex A6.

[c] These values will be specified by the purchaser and contractor, if applicable, on a case-by-case basis.

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

8.4 Retesting

Should the above fail to produce acceptable results then, at the forging manufacturer/supplier's option, their QTSs may be subjected to an additional QHT within the requirements of 7.2.1.

9 Weldability of Service Category B Forgings

9.1 SCB Welding Prequalification

9.1.1 General

SCB forgings are intended for welding by a subsequent fabricator. This section defines weldability prequalification to be performed by the manufacturer. Welding PQTs to be performed by the fabricator are outside the scope of this specification.

9.1.2 Test Material

Test materials for weldability qualification testing shall be samples of forged material with representative chemical composition, hot work, and QHT.

9.1.3 Material Thickness

The manufacturer shall provide weldability data for forgings with a weld bevel thickness above 25 mm (1 in.). The maximum thickness qualified is the thickness of the test weld plus 25 %.

9.1.4 Weld Preparation

Grooves for weldability qualification test shall be an asymmetric K-weld preparation.

The welding consumables and procedures shall be selected by the manufacturer and be sufficient to provide a test of the welded forging and heat-affected zone to the specified capabilities. Welding shall be in the flat position. Heat input and layer thickness for each pass shall be reported.

9.1.5 Essential Variable Information Applicable to the Fabricator

The fabricator is responsible for performing the procedure qualification for production welding. The forging manufacturer shall provide a weld procedure specification and a procedure qualification report for the weldability tests performed. Essential variables of particular importance to the heat-affected zone include (but are not limited to) the following:

— a change of heat treatment including stress relief after welding;

— an increase in heat input (kJ/in.) or thickness of any weld pass.

9.1.6 Hold Time

Inspection and testing of weldability samples shall be performed at least 48 hours after welding.

9.2 Tensile Tests

Two transverse tensile tests shall be performed. The results shall meet the tensile strength requirements specified for the base metal.

9.3 CVN Testing

9.3.1 Three standard Type A CVN specimens shall be machined and tested in accordance with ASTM E23 from each of the locations.

a) *Weld Metal Root Location A*—Center of notch in root area weld metal; center of notch at centerline of weld metal.

b) *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.

c) *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.

d) *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.

e) *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.

9.3.2 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 on the straight side of the “K.”

9.3.3 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. The scribing of CVN specimen blanks for machining of V-notches shall be accomplished by:

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.

9.3.4 CVN test temperature, acceptance requirements, and retest provisions shall be the same as that specified for the base metal in 8.3, unless alternative requirements have been specified by the purchaser (e.g. materials class in accordance with ISO 19902).

9.4 Macrosection Microhardness Survey

9.4.1 Macrosection Evaluation

One macrosection shall be extracted from the middle of the weldability test 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 three times magnification shall be included in the PQR documentation.

9.4.2 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 E384 or ISO 6507-1. Hardness test indention locations shall be in accordance with ISO 9015-1.

9.4.3 Acceptable Microhardness

The maximum acceptable microhardness for the hardness traverses shall be as follows:

— Grade F345, HV10 = 280 max;

— Grade F414, HV10 = 280 max;

— Grade F480, HV10 = 300 max;

— Grade F552, HV10 = 320 max;

— Grade F586, HV10 = 350 max.

10 NDE of Forgings

10.1 Ultrasonic Testing (UT)

10.1.1 General

All forgings shall receive UT after final QHT in accordance with AMS-STD-2154 prior to shipment by the forging manufacturer/supplier. By agreement between the purchaser and manufacturer, ASTM E2375 may be substituted as an alternative to AMS-STD-2154.

10.1.2 UT Coverage

Volumetric coverage shall be 100 % with straight beam from three mutually orthogonal directions over 100 % of the external surface whenever practicable. When scanning with straight beam from three mutually orthogonal directions is not practicable, angle beam may be utilized to effect 100 % volumetric coverage.

10.1.3 UT Procedures

Written UT procedures shall be approved by the principal and contractor, if applicable, prior to UT on production parts.

10.1.4 UT Scan Plans

Separate written UT scan plans are required for each forging configuration and size to be examined that show the test configuration at the time of examination, amount (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. UT scan plans shall be approved by the principal and contractor, if applicable, prior to UT on production parts.

10.1.5 Acceptance Criteria

UT acceptance criteria shall be in accordance with AMS-STD-2154 Class B, except that for edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the forging manufacturer/supplier, AMS-STD-2154 Class A acceptance criteria shall apply. Flaws interpreted as cracks shall be rejected regardless of size.

10.2 Magnetic Particle Examination (MT)

10.2.1 General

All forgings shall receive MT after final QHT and any machining performed by the forging manufacturer/supplier utilizing the wet continuous method in accordance with ASTM E1444 prior to shipment by the forging manufacturer/supplier.

10.2.2 MT Coverage

Surface coverage shall be 100 % of all accessible surfaces, including end faces and bores, but not required to exceed a length of 760 mm (30 in.) on the ID of tubes or hollow shafts, unless specifically approved otherwise by the principal and contractor, if applicable. Magnetization shall be in at least two mutually perpendicular directions (circumferential and longitudinal for tubes or hollow shafts).

10.2.3 MT Procedures

Written MT procedures in compliance with ASTM E1444, Paragraph 5.4 shall be approved by the principal and contractor, if applicable, prior to MT on production parts.

10.2.4 MT Technique Sheets

Separate written MT technique sheets are required for each forging 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, and acceptance criteria shall also be approved by the principal and contractor, if applicable, prior to MT of production parts. MT of parts with L/D < 2 shall be accomplished using an electromagnetic yoke.

10.2.5 MT Acceptance Criteria

MT acceptance criteria shall be in accordance with the following. Indications that have any dimension > 0.8 mm (0.03 in.) shall be considered relevant. A linear indication is one having a length greater than three times the width. A rounded indication is one of circular or elliptical shape with a length not exceeding three times its width. Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

Surfaces shall be free of the following.

a) Linear indications determined to be cracks, cold shuts, flakes, laminations, and other linear defects that can propagate.

b) Linear indications on machined surfaces determined to be seams or laps.

c) Linear indications on unmachined surfaces determined to be seams or laps > 25.4 mm (1.00 in.) long or > 12.7 mm (0.50 in.) long for pipeline components and edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the forging manufacturer. Relevant linear indications on unmachined surfaces shall be no closer to each other than 12.7 mm (0.50 in.) linearly and 6.4 mm (0.25 in.) in a parallel direction.

d) Surface linear indications determined to be nonmetallic inclusions (stringers) > 9.5 mm (0.375 in.) long or > 3.2 mm (0.125 in.) long for pipeline components, and edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the forging manufacturer. Relevant surface linear indications determined to be nonmetallic inclusions (stringers) shall be no closer to each other than three times the maximum size.

e) Subsurface linear indications determined to be nonmetallic inclusions (stringers) > 12.7 mm (0.50 in.) long or > 4.7 mm (0.187 in.) long for pipeline components and edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the forging manufacturer. Relevant subsurface linear indications determined to be nonmetallic inclusions (stringers) shall be no closer to each other than three times the maximum size.

f) Surface rounded indications > 1.19 mm (0.047 in.) or > 0.79 mm (0.031 in.) for pipeline components and edges [including the adjacent 76 mm (3 in.)] designated for subsequent fabrication welding by an entity other than the forging manufacturer/supplier. Relevant surface rounded indications shall be no closer to each other than three times the maximum size.

g) Subsurface rounded indications > 1.6 mm (0.063 in.) or > 1.19 mm (0.047 in.) for pipeline components and edges (including the adjacent 76 mm [3 in.]) designated for subsequent fabrication welding by an entity other than the forging manufacturer/supplier. Relevant subsurface rounded indications shall be no closer to each other than three times the maximum size.

h) Porosity, whether they be single pores or clusters, on surfaces designated for painting or coating.

10.2.6 Defect Removal

Local grinding to remove nonconforming surface defects is permitted provided dimensions and remaining forging thickness comply with tolerances stipulated in project documents or AFC drawings. Ground regions shall be faired 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.

10.3 Visual Examination (VT)

10.3.1 General

All forgings shall receive VT after final QHT and any machining performed by the forging manufacturer/supplier in compliance with ASME *BPVC*, Section V, Article 9.

10.3.2 VT Coverage

Surface coverage shall be 100 % of all surfaces, including end faces and bores. Surfaces not accessible for direct VT shall be examined by remote VT.

10.3.3 VT Procedures

Written VT procedures in compliance with ASME *BPVC*, Section V, Article 9, Paragraph T-941.2 shall be approved by the principal and contractor, if applicable, prior to VT on production parts.

10.3.4 VT Acceptance Criteria

All forgings shall be visually examined with 100 % surface coverage to be free from laps, cold shuts, cracks, porosity, slag, excessive scale, seams, slivers, mechanical marks, abrasions, or pits and other surface imperfections.

10.3.5 Defect Removal

Local grinding to remove nonconforming surface defects is permitted provided dimensions and remaining forging thickness comply with tolerances stipulated in project documents or AFC drawings. Ground regions shall be faired 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.

10.4 Documentation of NDE Results

The results of all NDE shall be included in the MTR for all forgings.

11 Dimensional Inspection

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

Dimensions and finish shall be in accordance with ASTM A788, Section 13.

12 Material Test Report

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 for each serialized part shall be electronically scanned into a multipage, purchaser-approved electronic image file and stored on digital media or transmitted electronically, as approved by the purchaser. Each forging serial number shall be presented as one image file, with the name of the file corresponding to the forging serial number. The purchaser shall specify the manner of electronic file transmission and any additional formats or hard (paper) copies on the project documents or on AFC drawings.

Annex A
(normative)

Supplementary Requirements

A.1 General

By agreement between the purchaser and the manufacturer, and when individually specified on the purchase order, the following supplementary requirements shall apply.

A.2 Supplementary Requirement S3—Additional Mechanical Testing

Two tension tests and three CVN tests shall be taken from near surface and midthickness of each QTS.

A.3 Supplementary Requirement S11—Preproduction Qualification

A.3.1 This supplementary requirement provides for prequalification of SCB forgings by special welding and mechanical testing of a specific chemical composition range, in combination with specific steelmaking and forging procedures, from a specific producer. The purpose of this supplementary requirement is to minimize the amount of time and testing necessary to prepare and certify critical welding procedures at the fabrication yard.

A.3.2 The specific testing required shall be that contained in Sections 5 (CTOD qualification for HAZ toughness) or Section 6 (delayed cracking test), or both, of API 2Z as specified on the purchase order. Prior qualification by a material manufacturer may be accepted for fulfillment of this supplementary requirement if documentation acceptable to the purchaser is provided.

A significant change in chemical composition or processing shall require either a separate full qualification (for major change), or an abbreviated requalification (for minor change) as described in Section 5 of API 2Z.

A.3.3 CTOD testing of weld heat-affected zone shall be performed in accordance with Section 3 of API 2Z, which provides for testing over the following range of conditions:

— heat input: 0.8 kJ/mm to 4.5 kJ/mm (20 kJ/in. to 114 kJ/in.);

— preheat: 100 °C to 250 °C (212 °F to 480 °F);

— required CTOD for Grade 345 forgings 3 in. (75 mm) and under in thickness: 0.25 mm at –10 °C (0.010 in. at 14 °F).

Required CTOD for thicker forgings and higher strength grades shall be by agreement between the purchaser and the manufacturer. In the absence of other specification or agreement, a default CTOD of 0.25 mm at 4 °C (0.010 in. at 40 °F) may be used.

Testing to a wider range of heat input, wider range of preheats, higher CTOD values, or lower test temperature is permitted at the option of the manufacturer or when specified by the purchaser and shall be deemed to satisfy the minimum requirements of this Supplement.

A.3.4 Weldability testing shall be conducted in accordance with Section 4 of API 2Z using two types of tests representing different levels of restraint: the controlled thermal severity test for moderate restraint and the V-groove test for high restraint.

A.3.5 Plates having the same melting practice, chemical composition, thickness, hot work, and heat treatment as the forgings they represent may be used for testing. The relevant thickness is that at the welds to be made during fabrication. Charpy curves as required by Section 1.3.5 of API 2Z shall be T-L orientation, at midthickness and near surface, for both the test plate and a prototype forging (or prolongation thereof).

A.3.6 Plates having the same melting practice, chemical composition, thickness, hot work, and heat treatment as the forgings they represent may be used for testing. The relevant thickness is that at the welds to be made during fabrication. Charpy curves as required by Section 1.3.5 of API 2Z shall be T-L orientation, at midthickness and near surface, for both the test plate and a prototype forging (or prolongation thereof).

Annex B
(informative)

API Monogram Program

B.1 Scope

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

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

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

For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, NW, Washington, DC 20005 or call 202-682-8145 or by email at certification@api.org.

B.2 Normative References

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

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

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

B.3 API Monogram Program: Licensee Responsibilities

B.3.1 Monogram Program Requirements

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) to which the organization is licensed;

d) the requirements contained in the API Monogram Program License Agreement.

B.3.2 Control of the Application and Removal of the API Monogram

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

a) Products that do not conform to API specified requirements shall not bear the API Monogram.

b) Each licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by this annex and any applicable API product specification(s) and/or standard(s). The marking procedure shall:

   1) define the authority responsible for application and removal of the API Monogram and license number;

   2) define the method(s) used to apply the Monogram and license number;

   3) identify the location on the product where the API Monogram and license number are to be applied;

   4) require the application of the date of manufacture of the product in conjunction with the use of the API Monogram and license number;

   5) require that the date of manufacture, at a minimum, be two digits representing the month and two digits representing the year (e.g. 05-12 for May 2012) unless otherwise stipulated in the applicable API product specification(s) or standard(s); and

   6) define the application of all other required API product specification(s) and/or standard(s) marking requirements.

c) Only an API licensee shall apply the API Monogram and its designated license number to API monogrammable products.

d) The API Monogram and license number, when issued, are site-specific and subsequently the API Monogram shall only be applied at that site specific licensed facility location.

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

For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. Requirements for alternative API Monogram marking are detailed in the *API Monogram Program Alternative Marking of Products License Agreement*, available on the API Monogram Program website at http://www.api.org/alternative-marking.

B.3.3 Design and Design Documentation

Each licensee and/or applicant for licensing shall maintain current design documentation as identified in API Q1 for all of the applicable products that fall under the scope of each Monogram license. The design document information shall provide objective evidence that the product design meets the requirements of

the applicable and most current API product specification(s) and/or standard(s). The design documentation shall be made available during API audits of the facility.

In specific instances, the exclusion of design activities is allowed under the Monogram Program, as detailed in Advisory # 6, available on API Monogram Program website at http://www.api.org/advisories.

B.3.4 Manufacturing Capability

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

B.3.5 Use of the API Monogram in Advertising

An API Monogram Licensee shall not use the API Monogram and/or license number on letterheads, buildings, or other structures, websites, or in any advertising without an express statement of fact describing the scope of Licensee's authorization (license number and product specification). The Licensee should contact API for guidance on the use of the API Monogram other than on products.

B.4 Product Marking Requirements

B.4.1 General

These marking requirements shall apply only to those API Licensees wishing to mark applicable products in conjunction with the requirements of the API Monogram Program.

B.4.2 Product Specification Identification

Manufacturers shall mark products in accordance with 4.6.2. Marking shall include reference to the applicable API specification. Unless otherwise specified, reference to the API specification shall be, as a minimum, "API 2SF." Unless otherwise specified, when space allows, the marking may include use of "Spec" (e.g. API Spec 2SF).

B.4.3 Units

Products shall be marked with units as specified in the API specification and/or standard. If not specified, equipment shall be marked with U.S. customary (USC) units. Use of dual units [USC units and metric (SI) units] may be acceptable if such units are allowed by the applicable product specification and/or standard.

B.4.4 License Number

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

B.5 API Monogram Program: Nonconformance Reporting

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

Bibliography

[1] API Specification 2SC, *Manufacture of Structural Steel Castings for Primary Offshore Applications*

[2] ISO 9000 [8], *Quality management systems—Fundamentals and vocabulary*

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

[4] ISO 19902, *Petroleum and natural gas industries -- Fixed steel offshore structures*

[5] MSS SP-53 [9], *Quality Standard for Steel Castings and Forgings for Valves, Flanges and Fittings and Other Piping Components—Magnetic Particle Examination Method*

[6] NAVSEA T9074-BD-GIB-010/0300 [10], *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*

8 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

9 Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street NE, Vienna, Virginia 22180-4602, http://mss-hq.org.

10 Naval Sea Systems Command, SEA 05M2, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard, DC 20376, www.navsea.navy.mil.

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