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Draft for Ballot #6026

Coiled Tubing, Snubbing, and Wireline Well Intervention Equipment

API Specification 16B
First Edition, XXXX **2023**

1 Scope

This specification defines the requirements for performance, design, materials, testing and inspection, welding, marking, handling, storing, and shipping of surface-installed well intervention pressure control equipment used in coiled tubing and snubbing well intervention, well servicing and drilling operations, and wireline well intervention and well servicing operations in the oil and gas industry. It also defines service conditions in terms of pressure, temperature, and wellbore fluids for which the equipment will be designed.

This specification is applicable to and establishes requirements for the following equipment:

- a) ram type coiled tubing and snubbing pressure control components;
- b) ram type wireline pressure control components;
- c) ram blocks, packers, top seals and rear seals.

This specification does not apply to field use or field testing of the coiled tubing, snubbing, or wireline well intervention pressure control equipment.

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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. When the latest edition is specified it may be used on issue and shall become mandatory 6 months from the date of the revision.

API Specification 5CT, *Specification for Casing and Tubing*

API Specification 5ST, *Specification for Coiled Tubing*

API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment*

API Specification 9A, *Specification for Wire Rope*

API Specification 20E *Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries*

API Specification 20F *Corrosion-Resistant Bolting for Use in the Petroleum and Natural Gas Industries*

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

API Specification 20N *Heat Treatment Services – Continuous Line for Equipment Used in the Petroleum and Natural Gas Industry*

API Standard 6X, *Design Calculations for Pressure-Containing Equipment*

ASME Boiler and Pressure Vessel Code Section V, Article 4. 2021

ASME Boiler and Pressure Vessel Code Section VIII, Division 1, Appendix 4, *Rounded Indication Charts Acceptance Standard for Radiographically Determined Rounded Indications in Welds*

ASME Boiler and Pressure Vessel Code Section IX, Articles I, II, III and IV

ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 6. 2004

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

ASTM A453, *Specification for Bolting Materials, High Temperature, 50 to 120 ksi Yield Strength, with Expansion Coefficients Comparable to Austenitic Steels*

ASTM D395, *Standard Test Methods for Rubber Property — Compression Set*

ASTM D412, *Test Methods for Vulcanized Rubber, Thermoplastic Rubbers and Thermoplastic Elastomers*

ASTM D1414, *Standard Test Methods for Rubber O-Rings*

ASTM D1415, *Standard Test Method for Rubber Property — International Hardness*

ASTM D1418, *Standard Practice for Rubber and Rubber Lattices — Nomenclature*

ASTM D2240, *Test Method for Rubber Property — Durometer Hardness*

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

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

ASTM E94, *Standard Guide for Radiographic Testing*

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

ASTM E140, *Hardness Conversion Tables for Metals*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

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

ASTM E569, *Standard Practice for Acoustic Emission Monitoring of Structures During Controlled Simulation*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

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

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

AWS D17.1, *Specification for Fusion Welding for Aerospace Applications*

ISO 2859-1: *Sampling procedures for inspection by attributes — Part 1: Sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection*

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

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

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO 9712, *International Standard for Nondestructive Testing Personnel Qualification and Certification*

ISO 18265, *Metallic materials — Conversion of hardness value*

NACE MR0175 "Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production, Parts 1, 2 and 3

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

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

3.1.1

acceptance criteria

Defined limits placed on characteristics of materials, products, or service.

3.1.2

actuator

Mechanism for the remote or automatic operation of a ram, valve, or choke.

3.1.3

adapter

Pressure-containing piece of equipment having end connections of different nominal size and/or pressure ratings, used to connect other pieces of equipment of different nominal sizes and/or pressure ratings.

3.1.4

blind ram

The ram assembly designed to seal opposing elastomeric elements against each other in an unobstructed bore to isolate pressure in the annulus below the ram.

3.1.5

body

Any portion of equipment between end connections, with or without internal parts, which contains wellbore pressure.

3.1.6

bolting

Threaded fasteners.

Note: includes studs, tap end studs, double ended studs, headed bolts, cap screws, screws, and nuts.

3.1.7

bonnet

Pressure containing closure for a body, other than an end or outlet connection.

3.1.8

calibration

Comparison to a standard of known accuracy and making any needed adjustment(s).

3.1.9

carbon steel

Alloy of carbon and iron containing a maximum of 2% mass fraction carbon, 1.65% mass fraction manganese, and residual quantities of other elements.

Note does not include those intentionally added in specific quantities for deoxidation (usually silicon and/or aluminium).

3.1.10

casting (*noun*)

Object at or near finished shape obtained by solidification of a fluid substance in a mould.

3.1.11

certificate of conformance

Document certifying that the repaired/remanufactured equipment and all of its component parts meet the requirements of the original product definition.

3.1.12

chemical analysis

Determination of the chemical composition of material.

3.1.13

closing ratio

A dimensionless factor equal to the area of the piston(s) operator divided by the area of the ram shaft.

3.1.14

coiled tubing (CT)

Continuous tubing spooled onto a reel that is used in well intervention operations.

3.1.15

connection

Flanges, hubs, and studded end terminations manufactured in accordance with API specifications, including dimensional requirements.

3.1.16

corrosion resistant alloy (CRA)

Nonferrous based alloys where any one or the sum of the specified amount of the elements titanium, nickel, cobalt, chromium, and molybdenum exceeds 50 % mass fraction.

Note: This definition is different from that in ISO 15156 (NACE MR0175; see Clause 2).

3.1.17

date of manufacture

Date of the manufacturer's final acceptance of finished equipment.

3.1.18

end connection

Integral male or female thread; used to join together equipment that contains or controls pressure.

Note: Clamp hub end connector and flange, studded or through-bolted, or any other means

3.1.19

equivalent round (ER)

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

3.1.20

exposed bolting (see non-exposed bolting 3.1.78)

Bolting that is exposed directly to the sour environment or that is buried, insulated, equipped with flange protectors, or otherwise denied direct atmospheric exposure.

3.1.21

fabrication weld

Weld joining two or more parts.

3.1.22

flange

Protruding rim, with holes to accept bolts and having a sealing mechanism, used to join pressure-containing equipment, with dimensions specified in this specification.

3.1.23

forging (*noun*)

Shaped metal part formed by the forging method.

3.1.24

**heat-affected zone
(HAZ)**

Portion of the base metal that has not been melted, but whose mechanical properties or microstructure has been altered by the heat of welding or cutting.

3.1.25

heat

Material originating from a final melt, or for remelted alloys, the raw material originating from a single remelted ingot.

3.1.26

heat treatment

heat treating

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

3.1.27

hold period

Period of time that the product is subjected to pressure and isolated from the pressure source.

3.1.28

hot-work (*verb*)

Deform metal plastically at a temperature above the recrystallization temperature.

3.1.29

indication

Visual sign of cracks, pits or other abnormalities found during liquid penetrant and magnetic particle examinations.

3.1.30

integral (*adjective*)

Parts joined by the forging, casting, or welding process.

3.1.31

leakage

Visible passage of pressurized fluid from the inside to the outside of the pressure-containment area of the equipment being tested.

3.1.32

linear indication

Liquid penetrant or magnetic particle examination indication whose length is equal to or greater than three times its width.

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3.1.33

low-alloy steel

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

3.1.34

non exposed bolting

Bolting that is not directly exposed to sour environments and is not intended to be buried, insulated, equipped with flange protectors, or otherwise denied direct atmospheric exposure.

3.1.35

other end connection (OEC)

Connection which is not specified in an API standard.

Note: This includes API flanges and hubs with non-API gasket preparations and manufacturer's proprietary connections.

3.1.36

part

Individual piece used in the assembly of a single unit of equipment.

3.1.37

pipe ram

The rams which are designed to close and seal around a tubular segment, isolating pressure in the annular space below the rams.

3.1.38

pipe-slip ram

The rams designed to secure the tubular segment within the slips and isolate pressure in the annular space below the rams in a single operation.

3.1.39

post-weld heat treatment (PWHT)

Any heat treatment subsequent to welding, including stress relief.

3.1.40

pressure integrity

Structural and leak-resistant capability of a product to contain applied pressure.

3.1.41

pressure-boundary penetration

Device that penetrates directly into or communicates with the wellbore and is not defined elsewhere in this standard.

Note: Examples Grease or sealant injection fitting; check valve; control, test or gauge port plug and fitting, needle valve on test, gauge or injection port; electric and control line penetration.

3.1.42

pressure-containing weld

Weld whose failure will reduce or compromise the pressure-containing integrity of the component.

3.1.43

procedure qualification record (PQR)

Record of the welding data used to make the test weldment containing the actual values or ranges of the essential and supplementary essential variables used in preparing the test weldments, including the test results.

**3.1.44
prolongation**

Extension of a piece of raw material or an extension of a product part made integrally during forging, hot working, cold working, or casting.

**3.1.45
quick union**

End connections that employ elastomer seals to hold pressure, while allowing thread make-up of the union connection by hand.

**3.1.46
ram piston balance pressure**

Amount of hydraulic actuator pressure required to create a force equal to that generated by wellbore pressure acting on the cross-sectional area of the ram piston rod. NOTE Typically determined by dividing the MASP by the closing ration of the ram for ram performance testing purposes

**3.1.47
rated working pressure**

Maximum internal pressure that the equipment is designed to contain and/or control.

**3.1.48
relevant indication** (*liquid penetrant or magnetic particle examination*),
Any indication with a major dimension greater than 1.6 mm (0.062 in)

**3.1.49
repair**

Process disassembly, reassembly and testing of well intervention pressure control equipment, with or without the replacement of parts.

Note 1: Repair does not include machining, welding, heat treating, or other manufacturing operation of component parts and does not include the replacement of pressure-containing part(s) or member(s).

Note 2: Repair may include replacement of parts other than pressure-containing part(s) or member(s).

**3.1.50
repair weld**

Welding performed subsequent to original heat treatment other than base weld repair.

**3.1.51
rounded indication** (*liquid penetrant or magnetic particle examination*),

Indication that is approximately circular or elliptical and whose length is less than three times its width.

**3.1.52
shear ram**

The rams which are designed to shear the tubular segment, including wire, tubing and/or cable inside the tubular segment.

3.1.53

shear-blind ram (standard)

The combination ram assembly which is designed to shear the coiled tubing and any spoolable components inside the coiled tubing (including wire, tubing, and/or cable) and seal the wellbore in a single operation.

3.1.54

shear-blind ram (dedicated)

The combination shear-blind ram assembly which is installed as close to the wellhead as possible and operated through the dedicated accumulator circuit on the well control closing unit.

3.1.55

slip ram

The rams which are designed to prevent movement of the tubular segment but does not isolate pressure or control flow.

3.1.56

stabilized (pressure testing)

State in which the initial pressure-decline rate has decreased to within the manufacturer's specified rate.

Note: Pressure decline can be caused by such things as changes in temperature, setting of elastomer seals or compression of air trapped in the equipment being tested.

3.1.57

stabilized (temperature testing),

State in which the initial temperature fluctuations have decreased to within the manufacturer's specified range.

Note: Temperature fluctuation can be caused by such things as mixing of different-temperature fluids, convection, or conduction.

3.1.58

stress relief

Controlled heating of material to a predetermined temperature for the purpose of reducing any residual stresses.

3.1.59

studded connection

Connection in which thread-anchored studs are screwed into tapped holes.

3.1.60

Surface NDE

Examination for surface material defects

Note: Examination by Magnetic Particle Inspection or Liquid Penetrant Inspection

3.1.61

traceability

Ability for parts to be traced as originating from a specifically identified group of parts processed together which identifies the included heat(s).

3.1.62

variable-bore ram (VBR)

Closing and sealing component in a ram assembly that is capable of sealing on a range of tubular size.

3.1.63

visual examination

Examination of parts and equipment for visible defects in material and workmanship.

3.1.64

**volumetric non-destructive examination
(NDE)**

Examination for internal material defects.

Note: Examination by radiography, acoustic emission, or ultrasonic testing.

3.1.65

weld (verb)

Act of fusing materials, with or without the addition of filler materials

3.1.66

welding

Application of any one of a group of weld processes, which applies heat energy sufficient to melt and join one or more pieces of metal through localized fusion and coalescence.

3.1.67

**welding procedure specification
(WPS)**

A document providing the required welding variables for a specific application to assure repeatability by properly trained welders and welding operators. Note: These variables and their meanings are defined, respectively, in Article II, of the ASME Boiler & Pressure Vessel Code Section IX—Welding and Brazing Qualifications.

3.1.68

weldment

Portion or area of a component on which welding has been performed.

Note: Includes the weld metal, the heat-affected zone (HAZ), and the base metal unaffected by the heat of welding.

3.1.69

wireline ram

The rams which are designed to close and seal around a wireline segment, isolating pressure in the annular space below the rams.

3.1.70

yield strength

Stress level, measured at room temperature, at which material plastically deforms and will not return to its original dimensions when the stress is released.

Note 1: All yield strengths specified in this specification are considered as being the 0.2 % yield offset strength as seen in ASTM A370 or ISO 6892-1.

3.2 Acronyms, Abbreviations, and Symbols

CRA	corrosion resistant alloy
HAZ	heat-affected zone
ID	inside diameter
LP	liquid penetrant
MOPFLPS	minimum operator pressure for low pressure sealing
MP	magnetic particle
NDE	non-destructive examination
OD	outside diameter
OEC	other end connection
OEM	original equipment manufacturer
PQR	procedure qualification record
PWHT	post-weld heat treatment
SBR	shear-blind ram
VBR	variable-bore ram
WPS	welding procedure specification

4 Design requirements

4.1 Size designation

Vertical through bore dimensions of equipment shall have size designations according to **Table 1**.

Table 1 — Equipment Size

Nominal Bore Diameter		Drift Diameter	
In.	mm	In.	mm
2-9/16	65.09	2.532	64.31
3	76.20	2.970	75.44
3-1/16	77.79	3.032	77.01
4-1/16	103.19	4.032	102.41
4-1/2	114.30	4.460	113.28
5	127.00	4.960	125.98
5-1/8	130.18	5.094	129.39
5-1/2	139.70	5.469	138.91
6-3/8	161.93	6.344	161.14
7-1/16	179.39	7.032	178.61
7-3/8	187.33	7.344	186.54
9	228.60	8.969	227.81
11	279.40	10.696	271.68
13-5/8	346.08	13.321	338.35
NOTE Tolerance on drift mandrel is +0.010/-0.000 in (+0.25/-0.00)			

4.2 Service conditions

4.2.1 Rated working pressure

Equipment shall be rated in the rated working pressures shown in **Table 2**.

Table 2 — Equipment Rated Working Pressures

psi	(MPa)
3 000	20.7
5 000	34.5
10 000	69.0
15 000	103.5

NOTE Information on strength of materials at elevated temperatures is found in API 6A and TR6MET

4.2.2 Temperature ratings

4.2.3 Metallic components

Minimum temperature is the lowest temperature the equipment may be subjected to in accordance with Table 3

Maximum temperature is the highest temperature the equipment may be subjected to in accordance with Table 3.

Equipment shall be designed for metallic parts to operate within the temperature ranges shown in Table 3.

Table 3 — Temperature Ratings for Metallic Materials

Classification	Operating range	
	°F	°C
T-75/250	– 75 to 250	– 59 to 121
T-75/350	– 75 to 350	– 59 to 177
T-50/250	-50 to 250	-45 to 121
T-50/350	-50 to 350	-45 to 177
T-20/250	– 20 to 250	– 29 to 121
T-20/350	– 20 to 350	– 29 to 177
T-0/250	0 to 250	– 18 to 121
T-0/350	0 to 350	– 18 to 121

NOTE Information on strength of materials at elevated temperatures is found in API 6A and TR6MET.4.2.4 Non-metallic Components

Continuous elevated temperature limit is the maximum average fluid temperature in an eight-hour span.

Extreme temperature limit is the maximum fluid temperature in a one-hour period.

Wellbore Elastomers shall be selected to operate in accordance with the temperature classifications of Table 4.

Elastomeric seals that do not operate within the ranges found in Table 4, shall be designed to operate within the temperatures of the manufacturer's written specifications.

Table 4 — Temperature Ratings for Non-metallic Sealing Materials

Low Temperature Limit (first letter)			Continuous Elevated Temperature Limit (second letter)			Extreme Temperature Limit (third letter)		
Code	Temperature		Code	Temperature		Code	Temperature	
	F	C		F	C		F	C
H	-40	-40						
J	-20	-29						
A	-15	-26	A	150	66	A	180	82
B	0	-18	B	180	82	B	200	93
C	10	-12	C	210	99	C	220	104
D	20	-7	D	240	116	D	250	121
E	30	-1	E	270	132	E	300	149
F	40	4	F	300	149	F	350	177
G	Other	Other	G	Other	Other	G	Other	Other
Example: Material "FDE" has a low temperature rating of 40 degrees F, a continuous								
elevated temperature rating of 240 degrees F and an extreme temperature limit of 300 degrees F								

4.2.4 Retained fluid ratings

Metallic materials that come in contact with well fluids and are designed for sour service shall meet the requirements of NACE MR0175 for sour service.

4.3 Equipment-specific design requirements

4.3.1 Flanged end and outlet connections

4.3.1.1 General

Flanged end and outlet connections shall be in accordance with the dimensional requirements of API 6A prior to assembly and testing.

Note: Dimensions apply to machining dimensions and not post test or post flange and ring gasket makeup.

Type API 6A 6B and 6BX flange connections may be used as integral connections.

Type API 6A 6B and 6BX flanges integral to drill-through equipment shall not contain test connections.

The designs of Type API 6A 6B and API 6BX flange connections shall be in accordance with Table 5.

Table 5 — Pressure Rating and Size Ranges of API 6A Flange Connectors

Pressure rating			Type 6B	Type 6BX
Psi	(MPa)			
3000	20.7		2-1/16 to 9	--
5000	34.5		2-1/16 to 9	--
10,000	69.0		--	1-13/16 to 13-5/8
15,000	103.5		--	1-13/16 to 13-5/8

4.3.1.2 API Type 6B flange connections

Type 6B flange connections are of the ring joint type and are not designed for face-to-face make-up. The connection make-up bolting force reacts on the metallic gasket. The type 6B flange shall be of the through-bolted or studded design.

Dimensions for type 6B integral flanges shall conform to API 6A.

Dimensions for all ring grooves shall conform to API 6A.

Note: dimensions apply to machining dimensions and not post-test or post flange and ring gasket makeup.

4.3.1.3 API Type 6BX flange connections

Type 6BX flanges are of the ring joint type and are designed with a raised face. Depending on tolerances, the connection make-up force may react on the raised face of the flange when the gasket has been properly seated. This support prevents damage to the flange or gasket from excessive bolt torque. The type 6BX flange shall be of the through-bolted or studded design.

Dimensions for type 6BX integral flanges shall conform to API 6A.

Dimensions for all ring grooves shall conform to API 6A.

4.3.2 Studded end and outlet connections

4.3.2.1 General

The two types of studded end and outlet connections (6B and 6BX) referred to in this specification shall conform to API 6A.

6B and 6BX studded connections may be used as integral connections.

The design for studded end and outlet connections shall be the same as specified in 4.3.1.1, except as required in 4.3.2.2 and 4.3.2.3.

4.3.2.2 Type 6B studded connections

Dimensions for type 6B studded connections shall conform to API 6A as it relates to the bore size, diameter of the bolt circle, and flange OD.

The studded connection shall be fully machined in accordance with API 6A.

Stud bolt holes shall be sized and located in accordance with API 6A. The thread form of the tapped hole shall be in accordance with API 6A. The minimum depth of the full threads in the hole shall be equal to the diameter of the stud. The maximum depth of the full threads in the hole shall be in accordance with the manufacturer's written specification.

4.3.2.3 Type 6BX studded connections

Dimensions for Type 6BX studded connections shall be in accordance with API 6A concerning bore size, diameter of the bolt circle, and flange OD.

The studded connection shall be fully machined in accordance with API 6A.

Stud bolt holes shall be sized and located in accordance with API 6A. The thread form of the tapped hole shall be in accordance with API 6A. The minimum depth of the full threads in the hole shall be equal to the diameter of the stud. The maximum depth of the full threads in the hole shall be in accordance with the manufacturer's written specification.

4.3.3 Bolting for Surface (Land and Offshore) Well Intervention Service

Original equipment manufacturers (OEM) shall have a documented procedure for the qualification of bolting manufacturers and shall be in accordance with **Table 6**. Exposed bolting shall meet the requirements of NACE MR0175. Original Equipment manufacturers (OEM) shall have documented specifications that include the thread form and dimensions of studs, nuts, and bolts.

Table 6 – Bolting Requirement

Bolting Class	Material	Surface Land & Offshore
Class C	Alloy Steel and Carbon Steel	API 20E BSL-1 See Section 4.3.3.1
	Stainless Steel and CRA	API 20F BSL-2 See Section 4.3.3.1
Class D	Alloy Steel and Carbon Steel	Mfg. Spec. See section 4.3.3.2
	Stainless Steel and CRA	Mfg. Spec. See section 4.3.3.2
Class E	Alloy Steel and Carbon Steel	Mfg. Spec. See section 4.3.3.3
	Stainless Steel and CRA	Mfg. Spec. See Section 4.3.3.3

4.3.3.1 Class C Bolting

See **Table 7** for Class C Bolting applications.

Marking shall be in accordance with API 20E and API 20F, as applicable.

When plating or coating is specified, it shall be in accordance with API 20E.

Bolting records shall be maintained in accordance with API 20E or API 20F, as applicable.

Threads shall be in accordance with Manufacturers specification.

Alloy steel and carbon steel bolting shall be in accordance with API 20E BSL-1 at a minimum and the following:

- a) Bolting manufactured from proprietary materials shall be in accordance with the manufacturer's written specification and with API 20E with the exception that the material meets manufacturer's specified chemical composition and mechanical properties.
- b) Bolting for Temperature Class T-50 and T-75 shall meet Impact testing requirements per section 5.3.5.3 and **Table 26**.

Corrosion-resistant bolting shall be in compliance with API 20F BSL-2 at a minimum and the following requirements.

- a) Bolting for Temperature Class T-50 and T-75 shall meet Impact testing requirements per 5.3.5.3 and **Table 26**.

Bolting used on 6B and 6BX flanged and studded connections shall be in accordance with API 6A.

- Recommended Assembly of Flange Bolting shall be in accordance with API 6A

4.3.3.2 Class D Bolting

See Table 7 for D Bolting Applications

Bolting shall be in compliance with:

- a) ASTM specifications or the manufacturers written material specification.
- b) Bolting for Temperature Class T-50 and T-75 shall meet Impact testing requirements per section 5.3.5.3 –**Table 26**.

4.3.3.3 Class E Bolting

See Table 7 for Class E Bolting Applications.

Bolting shall be in compliance with:

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- a) Alloy steel and carbon steel bolting shall be in accordance with the manufacturer's specification.
- b) Stainless steel and CRA bolting shall be in accordance with the manufacturer's specification.

Table 7 – Applicable Bolting Class

Application	Class
Bolting used to assemble two or more Level 2 parts together. (see Table 21) Examples include but are not limited to: Flange bolting, Bonnet Bolts, Bolts used to secure an item or component that retains well bore fluid, etc.	Class C
Bolting used for assembly of wellbore pressure assist chambers that contains wellbore pressure	Class C
Bolting used for end and outlet connections	Class C
Bolting used in ram assemblies which are loaded by wellbore pressure or the closing of the rams.	Class C
All other ram bolting	Class E
Bolting used to contain hydraulic pressure	Class D
Bolting that is loaded when the Ram Locks are engaged	Class D
Bolting used for brackets, tags, or mounting accessories to the equipment	Class E

4.3.4 Ring gaskets

Gaskets used for equipment manufactured to this specification shall meet all the requirements of API 6A.

Type R, RX and BX ring-joint gaskets are used in flanged, studded and hub connections. Types R and RX gaskets are interchangeable in type R ring grooves. Only type RX gaskets shall be used with SR ring grooves. Only type BX gaskets shall be used with 6BX ring grooves. Type RX and BX gaskets are not interchangeable.

4.3.5 Other end connections (OECs)

4.3.5.1 General

This subsection provides requirements for other end connections (OEC) which may be used for joining well intervention pressure control equipment and which are not specified in an API standard. OECs include flanges and hubs in accordance with this standard, but with proprietary gasket preparations. OECs may also be in accordance with the manufacturer's specifications.

4.3.5.2 Design

OECs shall be designed in accordance with 4.4.

OECs shall be designed with the designated sizes shown in **Table 1**.

The bore diameter shall conform to the minimum bore dimension as shown in **Table 1**.

4.3.5.3 Materials

OEC materials shall meet the requirements of **Section 5**.

4.3.5.4 Testing

Equipment utilizing OECs shall successfully complete the tests required in **7.2**.

4.3.6 Blind connections

4.3.6.1 Flanges

Type 6B and 6BX blind flanges (End or outlet connection with no center bore, used to completely close off a connection) shall conform to the dimensional requirements of API 6A.

4.3.6.2 Other end connections (OECs)

The design and configuration of blind OECs shall conform to API 6A.

4.3.6.3 Adapters

Length of adapters is not addressed in this specification. End connections shall meet the requirements of 4.3.1, 4.3.2, 4.3.3, 4.3.5 and/or 4.3.6.

4.3.6.4 Test, vent, injection and gauge connections

Sealing and porting of flanges, hubs and OECs shall conform to the requirements of API 6A.

4.4 Design methods

4.4.1 End and outlet connections

End and outlet connections shall conform to the requirements of this specification.

4.4.2 Level 2 Items (Level 2 Items per Table 21)

Items shall be designed in accordance with one or more of the methods given in 4.4.2.1 to 4.4.2.3.

The use of elastic stress analysis combined with stress classification procedures to demonstrate structural integrity for heavy-wall pressure containing components, especially around structural discontinuities, may produce non-conservative results and is not recommended. A more accurate estimate of the protection against plastic collapse of a component can be obtained using elastic-plastic stress analysis. The plastic collapse load is taken as the load which causes overall structural instability. ASME considers heavy-wall vessels as having $R/t \leq 4$ or $D/d \geq 1.25$. Pressure containing equipment within the scope of this specification typically has heavy-walls due to intersecting bore and other geometry constraints.

NOTE fatigue analysis and localized bearing stress values are outside the scope of this specification. Design Methodology

4.4.2.1 API Standard 6X

If used the design methodology shall be in accordance with API Std 6X. The von Mises equivalent stress may be used.

4.4.2.2 Distortion energy theory

If used distortion energy theory, also known as the von Mises Law, may be used for design calculations for pressure-containing equipment. Rules for the consideration of discontinuities and stress concentrations are beyond the scope of this method. However, the basic pressure –vessel wall thickness may be sized by combining triaxial stresses based on hydrostatic test pressure and limited by the following criterion.

$$S_e = S_y$$

Where

S_e is the maximum allowable equivalent stress at the most highly stressed distance into the pressure vessel wall computed by the distortion energy theory method

S_y is the material's specified minimum yield strength.

4.4.2.3 Experimental stress analysis

Application of experimental stress analysis is described in the 2004 ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 6.

Finite Element Analysis

Finite element analysis (FEA) is a design verification methodology that may be utilized to predict equipment performance for complex geometry and/or complex loading where conventional verification methodologies are considered incomplete by the design engineer. FEA shall include the following information (as applicable) to enable verification of the results:

- a) description of the numerical method used, including name and version of computer software;
- b) geometry details:
- c) loading conditions:
- d) boundary conditions:
- e) material properties at temperature:
- f) numerical analysis procedure:
- g) graphical display of results:
- h) validation of numerical model:
- i) summary report:

The FEA study shall be documented and electronically archived such that the study can be re-evaluated at a later date. The data to archive shall include inputs, outputs, and a summary report of the FEA study.

4.4.2.4 Class C bolting

The maximum tensile stress for Class C (**Table 7**) bolting shall be determined considering:

- a) Initial Bolt-up
- b) Operating conditions including pressure loads, external mechanical loads, and thermal stress;
- c) Hydrostatic test pressure conditions

Bolt tensile stress, based on the minimum cross-sectional area of the bolt or stud, shall not exceed the following limits

$$S_a \leq 0.83 S_y \text{ and}$$

$$S_b \leq 1.0 S_y$$

Where

S_a is the maximum allowable tensile membrane stress;

S_b is the maximum allowable tensile membrane plus bending stress

S_y is the bolting material's specified minimum specified yield strength.

4.4.3 Other parts

Level 1 Items per table 28 shall be designed to satisfy the manufacturer's written specifications and the service conditions defined in 4.2.

4.4.4 Miscellaneous design information

General

End and outlet connections to the well intervention pressure control equipment shall be integral or welded for Coiled Tubing and Snubbing.

Acme threads with elastomer seals between the body and the outlet connection are acceptable for wireline class.

4.4.5 OECs

OEC's include Quick Unions, and Acme threads with elastomer seals.

The manufacturer shall document the structural load/capacity for the OEC that relates pressure to allowable bending moment at maximum working pressure and 50% of maximum working pressure..

Analytical design methods shall conform to 4.4.

4.5 Design Validation

4.5.1 General

Design validation shall be performed on equipment specified in the scope of this document and shall be described in the manufacturer's written specification(s). Design validation shall not be required on adapters, spools, flanges and ring gaskets.

Experimental confirmation of the design shall be documented and verified as in 4.6.

Safety procedures shall be in accordance with the manufacturer's written documentation

4.5.2 Well Intervention Pressure Control Ram Components

Tests of the operating characteristics for well intervention pressure control ram components shall conform to 4.7.

4.5.3 Ram blocks, front seals, and top seals

Tests on ram blocks, front seals and top seals shall conform to 4.7.

Design temperature validation on ram front seals and top seals shall conform to 4.7.3.10, 4.7.3.11 and 4.7.3.12.

Manufacturer shall maintain documentation which identifies the essential variables related to manufacture of elastomer components, raw materials and molded seals. Changes to essential variables shall require re-validation according to this documentation. The minimum essential variables evaluated for inclusion in the documentation are:

- Compound or compound components

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- Manufacturing process
- Compound vendors
- Metallic insert design
- Bonding agents and application
- Mold design

4.5.4 Tests of the operating characteristics for OECs shall conform to the manufacturer's written specification.

4.6 Documentation

4.6.1 Design documentation (verification)

Designs, including design requirements, methods, assumptions and calculations, shall be documented. Design documentation media shall be clear, legible, reproducible, and retrievable.

4.6.2 Design review

Design documentation shall be reviewed and verified by personnel other than the individual who created the original design.

4.6.3 Design Validation

The following shall be included in the design validation documentation:

1. Design Validation test procedures.
2. Calibration documentation for measuring and testing equipment.
3. Traceability for the equipment subject to Design Validation.
4. Design Validation results.

4.6.4 Documentation retention

Documents required in accordance with **Section 4** shall be retained for ten years after the last unit of that model, size and rated working pressure is manufactured.

4.7 Tests for Well Intervention Pressure Control Operational Characteristics

4.7.1 Validation Testing

4.7.1.1 General

All products shall be validated according to the requirements of **4.7**. There are three categories of equipment which consists of coiled tubing, wireline and snubbing components. The performance requirements for each class of well intervention pressure control service are documented in the sections below.

For the purpose of the tables in this Section, the word reportable means that a test shall be performed and documentation shall be provided to the purchaser of the equipment in accordance with **4.8**.

4.7.1.2 Procedure

Tests for operational characteristics shall be conducted using water, or water with additives (the manufacturer shall specify the test fluid used) at ambient temperature as the wellbore fluid. Elevated temperature testing may be performed with an oil based fluid.

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4.7.1.3 Acceptance criteria

With the exception of stripping tests, the acceptance criterion for all tests that verify pressure integrity shall be zero visible leakage.

All test pressures contained in this standard shall be at normal atmospheric levels and gauge pressure “psig” (absolute pressure – atmospheric pressure [14.7 psi] is acceptable for testing and qualification purposes).

The allowable test pressure tolerance above rated working pressure shall be 5 % of rated working pressure or 500 psi (3.45 MPa), whichever is less.

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4.7.2 Testing Requirements and Minimum Performance Criteria

4.7.2.1 Well Intervention Pressure Control Component qualification

Well intervention pressure control components shall be hydrostatic proof tested in accordance with **7.5.6.6** prior to validation testing.

Well intervention Ram-type pressure control components shall be tested in accordance with **Table 12**. The indicated tests shall be performed and the minimum performance criteria for the applied service level shall be achieved.

The tests and performance criteria for the body and actuator assemblies **in the ram well intervention pressure control components, shall be in accordance with Table 10.**

The critical body dimensions on the test body should be the same and the body to actuator interface should be the same.

It is not required to test every ram body (single, dual, quad) combination.

TABLE 10 – Tests and Performance Criteria for the Body and Actuator assemblies in the Ram Well Intervention Pressure Control Components

Test	Wireline Class	CT Class	Snubbing Class
Ram access	4.7.3.8 200 Cycles with 10 pressure cycles	4.7.3.8 200 Cycles with 10 Pressure Cycles	4.7.3.8 200 Cycles with 10 Pressure Cycles
Ram locking	4.7.3.9 7 locking pressure tests	4.7.3.9 7 locking pressure tests	4.7.3.9 7 locking pressure tests

Test results may be used to qualify other well intervention pressure control components provided the following criteria are met:

1. The rated working pressure is equal to or lower than the equipment tested.
2. The rated working pressure is lowered by only changing the end connections.
3. The temperature rating is within the qualified temperature range.
4. Seal geometry (excluding ram seals) and ram cavity cross section as applied is identical.

4.7.2.2 Ram Validation Tests

4.7.2.2.1 Fixed-Bore Pipe Rams and Blind Rams

Pipe, tubing, and wireline sizes to be tested for qualification are listed in **Table 11** unless otherwise noted in the specified design validation test.

TABLE 11 – Test Mandrel Wire or Pipe Size(s) for Ram Testing

Nominal size designation		Wireline Size		Coiled Tubing Size		Snubbing Pipe Size	
In	(mm)	in	(mm)	in	(mm)	in	(mm)
2-9/16	65.09	0.125	3.18	1.50	38.10	1.315	33.40
3-1/16	77.79	0.125	3.18	1.75	44.45	1.315	33.40
4-1/16	103.19	0.125	3.18	2.00	50.80	1.900	48.26
5-1/8	130.18	0.125	3.18	2.375	60.33	2.375	60.33
6-3/8	161.93	0.125	3.18	2.375	60.33	1.900 and 2.375	48.26 and 60.33
7-1/16	179.39	0.125	3.18	2.375	60.33	2.375 and 3.500	60.33 and 88.90
9	228.60	0.125	3.18	--	--	2.375 and 3.500	60.33 and 88.90
11	279.40	--	--	--	-	2.375 and 3.500	60.33 and 88.90
13-5/8	346.08	--	--	-	-	2.375 and 3.500	60.33 and 88.90

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TABLE 12 – Required Tests and Performance Criteria for Wireline, Pipe Rams, and Blind Rams

Test	Wireline Class Section and Minimum Performance Criteria	CT Class Section and Minimum Performance Criteria	Snubbing Class Section and Minimum Performance Criteria
Sealing characteristics	4.7.3.1 ^c Reportable	4.7.3.2 ^c Reportable	4.7.3.2 ^c Reportable
Differential Pressure	N/A	4.7.3.17 Reportable	N/A
Fatigue	4.7.3.3 52 Pressure Cycles	4.7.3.4 52 Pressure Cycles	4.7.3.4 (Pipe and Blind Rams 52 Pressure Cycles)
			4.7.3.5 (Snubbing Rams) 70 pressure cycles and 721 pressure cycles
Stripping	N/A	N/A	4.7.3.6 ^{a,b} 500 ft
Low temperature	4.7.3.10 3 pressure cycles	4.7.3.10 3 pressure cycles	4.7.3.10 3 pressure cycles
Continuous high temperature	4.7.3.11 10 pressure cycles	4.7.3.11 10 pressure cycles	4.7.3.11 10 pressure cycles
Extreme high temperature	4.7.3.12 1 hour hold time	4.7.3.12 1 hour hold time	4.7.3.12 1 hour hold time
^a Not applicable to blind rams if tested separate from fixed-bore pipe rams ^b Qualifies all rated working pressures of the product tested and qualifies all equipment size designations of the product tested. ^c The results of these tests can be scaled to create data for other operator sizes using evaluation of closing ratios and operating pressures and hydraulic areas.			

Test results may be used to qualify other blind rams and other pipe rams of different nominal pipe sizes, provided all the following criteria are met:

1. no essential variables have changed as specified in **4.5.3**, other than those dimensional changes required to accommodate a different pipe size;
2. the rated working pressure is equal to, or lower than, the equipment tested;
the temperature rating is within the qualified temperature range.

4.7.2.2.2 Variable Bore Rams

Variable Bore Rams shall be tested in accordance with **Table 13**. The indicated tests shall be performed and the minimum performance criteria shall be achieved.

TABLE 13 – Required Tests and Performance Criteria for Variable Bore Rams

Test	Wireline Class Minimum Performance Criteria	CT Class Minimum Performance Criteria	Snubbing Class Minimum Performance Criteria
Sealing characteristics	4.7.3.1 ^a Reportable	4.7.3.2 ^a Reportable	4.7.3.2 ^a Reportable
Fatigue	4.7.3.3 28 pressure cycles	4.7.3.4 28 pressure cycles	4.7.3.5 28 pressure cycles
Stripping	N/A	N/A	4.7.3.6 500 ft
Low temperature	4.7.3.10 3 pressure cycles	4.7.3.10 3 pressure cycles	4.7.3.10 3 pressure cycles
Continuous high temperature	4.7.3.11 10 pressure cycles	4.7.3.11 10 pressure cycles	4.7.3.11 10 pressure cycles
Extreme high temperature	4.7.3.12 1 hour hold time	4.7.3.12 1 hour hold time	4.7.3.12 1 hour hold time
^a The results of these tests can be scaled to create data for other operator sizes using evaluation of closing ratios and operating pressures and hydraulic areas.			

Test results can be used to qualify other variable-bore ram assemblies provided:

1. No essential variables have changed as specified in **4.5.3**.
2. The rated working pressure is equal to or lower than the equipment tested.
3. The temperature rating is within the qualified temperature range.

4.7.2.2.3 Shear-Blind Rams

Shear-Blind Rams (SBR) shall be tested in accordance with **Table 14** through **Table 17**. The indicated tests shall be performed, and the minimum performance criteria shall be achieved.

TABLE 14 – Required Tests and Performance Criteria for Shear-Blind Rams

Test	Wireline Class Minimum Performance Criteria	CT Class Minimum Performance Criteria	Snubbing Class Minimum Performance Criteria
Sealing characteristics	4.7.3.1 ^a Reportable	4.7.3.2 ^a Reportable	4.7.3.2 ^a Reportable
Fatigue	4.7.3.3 52 pressure cycles	4.7.3.4 52 pressure cycles	4.7.3.5 52 pressure cycles
Shear Blind	4.7.3.7.6 3 complete shear and seal tests	4.7.3.7.1 3 complete shear and seal tests	4.7.3.7.1 3 complete shear and seal tests
Shearing Range		4.7.3.7.2 Reportable	4.7.3.7.2 Reportable

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Off-Center Shearing	4.7.3.7.4 Reportable	4.7.3.7.3 Reportable	4.7.3.7.3 Reportable
Shear side-load testing	N/A	4.7.3.7.5 Reportable	4.7.3.7.5 Reportable
Low temperature	4.7.3.10 3 Pressure cycles	4.7.3.10 3 pressure cycles	4.7.3.10 3 pressure cycles
Continuous high temperature	4.7.3.11 10 Pressure cycles	4.7.3.11 10 pressure cycles	4.7.3.11 10 pressure Cycles
Extreme high temperature	4.7.3.12 1 hour hold time	4.7.3.12 1 hour hold time	4.7.3.12 1 hour hold time
^a The results of these tests can be scaled to create data for other operator sizes using evaluation of closing ratios and operating pressures and hydraulic areas.			

Test results can be used to qualify other SBR assemblies provided:

1. No essential variables have changed as specified in **4.5.3**.
2. The rated working pressure is equal to or lower than the equipment tested.
3. The temperature rating is within the qualified temperature range.
4. The same shear blade profile geometry is used.

Table 15 – Shear Requirements Wireline Class

Nominal bore size	Material size and grade ^a
2-9/16 in (65.09 mm)	For all bore sizes the following wire shall be successfully sheared: <ul style="list-style-type: none">○ Single wire 0.125 in Material: Extra Improved Plow Steel○ Single wire 0.160 in Material: Extra Improved Plow Steel○ Single wire 0.219 in Material: Galvanized Improved Plow Steel○ Single cable 5/16 in Material: Galvanized Improved Plow Steel○ Single cable 15/32 in Material: Galvanized Extra Improved Plow Steel○ Four wires 0.125 in Material: Extra Improved Plow Steel○ Two cables 7/32 in Material: Galvanized Improved Plow Steel
3-1/16 in (77.79 mm)	
4-1/16 in (103.19 mm)	
5-1/8 in (130.18 mm)	
6-3/8 in (161.93 mm)	
7 -1/16 in (179.39 mm)	
9 in (228.60 mm)	
Wire standard API 9A Specification for Wire Rope may be used.	

Table 16 – Shear Requirements CT Class

Nominal bore size	Material size and Grade ^a
2-9/16 in (65.09 mm)	1.25 in OD minimum wall 0.175" minimum Grade 90K
3-1/16 in (77.79 mm)	1.50 in OD minimum wall 0.175" minimum Grade 90K
4-1/16 in (103.19 mm)	2.00 in OD minimum wall 0.203" minimum Grade 90K
5-1/8 in (130.18 mm)	2.375 in OD minimum wall 0.224" minimum Grade 90K
6-3/8 in (161.93 mm)	2.375 in OD minimum wall 0.224" minimum Grade 90K
7 1/16 in (179.39 mm)	2-3/8 in OD minimum wall 0.224" minimum Grade 90K
^a Coiled Tubing Manufacturing Standard API 5ST may be used.	

Table 17 – Shear Requirements Snubbing Operations

Nominal bore size	Material size and Grade ^a
3-1/16 in (77.79 mm)	1.315 in OD Grade N80 1.80 lb/ft
4-1/16 in (103.19 mm)	1.900 in OD Grade N80 2.90 lb/ft
5-1/8 in (130.18 mm)	2 3/8 in OD Grade N80 5.95 lb/ft
7 1/16 in (179.39 mm)	3.50 in OD Grade E75 13.3 lb/ft
9 in (228.60 mm)	3 1/2 in OD Grade G105 13.3 lb/ft
11 in (279.40 mm)	5 in OD Grade G105 19.5 lb/ft
13-5/8 in (346.08 mm)	5 in OD Grade G105 19.5 lb/ft
^a Tubing Manufacturing standard API 5CT and 5DP may be used.	

4.7.2.2.4 Non-sealing Shear Rams

Non-sealing shear rams shall be tested in accordance with **Table 18**. The indicated tests shall be performed and the minimum performance criteria shall be achieved.

Test results can be used to qualify other non-sealing shear ram assemblies provided:

1. No essential variables have changed as specified in **4.5.3**.
2. The rated working pressure is equal to or lower than the equipment tested.
3. The same shear blade profile geometry is used.

TABLE 18 – Required Tests and Performance Criteria for Non-Sealing Shear Rams

Test	Wireline Class Minimum Performance Criteria	CT Class Minimum Performance Criteria	Snubbing Class Minimum Performance Criteria
Shearing test	4.7.3.7.6 3 complete Shear Tests	4.7.3.7.1 3 complete shear tests	4.7.3.7.1 3 complete Shear Tests
Shearing range		4.7.3.7.2 Reportable	4.7.3.7.2 Reportable
Off-Center Shearing	4.7.3.7.4 Reportable	4.7.3.7.3 Reportable	4.7.3.7.3 Reportable
Shearing side-load testing	N/A	4.7.3.7.5 Reportable	4.7.3.7.5 Reportable

4.7.2.2.5 Slip and Pipe-Slip Rams

Slip and Pipe-Slip Rams shall be tested in accordance with **Table 19**. The indicated tests shall be performed, and the minimum performance criteria shall be achieved.

TABLE 19 – Required Tests and Performance Criteria for Pipe-Slip Rams

Test	Pipe Slip CT Class Minimum Performance Criteria	Slip CT Class Minimum Performance Criteria
Sealing characteristics	4.7.3.2 ^a Reportable	-
Differential Pressure	4.7.3.17 Reportable	-
Fatigue	4.7.3.4 52 pressure cycles	-
Slip Ram Testing	4.7.3.13 Reportable	4.7.3.13 Reportable
Low temperature	4.7.3.10 3 pressure cycles	-
Continuous high temperature	4.7.3.11 10 pressure cycles	-
Extreme high temperature	4.7.3.12 1 hour hold time	-
^a The results of these tests can be scaled to create data for other operator sizes using the evaluation of closing ratios, operating pressures, and hydraulic areas		

Test results can be used to qualify other Slip or Pipe-Slip rams assemblies provided:

1. No essential variables have changed as specified in **4.5.3**.
2. The rated working pressure is equal to or lower than the equipment tested.
3. The temperature rating is within the qualified temperature range.
4. The same slip geometry is used.

4.7.3 Design Validation Tests

4.7.3.1 Test of sealing characteristics, Wireline Ram-type Pressure Control Component

4.7.3.1.1 Ram closure against zero initial wellbore pressure

4.7.3.1.1.1 Purpose

This test determines the actual opening or closing pressure required to either maintain or break a wellbore pressure seal.

4.7.3.1.1.2 Protocol

The Test Protocol shall be as follows:

- a. Disengage any automatic locking system on the ram closing device.
- b. Close the rams using manufacturer's recommended closing pressure.
- c. Initially apply 500 psi (3.45 MPa) wellbore pressure and then reduce the closing pressure slowly until a leak develops. Note the operating pressure at which the leak occurs or note that a leak did not occur at zero closing pressure.
- d. Reapply the recommended closing pressure, increase the wellbore pressure by 500 psi (3.45 MPa) above the previous step, and again reduce the closing pressure (or increase opening pressure) until a wellbore leak occurs. Record the operating pressure at which the leak occurs or note that a leak did not occur at zero closing pressure.
- e. Repeat **step d** until the wellbore pressure equals the rated working pressure of the ram component. The wellbore pressure increment shall be 500 psi (3.45 MPa) until the wellbore pressure exceeds 5 000 psi (34.45 MPa). Thereafter the wellbore pressure increment shall be 1 000 psi (6.89 MPa).

4.7.3.1.2 Ram closure against elevated wellbore pressure, Wireline Ram-type Component

4.7.3.1.2.1 Purpose

The test determines the ability of the ram front seal to affect a seal when closing against elevated wellbore pressures.

4.7.3.1.2.2 Protocol

The Test Protocol shall be as follows:

- a. Apply the test-step wellbore pressure [initially the wellbore pressure is 500 psi (3.45 MPa)].

- b. Close ram component with manufacturer's recommended closing pressure (adjust upward if required).
- c. Ensure that the wellbore pressure above and below the ram is equal.
- d. Increase the wellbore pressure below the ram by 500 psi (3.45 MPa) above the set level.
- e. Confirm a wellbore pressure seal.
- f. Lower the operator closing pressure until a leak develops.
- g. Bleed off wellbore and top flange pressures and open ram component.
- h. Repeat steps **a** through **g**, increasing the wellbore pressure to the rated working pressure of the ram component.

4.7.3.1.3 Sealing Characteristics Documentation, Wireline Ram-type Component

Documentation for Sealing Characteristics shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- Record of wellbore pressure and operator closing pressure throughout the tests.
- Closing pressure required to maintain a wellbore pressure seal for each test step closing against zero initial wellbore pressure.
- Closing or opening pressure required to break a wellbore pressure seal for each test step closing against zero initial wellbore pressure.
- Closing pressure to effect a wellbore pressure seal for each test step closing against elevated wellbore pressure.
- Closing pressure at which a leak developed for each test step closing against elevated wellbore pressure.

4.7.3.2 Test of sealing characteristics, CT, and Snubbing Ram-type Components

4.7.3.2.1 Minimum Operator Pressure for Low Pressure Sealing (MOPFLPS) against zero wellbore pressure

4.7.3.2.1.1 Purpose

This test determines the minimum operator pressure required for the ram assemblies to affect a low-pressure wellbore seal when closing against zero initial wellbore pressure.

4.7.3.2.1.2 Protocol

The Test Protocol shall be as follows:

- a. Close rams at lowest expected closing pressure required to affect a seal.
- b. Attempt a 200 psi to 300 psi (1.38 MPa to 2.07 MPa) wellbore pressure test with a hold period of 5 minutes.
- c. If test is unsuccessful, bleed all wellbore pressure, increase closing pressure.
- d. Repeat **step b & step c** as required determining the lowest closing pressure that results in a successful wellbore seal. This is the ram's MOPFLPS closing against zero wellbore pressure for the operator assembly used.

4.7.3.2.2 Minimum Operator Pressure for Low Pressure Sealing (MOPFLPS) at elevated wellbore pressure

4.7.3.2.2.1 Purpose

This test determines the minimum operator pressure required for the ram assemblies to affect a low (differential) pressure wellbore seal when closing against elevated wellbore pressure.

4.7.3.2.2.2 Protocol

The Test Protocol shall be as follows:

- a. Pressurize wellbore above and below rams to 1 000 psi (+500/-0 psi).
- b. Close rams (on mandrel, if applicable) with MOPFLPS obtained in **4.7.3.2.1.2** plus the additional closing pressure required to overcome actual wellbore pressure (actual wellbore pressure divided by closing ratio).
- c. Increase the wellbore pressure below the rams by 200 psi to 300 psi (1.38 MPa to 2.07 MPa) with a hold period of 5 minutes.
- d. Confirm a wellbore seal by recording the wellbore pressure above and below the rams and verify they are stabilized per the manufacturer's defined criteria.
- e. If unsuccessful, bleed all wellbore pressure, increase closing pressure and repeat **step b, step c and step d**.
- f. The lowest closing pressure that results in a successful wellbore seal is the ram's MOPFLPS at that elevated wellbore pressure increment for the operator assembly used.
- g. Open rams and repeat **step a through step f**, increasing the wellbore pressure in increments until it equals the rated working pressure of the ram component (+500/-0psi). The wellbore pressure increment shall be determined to result in a minimum of five approximately equal-spaced data points.

4.7.3.2.3 Wellbore Pressure Assist

4.7.3.2.3.1 Purpose

This test is to quantify the effect of wellbore pressure assist on maintaining a seal. The result is the minimum operating pressure required to maintain a seal at rated wellbore pressure with the locking mechanism disengaged, or the minimum wellbore pressure that maintains a seal at zero operator pressure with the locking mechanism disengaged.

4.7.3.2.3.2 Protocol

The Test Protocol shall be as follows:

- a. Close rams at manufacturer's recommended operating pressure.
- b. Raise wellbore pressure to rated working pressure
- c. Confirm a wellbore seal with a 3-minute hold.
- d. Reduce operator closing pressure in increments until a leak develops or closing pressure is fully vented.
- e. If a leak develops, record the wellbore pressure and minimum operator closing pressure obtained.
- f. If closing pressure is fully vented, reduce wellbore pressure in increments until a leak develops.
- g. If a leak develops, record the minimum wellbore pressure obtained and the operator closing pressure.

4.7.3.2.4 Sealing Characteristics Documentation

Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)

Record of test results shall include:

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- MOPFLPS at zero wellbore pressure
- Table of MOPFLPS at elevated wellbore pressures
- Wellbore pressure assist results at which leakage occurred.

4.7.3.3 Fatigue test, Wireline Class, Ram-type Component

4.7.3.3.1 Purpose

This test determines the ability of the ram seals to maintain a wellbore pressure seal after repeated closings and openings.

4.7.3.3.2 Protocol

The Test Protocol shall be as follows:

- a. Install test mandrel in well intervention pressure control component for pipe ram tests. No test mandrel is required in SBR tests.
- b. Close and open the rams seven times using manufacturer's recommended operating pressure, On every seventh closure, pressure-test the rams at 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and the full rated working pressure (+500/-0 psi) of the ram. The operating pressure for this step shall be consistent until minimum performance criteria have been achieved.
- c. On every seventh pressure test cycle, close the rams and engage the ram locking device, then relieve all hydraulic pressure prior to performing the pressure test. Test pressures shall each be stabilized and held for a minimum period of 3 min.
- d. Repeat **step b** and **step c** until the rams fail a pressure test or until the minimum performance requirements of section are met.
- e. Document any observed wear following the test.
- f. The ram blocks shall be MP or LP inspected after testing, in accordance with the manufacturer's written procedures

NOTE: Ram Locking Device failure may be repaired during fatigue testing unless test is also qualifying ram locking device test.

NOTE: Minimum performance requirements can be found on **Tables 9, 10, and 11**.

4.7.3.3.3 Fatigue Test Documentation, Ram-type Component

Fatigue Test Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- Magnetic particle (MP) or Liquid Penetrant (LP) inspection of ram blocks, after testing, in accordance with manufacturer's written procedure.
- The number of successful closures and pressure cycles attained.
- Record of wellbore pressure and operator closing pressure throughout the test.

4.7.3.4 Fatigue test, CT Class and Snubbing Class, Ram-type Component

4.7.3.4.1 Purpose

This test determines the ability of the ram seals to maintain a wellbore pressure seal after repeated closings and openings.

4.7.3.4.2 Protocol

The Test Protocol shall be as follows:

- a. Install test mandrel in well intervention pressure control component for pipe ram tests. No test mandrel is required in SBR tests.
- b. Close and open the rams seven times using manufacturer's recommended operating pressure, for SBRs, the rams should be closed with an average closing time of 30 seconds or less. On every seventh closure, pressure-test the rams at 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and the full rated working pressure (+500/-0 psi) of the rams. The hydraulic operating pressure for this step shall be consistent until the minimum performance criteria has been achieved.
- c. On every seventh pressure test cycle, close the rams and engage the ram locking device, then relieve all hydraulic pressure prior to performing the pressure test. Test pressures shall each be stabilized and held for a minimum period of 3 min.
- d. Repeat **step b** and **step c** until the rams fail a pressure test or until the minimum performance requirements are met.
- e. Document any observed wear following the test.
- f. The ram blocks shall be MP or LP inspected after testing, in accordance with the manufacturer's written procedures

NOTE: Ram Locking Device failure may be repaired during fatigue testing unless test is also qualifying ram locking device test.

NOTE: Minimum performance requirements can be found on **Tables 9, 10, and 11**.

4.7.3.4.3 Fatigue Test Documentation, Ram-type Component

Fatigue Test Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- MP or LP inspection of ram blocks, after testing, in accordance with manufacturer's written procedure.
- The number of successful closures and pressure cycles attained.
- Record of wellbore pressure and operator closing pressure throughout the test.

4.7.3.5 Fatigue test, Snubbing Class, Ram-type Component

4.7.3.5.1 Purpose

This test determines the ability of the ram seals to maintain a wellbore pressure seal after repeated closings and openings.

4.7.3.5.2 Protocol

The Test Protocol shall be as follows:

- a. Install test mandrel in well intervention pressure control component for pipe ram tests. No test mandrel is required in SBR tests.
- b. The rams shall be closed with an accumulator system with an average closing time of 30 seconds or less. Close the Stripping rams and on every cycle perform a pressure test to the full rated working pressure (+500/-0 psi). Test pressures shall be stabilized and held for a minimum

period of 3 minutes. On every seventh closure, pressure-test the rams at 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and the full rated working pressure (+500/-0 psi) of the ram. The operating pressure for this step shall be consistent until minimum performance criteria have been achieved. Perform this test for 70 Cycles (70 successful pressure tests). After the 70 cycles are achieved change the procedure to close and open the rams and on every 7th cycle perform the pressure test at 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and the full rated working pressure (+500/-0 psi) of the ram. Continue cycling the rams until you have achieved 721 cycles (during the additional cycles after the 70th cycle it is allowable to change snubbing ram inserts, but no other seal can be replaced). All 721 cycles shall be achieved with no leakage (if you have a leakage on the ram inserts after the initial 70 cycles it is acceptable to replace the insert and continue until you reach the 721 cycles. Bonnet Gasket and ram seals can be replaced after the initial 70 Cycles.

- c. On every seventh pressure test cycle, close the rams and engage the ram locking device, then relieve all hydraulic pressure prior to performing the pressure test. Test pressures shall each be stabilized and held for a minimum period of 3 min. The minimum number of ram locking device tests is 10.
- d. Document any observed wear following the test.
- e. The ram blocks shall be MP or LP inspected after testing, in accordance with the manufacturer's written procedures

NOTE: Minimum performance requirements can be found on **Table 9**.

NOTE: Ram Locking Device failure may be repaired during fatigue testing.

4.7.3.5.3 Fatigue Test Documentation, Ram-type Component

Fatigue Test Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- MP or LP inspection of ram blocks, after testing, in accordance with manufacturer's written procedure.
- The number of successful closures and pressure cycles attained.
- Record of wellbore pressure and operator closing pressure throughout the test.

4.7.3.6 Test for Stripping Life, Snubbing Stripping Ram-type Component

4.7.3.6.1 Purpose

This test determines the ability of the ram packers and seals to control wellbore pressure while running pipe through the closed rams without exceeding a leak rate of 1.0 gal/min (3.8 liter/min).

4.7.3.6.2 Protocol

The test protocol shall be as follows:

Fixed-bore rams shall use test mandrel in accordance with **Table 11**. No tool joint is required for stripping on Fixed Bore Rams.

Variable Bore Rams shall use a test mandrel selected in the sealing range by the equipment manufacturer. No tool joint is required for stripping on Variable Bore Rams.

The Test Protocol shall be as follows:

- a. Determine the initial closing pressure by adding 100 psi (0.69 MPa) (frictional effects) to the manufacturer's minimum recommended closing pressure for 1000 psi (6.89 MPa) wellbore pressure. After closing on the test mandrel using this pressure and applying 1000 psi (6.89 MPa) wellbore pressure, reduce the closing pressure until the ram component leak occurs, not to exceed 1.0 gal/min (3.8 liter/min) (to wet the test mandrel wall).
- b. Reciprocate the test mandrel at a speed of approximately 2 ft/sec (600 mm/s) until an equivalent of 30 ft (9.1 m) of pipe has been lubricated through the packer seals.
- c. Bleed off wellbore pressure, and open the rams.
- d. Close ram with previously used closing pressure.
- e. Repeat **step b, step c and step d**. As the leak rate increases, raise the closing pressure, as needed, not to exceed the maximum operating pressure, until the leak rate exceeds 1.0 gal/min (3.8 liter/min) or an equivalent of 10 000 ft (3048 m) of pipe has passed through the packer seals.

4.7.3.6.3 Stripping Test Documentation, Ram-type Component

Documentation shall include:

- Diameter of test mandrel used
- Record of reciprocating speed
- Equivalent length of pipe stripped
- Record of wellbore pressure and operator closing pressure throughout the test.
- Document condition of all ram packers as they are removed after tests.

4.7.3.7 Shear and Shear-Blind Ram

4.7.3.7.1 Shear and Shear-Blind Coiled Tubing Rams and Snubbing Class Rams

4.7.3.7.1.1 Purpose

This test determines the shearing and sealing capabilities (for rams with seals) for selected tubular shear samples.

4.7.3.7.1.2 Protocol

The test protocol shall be as follows:

The specimen used for the shear test as a minimum shall be in accordance with **Table 16** for Coiled Tubing and **Table 17** for Snubbing well intervention pressure control components.

The Test Protocol shall be as follows:

1. For Shear and Shear-Blind Rams, suspend a section of pipe/tubing (as specified in **Table 16** and **Table 17** as appropriate for the ram size), vertically above the ram component and lower it into the wellbore. Testing shall be performed without axial loading of the pipe/tubing. Close the rams and shear the pipe/tubing in a single operation.
2. CT Shear-Blind Ram Tests:
 - a. For the "standard" CT Shear-Blind Rams, the shear cut shall provide an opening in the lower cut end of at least 30% of the original cross-sectional area to facilitate subsequent through-tubing pumping and well killing operations. The geometry of the shear cut should also enable fishing operations.
 - b. For the "dedicated" CT Shear-Blind Rams, the shear cut may or may not provide an opening or specific geometry of the lower cut end of the CT workstring.

3. CT or Snubbing Shear-Blind Ram Tests:
 - a. Raise the wellbore pressure to 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.
 - b. Raise wellbore pressure to maximum rated working pressure of ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
 - c. Reduce wellbore pressure to zero, open rams, and inspect.
4. Repeat steps 1, 2 and 3 as seen above for two additional samples.
 - a. For the CT Shear and/or Shear-Blind Ram Tests,
 - i. One test shall be performed with the slips closed on the tubing below the Shear or Shear-Blind rams.
 - ii. One test shall be performed with 7/32" OD cable installed inside the coiled tubing sample.
 - b. For the Snubbing Test, the bottom of the pipe shall be constrained from moving downward on the final shear test.

4.7.3.7.1.3 Shear Ram and Shear-Blind Ram Test Documentation

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- For the Coiled Tubing Class the coiled tubing description (nominal OD size, wall thickness, and grade), actual OD, wall thickness, mechanical properties, and impact properties as specified in API Specification 5ST.
- For the Coiled Tubing "standard" Shear-Blind Ram Class, it is required to document the ID cross sectional area of the lower cut end of the coiled tubing to verify at least 30% of the original ID cross sectional area is available to pump down.
- For the Snubbing Shear-Blind Ram Class, the pipe description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API Specification 5CT or 5DP
- Record of wellbore pressure and operator closing and opening pressure throughout the test;
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers and Shear Blades/Rams as they are removed after tests.

4.7.3.7.2 Shearing Diametrical Design Range Test

4.7.3.7.2.1 Purpose

This test determines the ability of a shear ram to shear a diametrical design range of tubular and effect a seal (for Shear-Blind Rams) without mechanically binding the ram. The shearing operator pressure is outside of the purpose of this test. Ram components may be changed between individual tests.

4.7.3.7.2.2 Protocol

The test protocol shall be as follows:

The tubular used for this test shall be designated by the equipment manufacturer. The equipment manufacturer shall demonstrate that the shear rams can shear (and seal for the Shear-Blind Rams) the wellbore for a specified minimum/maximum outer diameter and maximum wall thickness. Three (3) cuts at the minimum and the maximum outer diameters shall be performed.

The Test Protocol shall be as follows:

- a. Suspend a section vertically above the ram component and lower it into the wellbore. Testing shall be performed without axial loading of the pipe, and with zero wellbore pressure. There is no requirement to axially constrain the bottom of the sample in this test.
- b. Close the rams and shear the pipe in a single operation.
- c. Raise the wellbore pressure to 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.
- d. Raise wellbore pressure to maximum rated working pressure of ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
- e. Reduce wellbore pressure to zero, open rams, and inspect.

NOTE: **Step c**, **step d** and **step e** are only applicable to Shear-Blind Rams.

4.7.3.7.2.3 Shearing Diametrical Design Range Documentation

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- For the Coiled Tubing Class the coiled tubing description (nominal OD size, wall thickness, and grade), actual OD, wall thickness, mechanical properties, and impact properties as specified in API Specification 5ST.
- For the Snubbing Class the pipe description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API Specification 5CT or 5DP
- Record of wellbore pressure and operator closing and opening pressure throughout the test.
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers and Shear Blades/Rams as they are removed after tests.

4.7.3.7.3 Diametrical Off-Center Shearing Test

4.7.3.7.3.1 Purpose

This test determines the ability for the shear rams to shear the tubular sample, and seal (sealing only required for Shear-Blind Rams) the wellbore when the shearing sample is initially in contact with the side of the wellbore for the minimum tubular size in the design range. There is not a requirement to restrain the pipe against the side of the wellbore in this test.

4.7.3.7.3.2 Protocol

The test protocol shall be as follows:

The pipe/tubing used for this test shall be designated by the equipment manufacturer. The equipment manufacturer shall demonstrate that the shear rams can shear (and seal for the Shear-Blind Rams) the wellbore for the minimum tubular size in the design range.

The Test Protocol shall be as follows:

- a. Suspend a section of tubing/pipe vertically above the ram component and lower it into the wellbore. Testing shall be performed without axial loading of the pipe/tubing, with the

pipe/tubing initially in contact with the side of the wellbore (perpendicular to the axis of the ram) and with zero wellbore pressure.

- b. Close the rams and shear the pipe/tubing in a single operation.
- c. Raise the wellbore pressure to 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.
- d. Raise wellbore pressure to maximum rated working pressure of the ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
- e. Reduce wellbore pressure to zero, open rams, and inspect.

NOTE: **step c**, **step d** and **step e** are only applicable to Shear-Blind Rams.

4.7.3.7.3.3 Diametrical Off-Center Shearing Documentation

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- For the Coiled Tubing Class the coiled tubing description (nominal OD size, wall thickness, and grade), actual OD, wall thickness, mechanical properties, and impact properties as specified in API Specification 5ST.
- For the Snubbing Class the pipe description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API Specification 5CT or 5DP
- Record of wellbore pressure and operator closing and opening pressure throughout the test.
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers and Shear Blades/Rams as they are removed after tests.

4.7.3.7.4 Off-Center Shearing Test Wireline

4.7.3.7.4.1 Purpose

This test determines the ability for the shear rams to shear wireline (and seal for the Shear-Blind Rams) the wellbore when the shearing sample is initially in contact with the side of the wellbore.

4.7.3.7.4.2 Protocol

The test protocol shall be as follows:

The equipment manufacturer shall demonstrate that the shear rams can shear (and seal for the Shear-Blind Rams) the wellbore for the specified wireline size.

The Test Protocol shall be as follows:

- a. Suspend a section of wire within the range of .092" - .125" OD and locate along the side of the ram component bore perpendicular to the axis of the ram. Apply a tension to the wire (maximum of 200 lbs [90kg]).
- b. Close the rams and shear the wire in a single operation.

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- c. Raise the wellbore pressure to 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.
- d. Raise wellbore pressure to maximum rated working pressure of ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
- e. Reduce wellbore pressure to zero, open rams, and inspect.

NOTE: **step c**, **step d** and **step e** are only applicable to Shear-Blind Rams.

4.7.3.7.4.3 Diametrical Off-Center Shearing Documentation

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- The wire description (nominal size, actual OD size, and grade, mechanical properties, as specified in API Specification 9A.
- Record of wellbore pressure and operator closing and opening pressure throughout the test.
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers and Shear Blades/Rams as they are removed after tests.

4.7.3.7.5 Shearing Side Load – Coiled Tubing and Snubbing

4.7.3.7.5.1 Purpose

This test determines the side load force the shear rams can resist and still shear and seal the wellbore (sealing only required for the Shear-Blind Rams) when the tubular is initially in contact with the side of the wellbore (perpendicular to the axis of the ram.)

The manufacturer shall validate through shear testing the maximum side load force the shear rams can resist when the shearable component is initially in contact with the side of the wellbore (perpendicular to the axis of the ram.) It is only required to perform one shear test with side load. The pipe used for this test as a minimum shall be in accordance with **Table 16** and **Table 17**.

4.7.3.7.5.2 Protocol

The test protocol shall be as follows:

The tubing/pipe used for this shear test shall be in accordance with **Table 16** and **Table 17**. The manufacturer shall validate through testing the side load force the shear rams can resist when the shearable component is initially in contact with the side of the wellbore (perpendicular to the axis of the ram.) The equipment manufacturer shall demonstrate that the shear rams can shear the sample, and then seal (sealing only required for the Shear-Blind Rams) the wellbore at rated working pressure.

The Test Protocol shall be as follows:

- a. The initial test setup shall be determined by the equipment manufacturer with the side load applied and zero initial wellbore pressure.
- b. Close the rams and shear the pipe in a single operation.
- c. Perform a low wellbore pressure test at 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.

- d. Perform a high wellbore pressure test at the maximum rated working pressure of the ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
- e. Reduce wellbore pressure to zero, open rams, and inspect.

4.7.3.7.5.3 Shearing Side Load Documentation

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly)
- The arrangement of the test setup, describing how the side load is applied and how the test sample is restrained.
- The side load through the duration of the test up to shearing point which may be measured or calculated.
- For the Coiled Tubing Class the coiled tubing description (nominal OD size, wall thickness, and grade), actual OD, wall thickness, mechanical properties, and impact properties as specified in API Specification 5ST.
- For the Snubbing Class the pipe description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API Specification 5CT or 5DP
- Record of wellbore pressure and operator closing and opening pressure throughout the test.
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers and Shear Blades/Rams as they are removed after tests.

4.7.3.7.6 Shearing Test for Wireline

4.7.3.7.6.1 Purpose

This test determines the ability of a shear ram to shear a required range of wireline sizes and effect a seal (for the Shear-Blind Rams). Ram components may be changed after the third shear of each specified shear sample.

4.7.3.7.6.2 Protocol

The test protocol shall be as follows:

The wire used for this test shall be in accordance with **Table 15**. The equipment manufacturer shall demonstrate that the shear rams can shear and seal (for the Shear-Blind Rams) the wellbore for all items in **Table 12**. Three (3) cuts shall be made for each specimen size.

The Test Protocol shall be as follows:

- a) Suspend a section vertically above the well intervention pressure control component and lower it into the wellbore. Testing shall be performed without axial loading of the wire, and with zero wellbore pressure.

A wireline clump weight (mass attached to the wireline that can be used during shearing operations) may be used, with the clump weight not to exceed 3 lbs.

- b) Close the rams and shear the wire in a single operation.

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- c) Raise the wellbore pressure to 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.
- d) Raise wellbore pressure to maximum rated working pressure of the ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
- e) Reduce wellbore pressure to zero, open rams, and inspect.

NOTE: **step c**, **step d** and **step e** are only applicable to Shear-Blind Rams.

4.7.3.7.6.3 Shearing Test for Wireline Documentation

Documentation shall include:

- The manufacturer's designation or model number for the Shear Ram or Shear-Blind Ram pressure control component.
- The wire description (nominal size, actual OD size, and grade, mechanical properties, as specified in API Specification 9A.
- Record of wellbore pressure and operator closing and opening pressure throughout the test.
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers and shearing blades/rams as they are removed after tests.

4.7.3.8 Ram access test, Ram-type Component

4.7.3.8.1 Purpose

This test determines the ability of the well intervention pressure control component to undergo repeated ram and/or ram packer changes without affecting operational characteristics.

4.7.3.8.2 Protocol

The test protocol shall be as follows:

A ram access cycle includes opening the ram bonnets or doors to access the ram blocks, then closing the ram bonnets or doors in accordance with the manufacturer's recommended guidelines. This test may be performed with any sealing ram.

The Test Protocol shall be as follows:

- a. Perform the manufacturer's recommended procedure for accessing ram. Open access points to their full extent required for ram removal.
- b. Perform the manufacturer's recommended procedure for closing all ram-access points.
- c. Repeat above steps a total of 200 times. Every twentieth time, pressure-test the ram to rated working pressure (+500/-0 psi) for a minimum hold period of 3 minutes after pressure stabilization.

4.7.3.8.3 Ram Access Test Documentation, Ram-type Component

Documentation shall include the

- The ram and well intervention pressure control component configurations used.

- Record of wellbore pressure, and operator closing pressure throughout the test;
- The number of access cycles to failure or 200 access cycles and 10 wellbore pressure cycles, whichever is less.

4.7.3.9 Ram locking device test, Ram-type Component

4.7.3.9.1 Purpose

This test determines the ability of the well intervention pressure control component ram-locking device to maintain a wellbore pressure seal after removing the closing and/or locking pressure(s).

4.7.3.9.2 Protocol

The test protocol shall be as follows:

Note This test may be carried out as part of the fatigue test provided the locking cycle count is documented and the lock is not serviced or replaced.

The Test Protocol shall be as follows:

- a) Close the rams with the manufacturers recommended closing pressure.
- b) Close the ram locks hydraulic or manual. Record the torque applied for manual locks.
- c) Bleed off the hydraulic closure pressure.
- d) Raise the wellbore pressure to 200 psi to 300 psi (1.38 MPa to 2.07 MPa) and hold for a minimum of 5 minutes after stabilization, examining for leaks.
- e) Raise wellbore pressure to maximum rated working pressure of the ram component (+500/-0 psi) and hold for a minimum of 10 minutes after stabilization, examining for leaks.
- f) The ram-locking device shall maintain the wellbore pressure seal after removing the closing and locking pressure(s).
- g) Visible wellbore leaks, evidence of control system leaks, or a failure to lock or unlock shall be considered a failed locking test.
- h) For hydraulic locks record the opening pressure required to open the locks.

4.7.3.9.3 Ram Locking Device Documentation

Documentation shall include:

- The ram and well intervention pressure control component configurations used;
- Record of wellbore pressure, operator closing pressure throughout the test;
- Record of the operator lock and unlock pressure (for applicable designs) for the locking device throughout the test;
- The number of locking cycles obtained.

4.7.3.10 Low Temperature Design Validation, Ram Type Component

4.7.3.10.1 Purpose

This test determines the ability of the non-metallic seals and molded sealing assemblies used as pressure controlling and or pressure containing members to maintain a wellbore pressure seal after

repeated closings and openings at the minimum rated temperature of the non-metallic sealing components.

4.7.3.10.2 Protocol

The test protocol shall be as follows:

The test shall not be started until the well intervention pressure control component and wellbore temperature is at or below the test temperature. The wellbore temperature below the rams shall be maintained at or below the test temperature for the duration of the hold times.

The Test Protocol shall be as follows:

- a. Open the well intervention pressure control component and begin the cooling cycle. Continue the cooling until the test fluid temperature is reached and has stabilized.
- b. Close and open the well intervention pressure control component up to seven times using the manufacturer's recommended operating pressure.
- c. With test fluid at or below test temperature, close the well intervention pressure control component and apply 200 psi to 300 psi (1.38 MPa to 2.07 MPa) wellbore pressure and hold for a minimum of 3 minutes after pressure stabilization.
- d. Apply the full rated working pressure (+500/-0 psi) of the well intervention pressure control component and hold for a minimum of 10 minutes after pressure stabilization.
- e. Bleed off wellbore pressure.
- f. Repeat **step b**, **step d** and **step e**, twice more for a total three pressure test cycles.

4.7.3.10.3 Low Temperature Design Validation Documentation, Ram-type Component

Documentation shall include:

- Record of equipment used (e.g. Model, actuator size & Type, Ram Assembly).
- Record of wellbore pressure and actuator closing pressure throughout the tests.
- Record of wellbore temperature throughout the test.

4.7.3.11 Continuous Operating Temperature Design Validation, Ram-type Component

4.7.3.11.1 Purpose

This test determines the ability of the ram packers and seals to maintain a wellbore pressure seal after repeated closings and openings at continuous elevated rated temperature of the non-metallic sealing components.

4.7.3.11.2 Protocol

The test protocol shall be as follows:

The test shall not be started until the wellbore temperature is at or above the test temperature. The wellbore temperature below the rams shall be maintained at or above the test temperature for the duration of the hold times.

The Test Protocol shall be as follows:

- a. Open the well intervention pressure control component and begin the heating cycle. Continue the heating until the test fluid temperature is reached and has stabilized.
- b. Close and open the well intervention pressure control component three times using the manufacturer's recommended operating pressure.
- c. With test fluid at or above test temperature, close the well intervention pressure control component and apply 200 psi to 300 psi (1.38 MPa to 2.07 MPa) wellbore pressure and hold for a minimum of 5 minutes after pressure stabilization.
- d. Apply the full rated working pressure (+500/-0 psi) of the well intervention pressure control component and hold for a minimum of 10 minutes after pressure stabilization.
- e. Bleed off wellbore pressure.
- f. Repeat **step b**, **step c** and **step d**, until the minimum acceptance criteria is met. See **Tables 12, 13, and 14**.

4.7.3.11.3 Continuous Operating Temperature Test Documentation, Ram-type Component

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly).
- Record of wellbore pressure and operator closing pressure throughout the tests.
- Record of wellbore temperature throughout the test.

4.7.3.12 Extreme High Temperature Design Validation, Ram-type Component

4.7.3.12.1 Purpose

This test determines the ability of the of the non-metallic seals and molded sealing assemblies used as pressure controlling and or pressure containing members to maintain a wellbore pressure seal at the extreme temperature of the non-metallic sealing components. The test shall consist of a full rated pressure test with a minimum hold time of 60 minutes at the extreme temperature rating.

4.7.3.12.2 Protocol

The test protocol shall be as follows:

The test shall not be started until the wellbore temperature is at or above the test temperature. The wellbore temperature below the rams shall be maintained at or above the test temperature for the duration of the hold times.

The Test Protocol shall be as follows:

- a. Open the well intervention pressure control ram component and begin the heating cycle. Continue the heating until the test fluid temperature is reached and has stabilized.
- b. With test fluid at or above test temperature, close the well intervention pressure control ram component and apply 200 psi to 300 psi (1.38 MPa to 2.07 MPa) wellbore pressure and hold for a minimum of 3 minutes after pressure stabilization.
- c. Apply the full rated working pressure (+500/-0 psi) of the well intervention pressure control ram component and hold for a minimum of 60 minutes after pressure stabilization.
- d. Bleed off wellbore pressure.

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4.7.3.12.3 Extreme High Temperature Test Documentation, Ram-type Component

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly).
- Record of wellbore pressure and operator closing pressure throughout the tests.
- Record of wellbore temperature throughout the test.

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TABLE 20 – Coiled Tubing Pipe Sizes(s) and Performance Criteria

Nominal size designation		Coiled Tubing Pipe Size Minimum of 90K Grade of CT		Min. Wall Thickness	Max. Wall Thickness	Minimum Loads, Lbs	
in	(mm)	mm	(in)			Pipe Light	Pipe Heavy
2-9/16	65.09	1.250	38.10	.087 - .109	.156 - .175	4.7.3.13.8	35,000
3-1/16	77.79	1.500	44.45	.095 - .118	.175 - .203	4.7.3.13.8	50,000
4-1/16	103.19	2.000	50.80	.125 - .145	.203 - .224	4.7.3.13.8	78,000
5-1/8	130.18	2.375	60.33	.156 - .175	.224 - .250	4.7.3.13.8	90,000
6-3/8	161.93	2.375	60.33	.156 - .175	.224 - .250	4.7.3.13.8	90,000
7-1/16	179.39	2.375	60.33	.156 - .175	.224 - .250	4.7.3.13.8	90,000

4.7.3.13 Slip Ram and Pipe-Slip Ram Test

4.7.3.13.1 Purpose: The purpose of this test is to determine the holding capabilities of the Slip Rams and Pipe-Slip Rams.

4.7.3.13.2 Protocol:

The test protocol shall be as follows:

The Slip Ram and Pipe-Slip Ram shall be tested to confirm the ability of the slip inserts to hold a segment of the CT OD within the designated wall thickness range without movement to the maximum projected axial load as specified in **Table 20**

4.7.3.13.3 Slip Ram and Pipe-Slip Ram tests shall be conducted using a segment of CT which meets the following conditions for the given ID bore of the well intervention pressure control component:

- Material yield strength equal to or greater than CT-90 Grade tubing specified in **Table 20**
- Outside diameter equivalent to the CT string as shown in **Table 20**
- Wall thickness within the range of wall thicknesses specified in **Table 20**
- The Slip Ram and Pipe-Slip Ram test shall be performed with the ID bore at atmospheric pressure.

4.7.3.13.4 For the Minimum Hydraulic pressure pipe-heavy Slip Ram and Pipe-Slip Ram test, the Slips shall hold the specified segment of CT without movement within the slip inserts to the axial tensile load as given in **Table 20**. The axial tensile load shall be applied from below the closed Slip Ram or Pipe-Slip Ram insert. This test is to validate the minimum hydraulic pressure required to hold the load.

The minimum hydraulic pressure to hold the CT shall not exceed the sum of the rated hydraulic actuator pressure minus the Ram Piston Balance Pressure

Effective hydraulic actuator pressure is the sum of the rated hydraulic actuator pressure minus the ram piston balance pressure

4.7.3.13.5 The minimum hydraulic pressure from **4.7.3.13.4** shall be used to conduct the ram locking system test on the Slip Ram and Pipe-Slip Ram to confirm that the CT segment remains secured without movement within the slip inserts to the test criteria established in **Table 20** after removal of ram actuator hydraulic pressure applied to the CT segment. The Slip Ram and Pipe-Slip Ram lock test shall be

conducted to confirm that the axial tensile load is retained by the mechanical locks engaged at the effective actuator pressure designated in **4.7.3.13.4** after the hydraulic actuator pressure is released.

4.7.3.13.6 A visual and dimensional inspection shall be conducted on the affected segment to confirm that the combined load of the hydraulic ram actuator and axial tensile load does not cause damage to the tubing beyond the indentation of the slip teeth.

4.7.3.13.7 A Maximum Hydraulic pressure pipe-heavy Slip Ram and Pipe-Slip Ram test is to be conducted to evaluate damage to the CT segment with respect to the maximum hydraulic actuator pressure, coupled with the minimum load from **Table 20** applied from below the closed slip insert. A visual and dimensional inspection shall be conducted on the affected segment to confirm that the combined load of the hydraulic ram actuator and axial tensile load does not cause damage to the tubing beyond the indentation of the slip teeth.

4.7.3.13.8 For the Minimum Hydraulic pressure pipe-light Slip Ram and Pipe-Slip Ram test, the slip inserts shall hold the specified segment of CT without movement within the slips inserts to a force greater than or equal to the rated working pressure of the ram component multiplied by the cross-sectional area of the tube body OD as given in **Table 11**. The axial compressive load should be applied from below the closed Slip Ram or Pipe-Slip Ram insert. It is acceptable to perform this test by pulling the CT segment from above the closed slip inserts, however, the results of the test may not be the same as pushing from below the rams. The minimum hydraulic system pressure required to secure the CT segment without movement within the slips inserts shall be recorded.

The minimum hydraulic pressure to hold the CT shall not exceed the sum of the Rated Hydraulic pressure minus the Ram Piston Balance Pressure

4.7.3.13.9 The minimum hydraulic pressure from **4.7.3.13.4** shall be used to conduct the ram locking system on the Slip Ram and Pipe-Slip Ram to confirm that the CT segment remains secured without movement within the slip inserts to the test criteria established in **Table 20** after removal of ram actuator hydraulic pressure applied to the CT segment. The Slip Ram and Pipe-Slip Ram lock test shall be conducted to confirm that the axial compressive load is retained by the mechanical locks engaged at the effective actuator pressure designated in **4.7.3.13.4** after the hydraulic actuator pressure is released.

4.7.3.13.10 A visual and dimensional inspection shall be conducted on the affected segment to confirm that the combined load of the hydraulic ram actuator and axial tensile load does not cause damage to the tubing beyond the indentation of the slip teeth.

4.7.3.13.11 A Maximum hydraulic pressure pipe-light Slip Ram and Pipe-Slip Ram test is to be conducted to evaluate damage to the CT segment with respect to the maximum hydraulic actuator pressure applied, coupled with the maximum anticipated upward thrust force acting on the CT string (axial compressive load applied from below the closed slip insert). A visual and dimensional inspection shall be conducted on the affected segment to confirm that the combined load of the hydraulic ram actuator and axial tensile load does not cause damage to the tubing beyond the indentation of the slip teeth.

4.7.3.13.12 Documentation shall Include

- a. Tube OD, average wall thickness, material yield strength from MTR and designated grade of tube
- b. manufacturer of slip ram assembly, including model, ID bore, rated working pressure and serial number
- c. model of ram assembly actuator, including maximum allowable hydraulic operating pressure of actuator
- d. serial number and/or part number of Slip Ram or Pipe-Slip Ram slip insert, along with description of slip design

- e. condition of slip inserts upon completion of each slip ram test
- f. digital record of hydraulic actuator pressure from start to end of each test, including documentation of test period where axial load is retained using only the ram locks (hydraulic actuator pressure is bled to zero)
- g. Record of wellbore pressure and operator closing and opening pressure throughout the test;
- h. Document the operator hydraulic closing and opening areas.

4.7.3.17 Differential Pressure Test for CT Pipe and CT Pipe-Slip Rams

4.7.3.17.1 Purpose

This test determines the ability of the of the pipe or pipe-slip rams to hold a differential pressure to allow for down-coil pumping kill operations. The pipe or pipe-slip rams should support a differential pressure above the ram greater than or equal to the kill pressure margin. (Kill pressure margin represents the pressure applied above the closed pipe or pipe-slip rams needed to pump kill fluid into the sheared end of the CT workstring and through the CT suspended in the well intervention pressure control stack to either bullhead the fluid to the formation or circulate the fluid within the annulus to create a hydrostatic balance within the wellbore).

4.7.3.17.2 Protocol

The test protocol shall be as follows:

Close the pipe or pipe slip rams with fluid in the bore, fill the cavity above the closed pipe ram with fluid.

For 3000 psi rated equipment, apply 1000 psi (6.90 MPa) pressure above the rams to simulate a pump down scenario. Hold the pressure for a minimum of 10 minutes, and record the starting and ending pressure.

For 5000 psi rated equipment, apply 1500 psi (10.35 MPa) pressure above the rams to simulate a pump down scenario. Hold the pressure for a minimum of 10 minutes, and record the starting and ending pressure.

For 10,000 psi rated equipment, apply 2500 psi (17.25 MPa) pressure above the rams to simulate a pump down scenario. Hold the pressure for a minimum of 10 minutes, and record the starting and ending pressure.

For 15,000 psi rated equipment, apply 2500 psi (17.25 MPa) pressure above the rams to simulate a pump down scenario. Hold the pressure for a minimum of 10 minutes, and record the starting and ending pressure.

4.7.3.17.3 Differential Pressure Test for CT Pipe and CT Pipe-Slip Rams Test Documentation.

Documentation shall include:

- Record of equipment used (e.g. Model, Operator size & Type, Ram Assembly).
- Record of Pump down pressure at the beginning and end of the hold period.
- Record the condition of the seals after the tests are performed.

4.8 Operating manual requirements

4.8.1 The manufacturer shall prepare and have available an operating manual for each model or type of well intervention pressure control component manufactured in accordance with this standard. The operating manual shall contain the following information as a minimum:

- a) operation and installation instructions;
- b) physical data;
- c) packers and seals information;
- d) maintenance and testing information, including recommended maintenance frequency based on time, cycles, measurable physical condition, etc;
- e) assembly and disassembly information;
- f) parts information including a recommended spares list;
- g) storage information;

4.8.2 Technical Data Sheet

A summary of the Validation Testing shall be available as per the documentation requirements for each section. The Testing summary will vary between WL, CT, and SB:

a) operational characteristics summary, as applicable;

- 1) sealing characteristics test,
 - i) MOPFLPS (rams only)
- 2) fatigue test,
- 3) stripping life test,
 - i) feet of pipe/ tool joint count
- 4) shear ram test,
 - i) diametrical shear rating
 - ii) shearing range results
 - iii) off-center shearing results
 - iv) shear side loading results
- 5) ram access test,
- 6) ram locking device test,
- 7) temperature rating
- 8) ram assembly temperature rating

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- 9) slip ram test
- 10) differential pressure test

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5 Material requirements

5.1 General

This section describes the material performance, processing and compositional requirements for bodies, bonnets, and end and outlet connections, end connectors, pressure-boundary penetrations. Other Level 2 and Level 1 parts shall be made of materials which satisfy **5.2**, **5.3**, **5.4** and the design requirements in **Section 4**.

(Bonnets described in this document is the item that retains the wellbore pressure and separates the wellbore from the hydraulic actuator.

All material requirements in **Section 5** apply to carbon steels, low-alloy steels and martensitic stainless steels (other than precipitation-hardening types). Other alloy systems (including precipitation-hardening stainless steels) may be used, provided they satisfy the requirements of **Section 5** and the design requirements of **Section 4**.

5.2 Written specifications

5.2.1 Applicability

All metallic and non-metallic **Level 2** or **Level 1** parts shall require a written material specification.

5.2.2 Metallic requirements

The manufacturer's written specified requirements for metallic materials for bodies, bonnets, end and outlet connections, stems, valve bore sealing mechanisms and mandrel hangers shall define the following, along with accept/reject criteria:

- material composition with tolerances;
- material qualification;
- allowable melting practice(s);
- forming practice(s), including hot-working and cold-working practices;
- heat-treatment procedure, including cycle time, quenching practice and temperatures with tolerances and cooling media;
- NDE requirements;
- mechanical property requirements;
- Heat-treating equipment calibration.

5.2.3 Non-metallic Parts

Non-metallic seals exposed to wellbore fluids shall have written material specifications. The manufacturer's written specified requirement for non-metallic materials shall include the following:

- a) Generic base polymer(s) (see ASTM D1418), if applicable
- b) Physical property requirements.
 - i. Hardness in accordance with ASTM D2240 or ASTM D1415
 - ii. Tensile and elongation properties in accordance with ASTM D412 or ASTM D1414
 - iii. Compression set in accordance with ASTM D395 or ASTM D1414
- c) Material qualification that shall meet the equipment class requirement
- d) Storage and age-control requirements

5.3 Level 2 Items

For classification of well control items refer to Table 21

Table 21 Classification of well intervention pressure control Items

Classification	Level
Well intervention pressure control assembly body	Level 2
Well intervention pressure control items, exposed to the wellbore and retains wellbore pressure. (Examples include but not limited to: Bonnets, doors)	Level 2
Integral end connections and loose connections	Level 2
Wireline Rams, CT Rams and Snubbing Rams	Level 2
Piston Rods, Stems exposed to wellbore fluids	Level 2
Wellbore Pressure Assist Chambers	Level 2

5.3.1 All **Level 2** Items parts shall be manufactured from materials as specified by the manufacturer that shall meet the requirements of **Table 22** and **Table 23**.

Charpy V-notch impact testing shall conform to **5.3.5.3**.

5.3.2 Nonstandard Materials

Non-standard materials for components shown in **Table 22** shall have a design stress intensity, S_m , as defined in 4.3.5.3 at least equal to that of the lowest-strength standard material permitted for that application. Nonstandard material shall conform to the manufacturer's written specification which shall include minimum requirements for

- tensile strength,
- yield strength,
- hardness,
- impact strength,
- a minimum of 15 % elongation,
- a minimum of 20 % reduction of area;

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Table 22 — Standard and non-standard material applications for Level 2 Items

Part	Material designations for pressure ratings			
	3 000 psi (20.7 Mpa)	5 000 psi (34.5 Mpa)	10 000 psi (69.0 Mpa)	15 000 psi (103.5 Mpa)
Body^a, bonnet, Rams, and piston Rods	60K, 75K, 80K NS ^b	60K, 75K, 80K NS ^b	60K, 75K, 80K NS ^b	75K, 80K NS ^b
Integral end connection				
Flanged	60K, 75K, 80K NS ^b	60K, 75K, 80K NS ^b	60K, 75K, 80K NS ^b	75K, 80K NS ^b
Other ^c (Integral Quick Union)	60K, 75K, 80K NS ^b	60K, 75K, 80K NS ^b	60K, 75K, 80K NS ^b	75K, 80K NS ^b
Loose connections Not integral to the body				
Flanges (studded or open face) or Wireline Quick Unions Including Threads to adapt to Wireline Quick Union	60K, 75K, 80K NS	60K, 75K, 80K NS	60K, 75K, 80K NS	75K, 80K NS
<p>a If end connections are of the material designation indicated, welding is in accordance with Clause 6 and design is in accordance with Clause 4</p> <p>b “NS” indicates non-standard materials as defined in 4.3.5.3 and 5.3.2.</p> <p>c As specified by Manufacturer</p>				

Table 23 — Standard material property requirements for Level 2 Items

Material designation	0.2 % offset Yield strength min. psi (Mpa)	Tensile strength min. psi (Mpa)	Elongation in 50 mm min. %	Reduction of area min. %
60K	60 000 (414)	85 000 (586)	18	35
75K	75 000 (517)	95 000 (655)	17	35
NS Materials	As specified	As Specified	15	20
80K	80,000 (552)	95,000 (655)	17	35

5.3.3 Processing

5.3.3.1 Melting, Casting, and Hot Working

5.3.3.1.1 Melting Practices

The manufacturer shall select and specify the melting practices for all materials for Level 2 Items.

5.3.3.1.2 Casting Practices

All castings used for bodies, bonnets and end and outlet connections shall meet the applicable requirements of **Section 5** and **Section 7**.

The manufacturer shall document foundry practices that establish limits for sand control, core-making, rigging, melting and heat treatment and NDE to ensure repeatability for producing castings that meet the requirements of this International Standard.

5.3.3.1.3 Hot-working practices

All wrought material(s) shall be formed using hot-working practice(s) that produces a wrought structure throughout. The manufacturer shall document hot-working practices.

5.3.3.2 Heat treating

5.3.3.2.1 Equipment

Heat-treatment operations shall be performed utilizing equipment qualified in accordance with the requirements specified by the manufacturer and the requirements as specified in one of the following:

- API 6A Annex on Heat-treat Equipment Survey
- API 16A Annex on Qualification of Heat-treating Equipment
- API 20H Section Heat Treatment Equipment Temperature Uniformity Survey (TUS) and Calibration HSL-1.

Heat-treatment processes shall be in accordance with the manufacturer's approved written specification.

5.3.3.2.2 Temperatures

Time at temperature and thermal cycles shall be in accordance with the manufacturer's heat-treatment specifications.

5.3.3.2.3 Quenching — (for quenched and tempered materials)

The following apply:

- a) water quenching:

The temperature of the water or quench media used to approximate the cooling rate of water shall not exceed 100°F (40°C) at the start of the quench. For bath-type quenching, the temperature of the water or quench media shall not exceed 120°F (50 °C) at any time during the quench cycle

- b) other quenching media:

The temperature range of other quenching media shall meet the manufacturer's written specification.

5.3.4 Chemical composition

5.3.4.1 General

Material shall conform to the manufacturer's written specification as follows.

- a) The manufacturer shall specify the range of chemical composition of the material used to manufacture the pressure containing parts.
- b) Material composition shall be determined on a heat basis (or a remelt-ingot basis for remelt-grade materials) in accordance with the manufacturer's written specification or a nationally or internationally recognized standard.

5.3.4.2 Composition limits

Table 24 lists element limits, expressed in percentage mass fraction, for carbon, low-alloy and martensitic stainless steels (other than precipitation-hardening types) required to manufacture pressure containing items (bodies, bonnets and end outlet connections). If the composition is specified by reference to a recognized industry standard, it is not necessary that those elements specified as residual/trace elements be reported, provided the residual/trace element limits of the industry standard are within the limits of this International Standard. **Table 24** does not apply to other alloy systems. Composition limits of other alloy systems are purposely omitted from these tables in order to provide the manufacturer with freedom to utilize alloy systems for the multiplicity of requirements encountered.

Table 24 — Steel composition limits for Level 2 Items

Alloying element	Composition limits % mass fraction	
	Carbon and low-alloy steels	Martensitic stainless steels
Carbon	0.45 max.	0.15 max.
Manganese	1.80 max.	1.00 max.
Silicon	1.00 max.	1.50 max.

Phosphorus	0.025 max.	0.025 max.
Sulphur	0.025 max.	0.025 max.
Nickel	1.00 max.	4.50 max.
Chromium	2.75 max.	11.0 to 14.0
Molybdenum	1.50 max.	1.00 max.
Vanadium	0.30 max.	N/A

5.3.4.3 Tolerance ranges

The permitted tolerances on alloy elements content shall conform to **Table 25**

Table 25 — Maximum tolerance range limits for alloying elements

Element	Maximum tolerance range ^a for alloying elements % mass fraction	
	Carbon and low-alloy steels	Martensitic stainless steels
Carbon	0.08	0.08
Manganese	0.40	0.40
Silicon	0.30	0.35
Nickel	0.50	1.00
Chromium	0.50	NA
Molybdenum	0.20	0.20
Vanadium	0.10	0.10

^a These values are the maximum allowable variation in any one element and shall not exceed the maximum specified in Table 24.

5.3.5 Material qualification testing

5.3.5.1.1 General

The required tests shall be performed on specimens from a QTC.

A QTC used, shall be in accordance with 5.3.6..

5.3.5.2 Tensile testing

5.3.5.2.1 Test Method:

Tensile tests shall be performed at a temperature between 40°F and 120°F (between 4°C and 50°C). Tensile Tests shall be in accordance with the procedures in ISO 6892-1 or ASTM A370.

A minimum of one tensile test shall be performed. The results of the tensile test(s) shall satisfy the applicable requirements of **Table 23**.

5.3.5.2.2 Retesting

If the results of the tensile testing(s) do not satisfy the applicable requirements, two additional tests on tensile specimens removed from the required location within the same QTC with no additional hear-

treatment may be performed to qualify the material, and the results of each of these tests shall satisfy the applicable requirements.

5.3.5.3 Impact Testing

5.3.5.3.1 Test Specimens

Impact testing of a QTC shall be used to qualify a heat and the parts produced from that heat shall conform to **Table 26**.

If subsize specimens are used, the Charpy V-notch impact requirements shall be equal to that of the 10mm x 10mm specimens multiplied by the adjustment factor listed in **Table 27**.

Table 26— Charpy V-notch impact requirements — 10 mm x 10 mm

Temperature		Minimum average impact value Transverse direction	
Classification	Test °F (°C)	(ft-lb)	(J)
T-75/250	-75 (-60)	15	(20)
T-75/350	-75 (-60)	15	(20)
T-50/250	-50 (-46)	15	(20)
T-50/350	-50 (-46)	15	(20)
T-20/250	-20 (-29)	15	(20)
T-20/250	-20 (-29)	15	(20)
T-0/250	0 (-18)	15	(20)
T-0/250	0 (-18)	15	(20)

Table 27 — Adjustment factors for sub-size impact specimens

Specimen dimension	Adjustment factor	Minimum average impact value, wrought materials	
		Transverse direction and castings ft-lb (J)	Longitudinal direction ft-lb (J)
10 mm x 10 mm (full size)	1 (none)	15 (20); ref.	20 (27); ref
10 mm x 7,5 mm	0,833	13 (17)	17 (23)
10 mm x 6,7 mm	0,780	12 (16)	16 (21)
10 mm x 5,0 mm	0,667	10 (13)	13 (18)
10 mm x 3,3 mm	0,440	7 (9)	9 (12)
10 mm x 2,5 mm	0,333	5 (7)	7 (9)

5.3.5.3.2 Test Method

Impact tests shall be performed in accordance with the procedures specified in ASTM A370 or ISO 148-1 using the Charpy V-notch technique. When using the ISO148-1, a striker with a radius of 8 mm shall be used.

Note 1 Refer to ISO 148-1 for further details.

To qualify material for a temperature rating, impact tests shall be performed at or below the lowest temperature shown in **Table 26** for that temperature range.

Three impact specimens shall be tested to qualify a heat of material. Impact properties determined from these tests shall satisfy the applicable requirements of **Table 26** or **Table 27**. In no case shall an individual impact value fall below two-thirds of that requires as a minimum average. No more than one of the three test results shall be below the required minimum average.

5.3.5.3.3 Retesting

If a test fails, then a retest of three additional specimens removed from the required location with the same QTC, with no additional heat-treatment, may be made, each of which shall exhibit an impact value equal to or exceeding the required minimum average value of **Table 26**.

5.3.5.3.4 Specimen Orientation

The values listed in **Table 26** or **Table 27** shall be the minimum acceptable values for wrought products (material that contains no cast dendritic structure) tested in the transverse direction, and for castings and weld qualifications.

Wrought products may be tested in the longitudinal direction instead of the transverse direction and shall meet the requirements of **Table 26** or **Table 27**.

For castings that have no directionality; the values of the transverse direction of **Table 26** shall apply.

5.3.6 Qualification Test coupons

5.3.6.1 General

The properties exhibited by the QTCs shall represent the properties of the thermal response of the material comprising the production parts it qualifies.

Note 1 Depending upon the hardenability of a given material, the results obtained from QTCs might not always correspond with the properties of the actual components at all locations throughout their cross-section.

Note 2 API 6HT provides guidance and good practices for heat-treatment of parts with large cross-section, with the goal of achieving the required mechanical properties at the depth below the surface established by the manufacturer.

For material heat treated in a continuous furnace, the QTC shall consist of a sacrificial production part or a prolongation removed from a production part. The sacrificial production part or prolongation QTC shall qualify only production parts having the same size and shape.

Note 3 For batch heat-treatment only, if the QTC is a trepanned core or prolongation removed from a production part, the QTC may qualify only production parts having the same or smaller ER.

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Trepanned core is a part produced by boring a narrow band or groove around the circumference of the hold and removing the solid core of material.

Note 4 A sacrificial production part may be usable depending on the size and location of the test specimen from which it is selected.

For material heat treated in a batch furnace, the QTC shall qualify only material and parts produced from the same heat. For material heat treated in a continuous furnace, the QTC shall qualify only material and parts produced from the same heat and heat treat lot.

When a prolongation is used, it shall remain integrally attached during all heat-treatment operations, except post-weld heat-treatment, stress relief, and any re-tempering or re-aging

For tubular parts, bar stock, mill shapes, and other raw material with a uniform cross-section, the prolongation shall have the same cross-section as that of the raw material.

For a production part with a complex shape or varying cross-section, it is not necessary that the prolongation be an extension of the largest cross-section of the part, but the extension shall meet or exceed the minimum ER required for a separate QTC.

5.3.6.2 Equivalent round

The following apply:

- a) selection: The size of a QTC for a part shall be determined using the ER methods given below.
- b) ER methods:

Figure 1 illustrates the basic models for determining the ER of simple solid and hollow parts and more complicated parts.

The ER of a part shall be determined using the actual dimensions of the part in the “as-heat-treated” condition.

The ER of a studded type part shall be determined by using a thickness, T, equal to that of the thickest flange of that part. ER determination for these parts shall be in accordance with the methods for complex- shaped parts.

- c) size requirements:

The ER of the QTC shall be equal to or greater than the dimensions of the part it qualifies, except as follows:

- For parts with an ER of less than 5 inches (125 mm), the ER of the QTC shall be equal to or greater than the dimensions of the part it qualifies.
- For parts with an ER of 5 inches (125 mm) or larger, the QTC size shall be 5 inches (125 mm) ER as a minimum, regardless of part size, with the exception for bodies noted in the following.

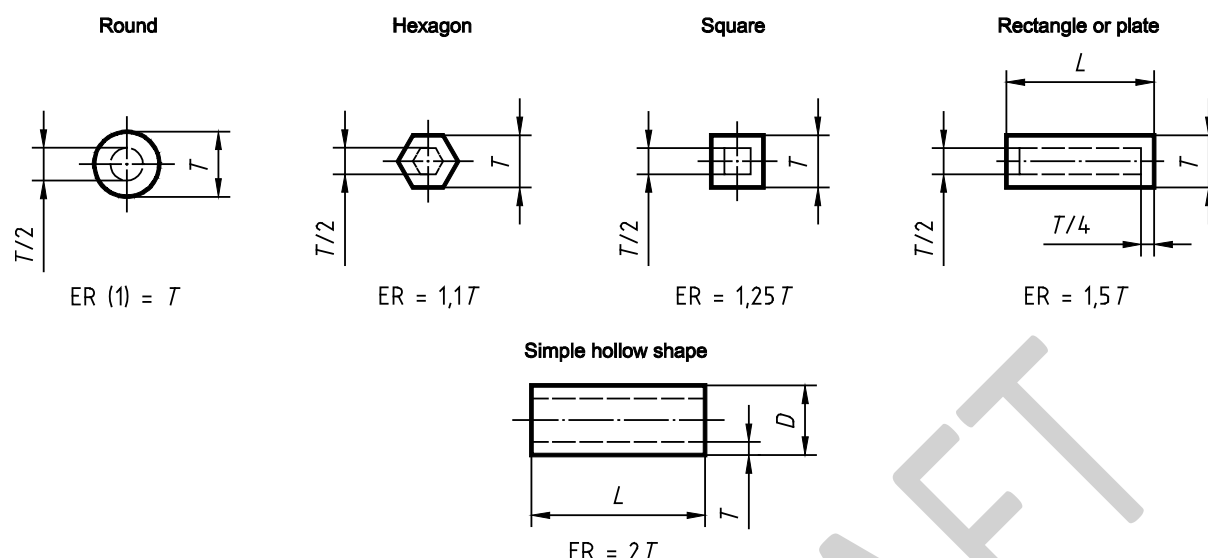
NOTE A QTC larger than 5 inches (125 mm) ER may be used when specified by the manufacturer or purchaser.

- For bodies that require a yield strength of 75K or greater and where the component's weight during heat treat is greater than 1000 lbs. (454 kilograms), the QTC ER shall be the same or greater than the part it qualifies but is not required to exceed 250 mm (10 in.).

NOTE A QTC larger than 10 inch (250 mm) ER may be used when specified by the manufacturer or purchaser.

- casting: size not required to exceed size shown in ASTM A703/A703M.

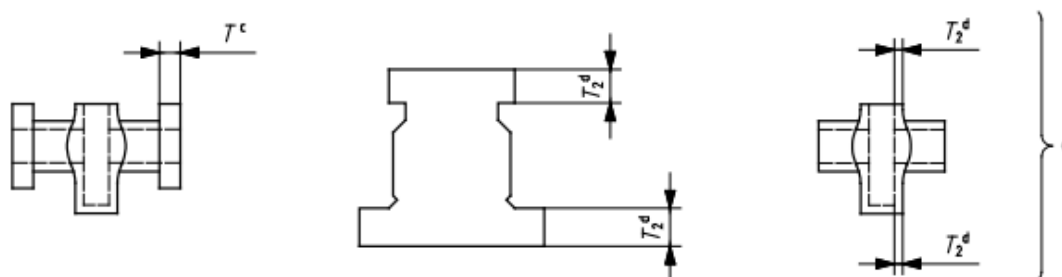
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When L is less than T , consider section as a plate of L thickness. Area inside dashed lines is $1/4 T$ envelope for test specimen removal.

When L is less than D , consider as a plate of T thickness

a) Simple geometric equivalent rounds (ER) sections/shapes having length L

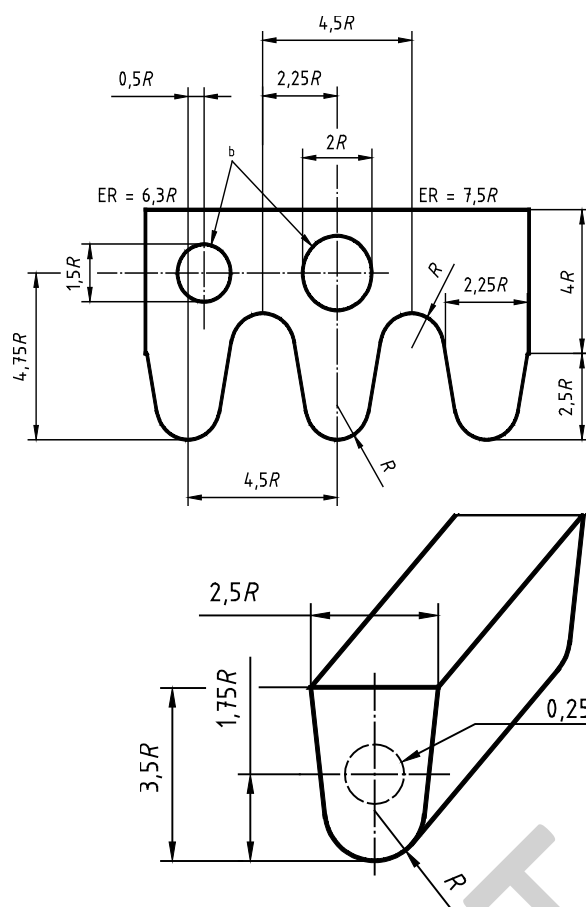


b) General flanged bodies for complex-shaped wellhead components

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

^a Where T is the thickness when the component is heat-treated, use the larger of the two indicated dimensions.

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c) Keel block configuration, $ER = 2.3 R$

Figure 1 — Equivalent Round Methods

5.3.6.3 Processing

5.3.6.3.1 Melting, casting and hot working

The following apply:

a) melting practices:

In no case shall the QTC be processed using a melting practice(s) cleaner than that of the material it qualifies [e.g. a QTC made from a remelt grade or vacuum-degassed material shall not qualify material from the same primary melt that has not experienced the identical melting practice(s)]. Remelt-grade material removed from a single remelt ingot may be used to qualify other remelt-grade material that is from the same primary melt; no additional alloying shall be performed on these individual remelt ingots.

b) casting practices:

The manufacturer shall use the same foundry practice(s) for the QTC as those used for the parts it qualifies, to assure accurate representation.

c) hot-working practices:

The manufacturer shall use on the QTC hot-working ratios that are equal to or less than those used in processing the production part(s) it qualifies. The total hot-work ratio for the QTC shall not exceed the total hot-work ratio of the part(s) it qualifies.

Note API 20B and API 20C provide guidance on hot work ratios.

5.3.6.4 Welding

Welding on the QTC is not allowed, except for attachment-type welds.

5.3.6.5 Heat treating

All heat-treatment operations shall be performed utilizing equipment qualified in accordance with the requirements specified by the manufacturer and the requirements as specified in one of the following:

- API 6A Annex on Heat-treat Equipment Survey
- API 16A Annex on Qualification of Heat-treating Equipment
- For Batch Type Equipment: API 20H Section Heat Treatment Equipment Temperature Uniformity Survey (TUS) and Calibration HSL-1.
- For Continuous Type Equipment: API 20N

The QTC shall experience the same specified heat-treatment as the parts it qualifies. The QTC shall be heat-treated using the manufacturer's specified heat-treatment procedures.

The following apply:

- a) equipment qualification:

All heat-treatment operations shall be performed utilizing equipment qualified in accordance with **5.3.4.1**.

- b) method for batch heat treatment:

The QTC shall be heat treated in the same heat-treat furnace and same quench tank as the production part that it qualifies. For bodies that use a material designation of 75K or greater and where the body during heat-treat is greater than 1000 lb (454 kg), the QTC shall be heat-treated in the same heat-treat furnace and same quench tank as the production parts that it qualifies.

- c) method for continuous furnace:

For material heat treated in a continuous furnace, the QTC shall be from the same heat and heat-treat lot as the material it qualifies.

5.3.6.6 Material qualification

5.3.6.7 Tensile and impact test specimens

When tensile and/or impact test specimens are required, they shall be removed from a QTC after the final QTC heat treatment cycle. tensile and impact specimens may be removed from multiple QTCs as long as multiple QTC's have had the same heat treatment cycle.

Tensile and impact specimens shall be removed from the QTC such that their longitudinal centerline axis is wholly within the center core 1/4T envelope for a solid QTC or within 1/8 inch (3 mm) of the mid-thickness of the thickest section of a hollow TC (see **Figure 1**).

For QTCs larger than the size specified in **5.3.7.2**, it is not necessary that the test specimens be removed from a location farther from the QTC surface than would be required if the specified QTC size were used.

Test specimens shall be removed from the QTC such that the tensile specimen gauge length and Charpy V-notch root are at least 1 /4T from the ends of the QTC.

When a sacrificial production part is used as a QTC, the test specimens shall be removed from a section of the part meeting the size requirements for a QTC for that production part as defined in **5.3.7.2**.

Standard-sized, 0.500 inch (12.7 mm) diameter tensile specimens shall be used to qualify carbon, low-alloy and stainless steels, unless the physical configuration of the QTC prevents their use. In this case, the standard sub-size specimens referenced in ASTM A370 may be used. Either standard 0.500 inch (12.7 mm) or standard sub-size specimens (see ASTM A370) may be used to qualify CRA materials.

Standard-sized impact specimens, 0.394 inch x 0.394 inch (10 mm x 10 mm) in cross-section, shall be used, except where there is insufficient material, in which case the next smaller standard size specimen obtainable shall be used. Impact specimens shall be removed such that the notch is within the 1 /4T envelope.

Unless specified otherwise, tensile testing shall be performed at a temperature between 40 °F and 120 °F (between 4 °C and 50 °C).

5.3.6.8 Hardness testing

At least one Rockwell or Brinell hardness test shall be performed on the QTC after the final heat-treatment cycle.

The QTC heat-treatment cycles prior to hardness testing shall be the same heat-treatment cycles experienced by the tensile and impact test specimens.

Hardness testing shall be performed in accordance with ISO 6506 (all parts) or ISO 6508 (all parts), or ASTM E10 or ASTM E18.

5.4 Level 1 Items

5.4.1 Property Requirements

Hydraulic actuator components - shall be manufactured from materials as specified by the manufacturer – see Table 28..

Table 28 – Hydraulic Actuator Components

Hydraulic Actuator Components	Level
-------------------------------	-------

Items that contain hydraulic pressure – forming the boundary of the hydraulic pressure envelope. Items include cylinders, end caps, hydraulic caps	Level 1
Items that are in the direct load path of the ram locks. Items include stems, tail rod	Level 1

5.4.2 Processing

5.4.2.1 Melting, Casting, and Hot Working

The melting, casting, and hot-working practices of Level 1 items shall be in accordance with 5.3.3.1

5.4.2.2 Heat Treating

All heat-treatment operations for Level 1 items shall be in accordance with 5.3.3.2.

5.4.3 Chemical Composition

5.4.3.1 General

Material composition shall be determined on a heat basis (or a remelt ingot basis for remelt grade materials) in accordance with the manufacturer's written specification.

5.4.3.2 Composition Limits

The chemical composition limits of **Level 1** Items manufactured from carbon and low-alloy steels or martensitic stainless steels shall be in accordance with the manufacturer's specifications.

5.4.3.3 Tolerance on Composition Limits

The permitted tolerances on alloying elements content shall be in accordance with **Table 25**.

5.4.4 Material Qualification

5.4.4.1 Tensile Testing

Tensile testing for Level 1 items shall be in accordance with 5.3.5.2.

5.4.4.2 Impact Testing for Level 1 items

Impact testing shall be performed in accordance with 5.3.5.3 on all **Level 1** items, except for shear blades and slip inserts. Acceptance criteria for shear blades and slip inserts shall be in accordance with the manufacturer's written specification.

5.5 Pressure-boundary penetrations

Material requirements for pressure-boundary penetrations shall be in accordance with the manufacturers written specification. Pressure boundary penetrations directly exposed to wellbore fluid and used in sour service shall be in accordance with NACE MR0175.

5.6 Shear Blades and Slip Inserts

Shear Blades and Slip Inserts when used in well intervention pressure control equipment can be harder material than the material they are trying to shear or hold.

The shear blades and slip inserts need not conform with NACE MR1075/ISO 15156.

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BALLOT DRAFT

6 Welding requirements

6.1 General

Welding of components exposed to wellbore fluid and rated for H₂S shall be in accordance with the welding requirements of NACE MR0175. Verification of compliance shall be established through implementation of the manufacturer's written welding procedure specification (WPS and the supporting procedure qualification record (PQR).

All welding of components exposed to wellbore fluid and not rated for H₂S shall be in accordance with the manufacturer's written WPS and the supporting PQR

When material specifications for **Level 2** Items require impact testing, verification of compliance shall be in accordance with the manufacturer's WPS and supporting PQR.

New and repair welds shall be mapped to provide traceability for the weld. Repair Welds shall be mapped on a separate weld map. Weld maps shall contain the following traceability Information, at a minimum:

- a.) part sketch denoting new weld /repair area;
- b.) part number;
- c.) serial number;
- d.) welder's name;
- e.) welders stamp number;
- f.) PT / MT report number of verifications of defect removal;
- g.) WPS used;
- h.) filler material heat/batch/lot;
- i.) weld flux heat/batch/lot, if used;
- j.) number PWHT hours used; and
- k.) number PWHT hours remaining.

6.2 Weldment design and configuration

6.2.1 Level 2 Items fabrication weldments

Level 2 Items fabrication weldments contain and are wetted by wellbore fluid.

Full penetration welds (weld that extends throughout the complete wall section of the parts joined) shall be fabricated in accordance with the manufacturer's written specification .**Figure 2** and **Figure 3** are provided for reference.

Welding and completed welds shall be in accordance with the quality control requirements of **Section 7**.

6.2.2 Load-bearing weldments

Load-bearing weldments are those subject to external loads and not exposed to wellbore fluids.

Joint design shall be in accordance with the manufacturer's written procedures.

Welding and completed welds shall be in accordance with the quality control requirements of **Section 7**.

Lifting points shall be designed with a safety factor of 2.5. Lifting points shall be load tested to 1.5 times the safe working load.

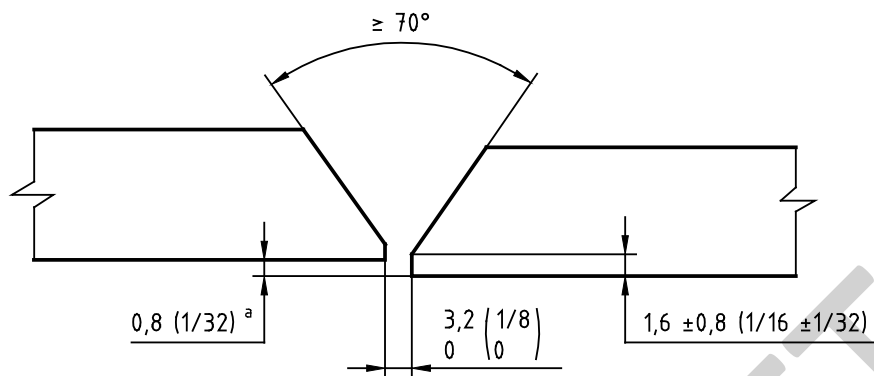
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Surface NDE shall be performed after the load test. The surface NDE quality control requirements shall be in accordance with **Section 7.5**

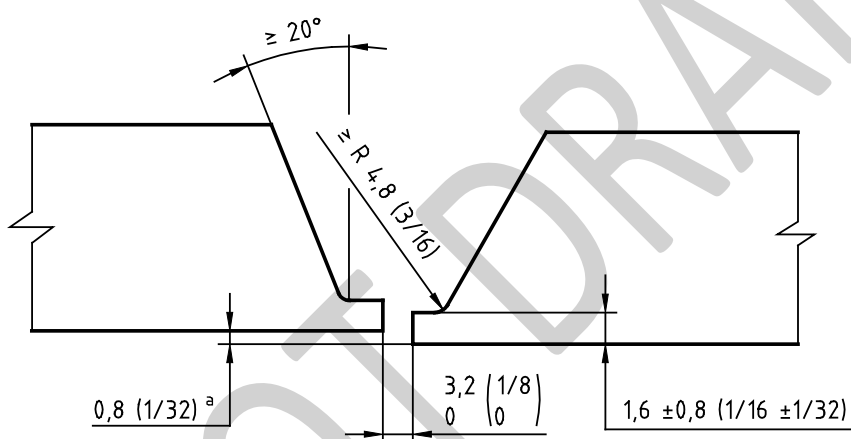
The safe working load shall be stamped adjacent to the lift point.

BALLOT DRAFT

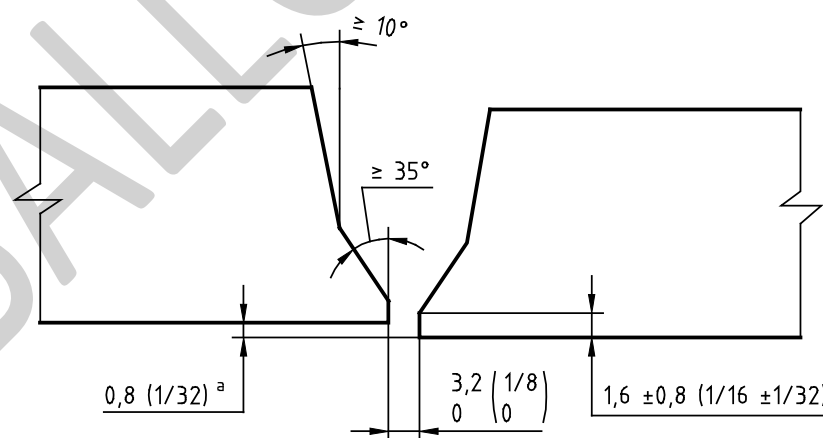
Dimensions in millimetres (inches)



10) V-groove



11) U-groove



c) Heavy wall V-groove

^a Maximum misalignment

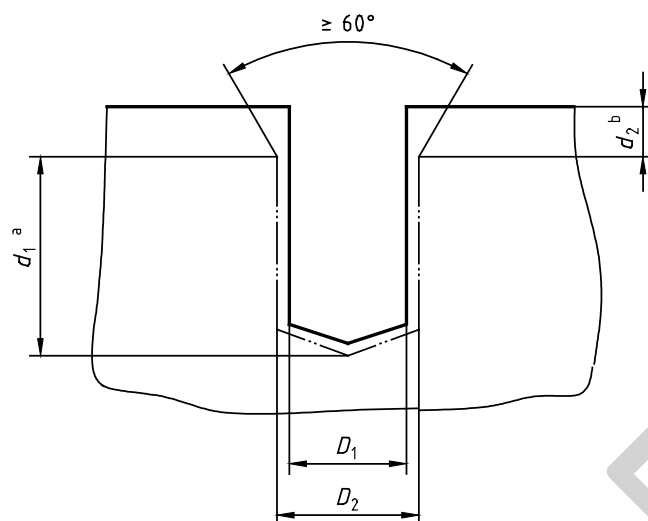
Figure 2 — Typical weld grooves for pipe butt joints

Technical drawing of a mechanical part showing dimensions and tolerances. The drawing includes a cross-section view of a component with a flange and a base. Key dimensions and tolerances are indicated:

- Top left dimension: $0,8 / 1/3$ over $0 / 0$
- Top center dimension: $\geq R4,8 (\geq R3/16)$
- Left side dimension: $\leq 0,8 (\leq 1/32)^a$
- Bottom left dimension: $\leq 0,8 (\leq 1/32)^c$
- Bottom center dimension: $\geq 6,4 (\geq 1/4)$
- Bottom right dimension: $1,6 (1/16)$ over $0 / 0$
- Right side dimension: $\geq 4,8 (\geq 3/16)$
- Angle dimension: $\geq 45^\circ$
- Dimension 'd' is indicated at the bottom center.

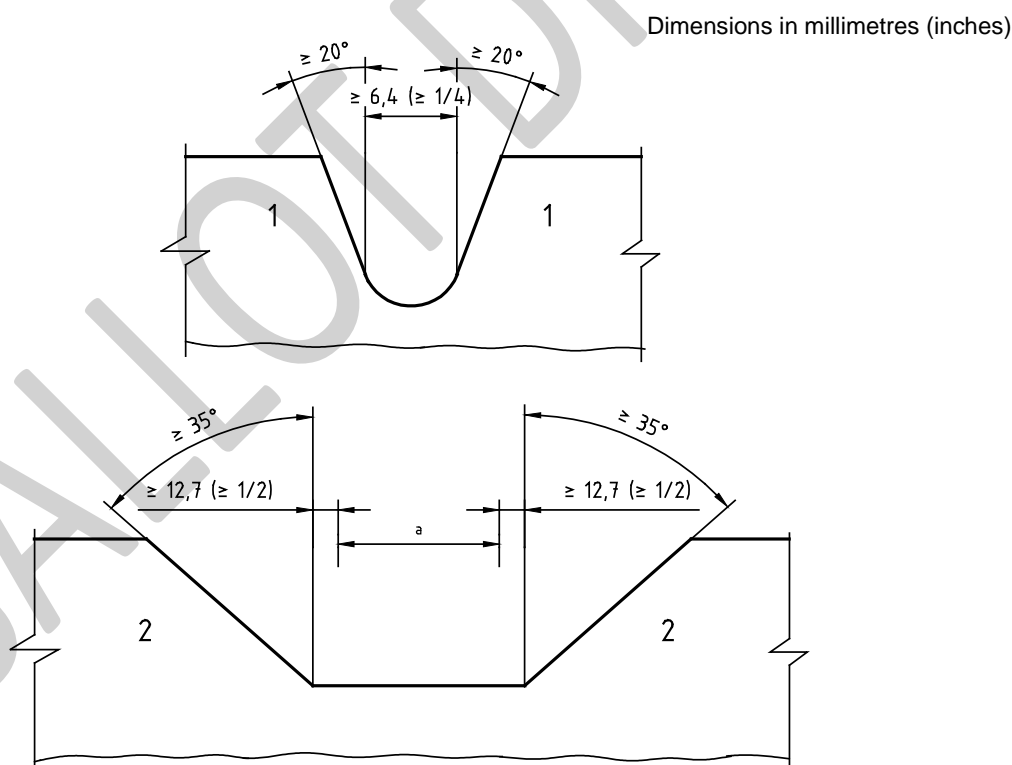
- a Mismatch (unless removed by machining)
- b Remove to sound metal by machining
- c Maximum mismatch
- d Backing to be removed. Material to be compatible with base material.

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- a $d_1 : D_2$ ratio shall not exceed 1.5 : 1
b d_2 = depth required to maintain a maximum of 1.5 : 1 depth (d_1)-to-diameter (D_2) ratio.

Figure 4 — Typical repair welds



Key

- 1 Side
2 End
a Original area

Figure 5 — Typical evacuation for repair welds

6.2.3 Repair welds

All repair welding shall be carried out in accordance with the manufacturer's written specification. **Figure 4** and **Figure 5** are provided for reference.

Welding and completed welds shall be in accordance with **Section 7**.

6.2.4 Weld surfacing (overlay) for corrosion resistance and wear resistance for material surface property controls

6.2.4.1 Corrosion-resistant ring grooves

Ring groove lined with a CRA or an austenitic stainless steel to resist metal loss corrosion.

Standard dimensions for type R and BX ring grooves are specified in API 6A.

6.2.4.2 Corrosion-resistant and wear-resistant overlays other than ring grooves

The manufacturer shall use a written procedure that provides controls for consistently meeting the manufacturer-specified material surface properties in the final machined condition. As a minimum, this shall include inspection methods and acceptance criteria.

Qualification shall be in accordance with Articles II and III of ASME Boiler and Pressure Vessel Code Section IX for corrosion-resistant weld metal overlay or hardfacing weld metal overlay as applicable.

6.2.4.3 Mechanical properties

Mechanical properties of the base material shall retain the minimum mechanical property requirements after thermal treatment. The manufacturer shall specify the methods to ensure these mechanical properties and shall record the results as a part of the PQR.

6.3 Welding controls

6.3.1 Procedures

Welding is a process that requires Validation and a documented procedure. The Manufacturer's shall have procedures for the qualification of Tack Welders, Welders and Welding Operators which defines the training, qualification, monitoring qualification, retaining and retesting (if failed initial test), requalification / Continuity Log, revoking certifications for poor performance, updating qualifications, records and the use of welding-procedure specifications. Records shall include failures, retaining and retesting.

6.3.2 Application

Welding shall be performed by personnel qualified in accordance with the requirements of **6.4.1**.

Welding shall be performed in accordance with written WPS and qualified in accordance with Article II of ASME Section IX. The WPS shall describe all the essential, non-essential and supplementary essential (in accordance with ASME Section IX) variables. Welders and welding operators shall have access to the welding parameters as defined in the WPS. Welders and welding operators shall conform to the welding parameters as defined in the WPS.

6.3.3 Designed welds

For all welds that are considered part of the design of a production part, the manufacturer shall specify the requirements for the intended weld.

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Dimensions of groove and fillet welds with tolerances shall be documented in the manufacturer's specification. Figures 1 and 2 depict some typical joint designs.

All thermally cut and ground surfaces shall be either MP or LP inspected and meet the requirements of 7.5.1.9.

6.3.4 Preheating

Preheating of assemblies or parts, when required, shall be performed in accordance with the manufacturer's written procedures (e.g. requirements for ensuring suitable/capable preheat/interpass temperature control that includes heating methods, distance set-off for torch heating, neutral flame, etc.).

6.3.5 Instrument calibration

Instruments to verify temperature, voltage and amperage shall be serviced and calibrated in accordance with the written specification of the manufacturer performing the welding.

6.3.6 Materials

6.3.6.1 Welding consumables

Filler metals shall conform to ASME II Part C/American Welding Society (AWS) or other recognized international standards. All consumables shall conform to the consumable manufacturer's approved specifications.

The manufacturer shall have a written procedure for storage and control of welding consumables. Materials of low-hydrogen type shall be stored and used as recommended by the consumable manufacturer to retain their original low-hydrogen properties.

6.3.6.2 Deposited weld metal properties

For welds requiring structural integrity, the deposited weld metal mechanical properties shall meet or exceed the minimum specified mechanical properties of the base material. Verification of properties shall be established through the implementation of the manufacturer's WPS and supporting PQR. When materials of differing strength are joined, the weld metal shall meet the minimum requirements of the lesser material.

6.3.7 Post-weld heat treatment

Post-weld heat treatment of components shall be in accordance with the manufacturer's written procedures. The written procedure approved by the manufacturer shall include:

- Method of temperature control (including ramp rates) and control of cooling rate to ambient temperature. The procedure shall include protection to fans, winds, or other environmental conditions that can affect the cooling rate.
- Location of controlling and monitoring thermocouples. A sketch shall be included in the routing or traveller to depict the location of the part thermocouples.

- Identification of part loading supporting equipment (racks or baskets) required and a sketch showing the location of parts in the furnace's qualified heating zone.
- Area to receive the source of heating for local heat treatments, the type and amount of insulation, and the methods to control for the heating gradient outside of the local heating area.
- Method and control of dehydrogenization heat treatments (DHT) (otherwise known as "bake-outs") performed immediately after welding and before the part is allowed to cool.
- Method and control of intermediate stress reliefs performed as an intermediate heat treat to allow further processing of the part prior to the final PWHT, such as a Larsen-Miller Parameter (LMP) in order to understand the diffusional effects to the material when performing an ISR.

All PWHT temperatures shall not exceed the manufacturer's stated minimum specified tempering temperature. WPS PWHT median temperature shall be at least 25°F (14°C) below the minimum specified tempering temperature.

Furnace post-weld heat treatment shall be performed in equipment meeting the requirements specified by the manufacturer.

Local post-weld heat treatment shall consist of heating a band around the weld at a temperature within the range specified in the qualified WPS. The minimum width of the controlled band adjacent to the weld, on the face of the greatest weld width, shall be the thickness of the weld. Localized flame-heating is permitted provided the flame is baffled to prevent direct impingement on the weld and base material.

Additional heat treatment procedures like diffusible-hydrogen heat treatment and Intermediate stress relief shall be documented.

For welds (excluding overlays) made on low-alloy steels that are allowed to cool below the minimum preheat temperature, prior to PWHT, and are made by SMAW, SAW or FCAW processes, after completion of welding and without allowing the weldment to cool below the minimum preheat temperature, the temperature of the weldment shall be raised to a temperature between 450°F (232°C) and 750°F (399°C) for a minimum period of two hours.

Note: This Dehydrogenation Heat Treatment may be omitted provided the electrode used is classified by the filler metal manufacturer with a diffusible-hydrogen designator of H4 (e.g., E7018-H4)

6.4 Welding procedure and performance qualifications

6.4.1 General

All weld procedures, welders and welding operators shall be qualified in accordance with the qualification and test methods of Section IX, ASME Boiler and Pressure Vessel Code, as amended below.

6.4.2 Base metals

The manufacturer may use ASME Section IX P number materials.

The manufacturer may use ASME BPVC Section IX P number materials. Materials not listed in ASME BPCV Section IX are unassigned and shall have their own WPS.

The manufacturer shall establish an equivalent P number (EP) grouping for carbon and low-alloy steels not listed in ASME BPVC Section IX with a carbon equivalent less than or equal to 0.43 for <1 inch or less and 0.45 for >1 inch material thickness (see Equation 5).

Prior to welding carbon and low-alloy steel, all elements in the carbon equivalency formula shall be adequately identified as per ASME BPVC Section IX, QW-403.26:

$$\text{C.E.} = \text{C}\% + \text{Mn}\%/6 + (\text{Cr}\% + \text{Mo}\% + \text{V}\%)/5 + (\text{Ni}\% + \text{Cu}\%) / 15 \text{ (Equation 5)}$$

Carbon and low-alloy steels not listed in ASME BPVC Section IX with a carbon equivalent as identified above and a nominal carbon content greater than 0.23 % (by weight) shall be specifically qualified for the manufacturer's specified base material.

Additionally, carbon and low-alloy steels not listed in ASME BPVC Section IX with an allowable carbon equivalent as identified above shall have a maximum carbon content less than or equal to 0.23 % (by weight) and shall have a maximum yield strength of 60 ksi (414 Mpa).

The manufacturer shall have a written specification that identifies the unassigned base metal by industrial specification, type, and grade, or by chemical analysis and mechanical properties.

Qualification of a base material with a similar chemistry and at a specified strength level shall qualify that base material chemistry at all lower strength levels.

6.4.3 Filler material qualification

Filler metals shall be specified in each WPS by ASME II, Part C/AWS specification and classification or other recognized international standard.

Welding consumables shall be clearly identified by trade name, as applicable, and the identity maintained until consumed.

6.4.4 Chemical Analysis

Chemical analysis of the base materials and filler metal for the test weldment shall be obtained from the supplier or by testing and shall be part of the PQR.

6.4.5 Heat-treat condition

All testing shall be done with the test weldment in the post-weld heat-treated condition. Post-weld heat treatment of the test weldment shall be according to the manufacturer's written specifications.

6.4.6 Procedure qualification record

The PQR shall record all essential and supplementary essential (when required by ASME) variables of the weld procedure used for the qualification test(s). Both the WPS and the PQR shall be maintained as records in accordance with the requirements of 7.6.

6.4.7 Tack welder performance Qualification

Tack welds shall be performed by qualified welders in accordance with 6.4.1.

6.4.8 Visual examination – personnel

All personnel performing welding operations shall have an annual (not to exceed 12 months) eye examination in accordance with AWS D17.1

6.5 Other requirements

6.5.1 ASME Section IX, Article I — Welding general requirements

6.5.1.1 General

Article I of ASME Section IX shall apply with additions as given below.

6.5.1.2 Hardness testing

6.5.1.2.1 General

Hardness testing shall be conducted across the weld and base material heat-affected zone (HAZ) cross section and shall be recorded as part of the PQR. Results of all pressure-containing and pressure controlling parts exposed to wellbore fluid shall be in conformance with NACE MR0175 requirements. The manufacturer shall specify the hardness testing method to be used. Testing shall be performed on the weld and base material HAZ cross-section in accordance with ASTM E 18; ISO 6508-1, Rockwell; ASTM E384; or ISO 6507-1, Vickers 10 kg.

6.5.1.2.2 Rockwell method (ASTM E18 or ISO 6508-1)

If the Rockwell method is selected by the manufacturer, the following procedure shall be used:

- a) for a weld cross-section thickness less than 0.500 inch (12.8 mm), four hardness tests each shall be made in the base material(s), the weld and the HAZ;
- b) for a weld cross-section thickness equal to or greater than 0.500 inch (12.8 mm), six hardness tests each shall be made in the base material(s), the weld and the HAZ;
- c) HAZ hardness tests shall be performed in the base material within 0.062 inch (1.6 mm) of the weld interface and at least one each within 0.125 inch (3.2 mm) from top and bottom of the weld. See **Figure 6** for test locations.

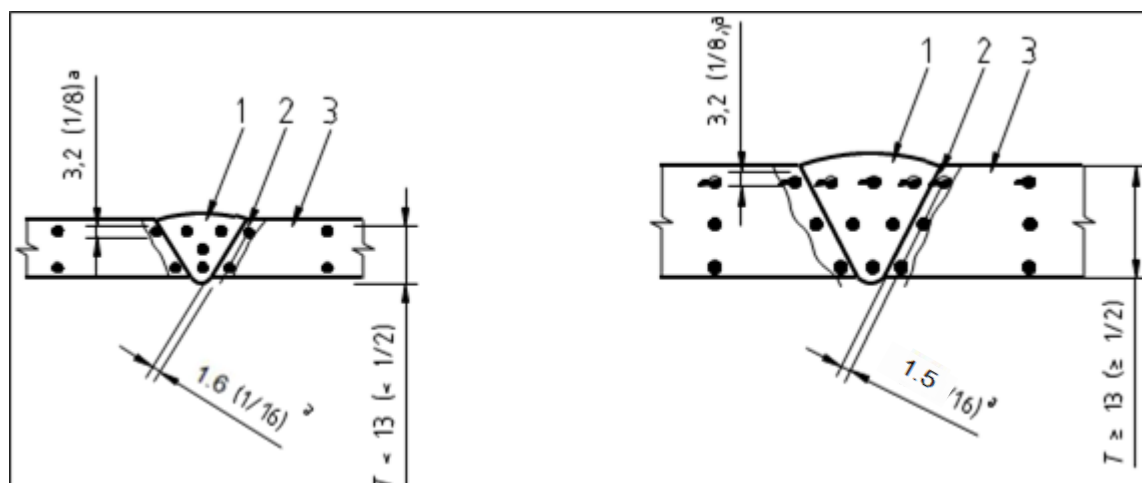
6.5.1.2.3 Vickers method (ASTM E384 or ISO 6507-1)

If the Vickers method is selected by the manufacturer, the following procedure shall be used:

- a) for a weld cross-section thickness less than 0.500 inch (13 mm), four hardness tests each shall be made in the base materials and the weld;
- b) for a weld cross-section thickness equal to or greater than 0.500 inch (13 mm), six hardness tests each shall be made in the base material(s) and the weld;
- c) multiple HAZ hardness tests equally spaced 0.125 inch (3.2 mm) apart shall be performed in each of the base materials within 0.01 inch (0.25 mm) of the weld interface and at least one within 0.062 inch (1.6 mm) from the top and the bottom of the weld. See **Figure 7** for test locations.

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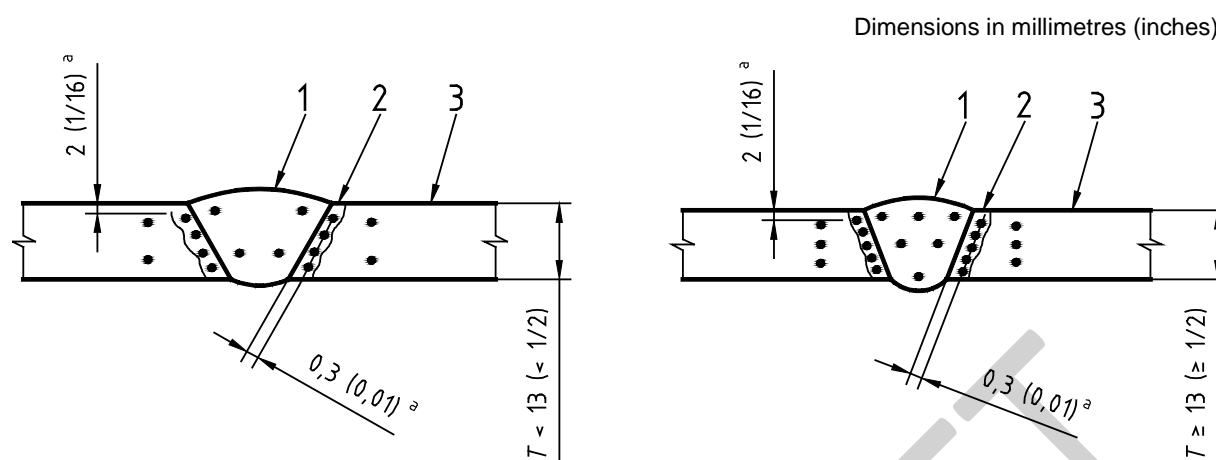
Dimensions in millimetres (inches)



Key

- 1 Weld
- 2 HAZ
- 3 Base
- a Typical

Figure 6 — Rockwell hardness test locations



Key

- 1 Weld
- 2 HAZ
- 3 Base
- ^a Typical

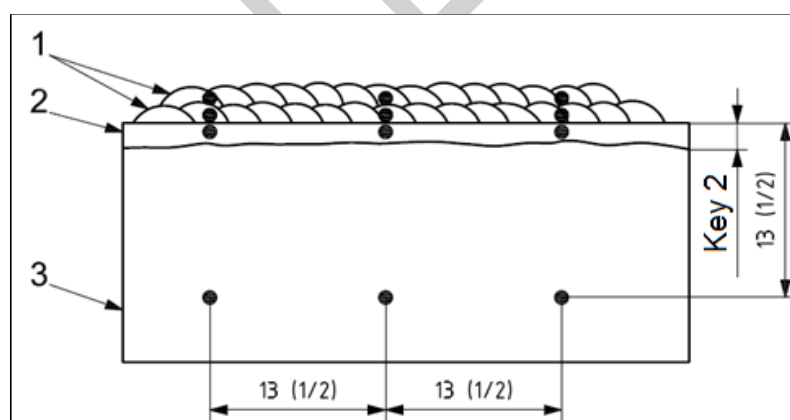
Figure 7 — Vickers hardness test locations

6.5.1.2.4 Hardness testing (optional) — Minimum mechanical properties

For the purpose of hardness inspection and qualifying production weldments, a minimum of three hardness tests in the weld metal shall be made and recorded as part of the PQR. These tests shall be made by the same methods used to inspect production weldments. These tests may be used to qualify weld metal with hardness less than shown in 7.5.1.4 by the method shown in the same subsection.

6.5.1.2.5 Hardness Testing for Overlays

Hardness tests shall be performed at a minimum of three test locations in each base material, the HAZ, and in each layer of the overlay up to a maximum of two layers in conformance with the test locations specified in **Figure 8**.



Key	Dimensions in millimeters (inches)
1 Weld	
2 HAZ Rockwell B&C impressions shall be within 0.062 inch (1.6 mm) of the fusion line. Vickers and Rockwell 15N impressions shall be as close to the fusion line as possible, but no more than 1 mm (0.039 in).	
3 Base	

Figure 8 – Hardness Test Locations for Weld Overlay

Using the Vickers or Rockwell 15N measurement methods per **6.5**, hardness impressions shall be entirely within the HAZ and located as close as possible to, but no more than 0.039 inch (1mm) from, the fusion boundary between the weld overlay and the HAZ.

The average of three or more test results shall be equal to or greater than 83 HRB and recorded as part of the PQR. The chemical composition of the deposited weld metal at that location shall be as specified by the manufacturer.

The average of the three measurements shall not exceed acceptance criteria for austenitic stainless steel or nickel-based alloy overlay.

6.5.1.3 Impact testing

When impact testing is required by the base material specification, the testing shall be performed in accordance with ASTM A370 using the Charpy V-notch technique. Results of testing in the weld and base material HAZ shall meet the minimum requirements of the base material. Records of results shall become part of the PQR.

When impact testing is required of the base material, one set of three test specimens each shall be removed at the 1/4 thickness location of the test weldment for each of the weld metal and base material HAZ. The root of the notch shall be oriented normal to the surface of the test weldment and located as follows:

- a) weld metal specimens (three each) 100 % weld metal.
- b) HAZ specimens (three each) shall include HAZ material as specified in the manufacturer's written procedure.
- c) If weld thickness of the product is equal to or greater than 2.00 inch (50.8 mm), then:
 - 1) impact testing shall be performed on weld metal and
 - 2) HAZ material shall be removed within ¼" thickness.

6.5.2 ASME BPVC Section IX, Article II — Welding procedure qualifications

6.5.2.1 General

Article II of ASME Section IX shall apply with additions as shown in this section

6.5.2.2 Heat treatment

The post-weld heat treatment of the test weldment and the production weldment shall be in the same range as that specified on the WPS. Allowable range for the post-weld heat treatment on the WPS shall be a nominal temperature of $\pm 25^{\circ}\text{F}$ ($\pm 14^{\circ}\text{C}$). The stress-relieving heat-treatment(s) time(s) at temperature(s) of production parts shall be equal to or greater than that of the test weldment.

6.5.2.3 Chemical analysis

Chemical analysis of the base materials for the test weldment shall be obtained from the supplier or by testing and shall be part of the PQR.

For corrosion-resistant ring groove overlay, chemical analysis shall be performed in the weld metal in accordance with the requirements of ASME Section IX at a location of 0.125 inch (3.2 mm) or less from the original base metal surface. The chemical composition of the deposited weld metal at that location shall be as specified by the manufacturer. For 300 series or austenitic stainless steel, the chemical composition shall be within the following limits:

- a) nickel 8.0 % mass fraction minimum;
- b) chromium 16.0 % mass fraction minimum;
- c) carbon 0.08 % mass fraction maximum.

For the nickel-base alloy N06625, the chemical composition shall meet one of the classes given in **Table 29**:

Table 29 — Chemical composition of the nickel-based alloy N06625

Class	Element	Composition, % mass fraction
Fe 5	Iron	5.0 max
Fe 10	Iron	10.0 max

Welds for use in hydrogen sulphide service shall conform to the requirements of NACE MR0175.

6.5.2.4 Hole Repair Procedure Qualification

Procedure qualification for bolt, tapped, and blind hole repairs shall include the following:

- Base material shall be of the same P number and group number per ASME Section IX. If not listed in ASME Section IX, the base material shall be of the same type and in the highest-strength heat-treated condition that the procedure will be qualified for;
- The hole repair weld procedure qualification shall demonstrate that the minimum mechanical properties for the product can be met.

6.5.3 ASME Section IX, Article III — Welding performance qualifications

6.5.3.1 General

Article III of ASME Section IX shall apply with additions as shown in this subsection.

6.5.3.2 Bolt, Tapped, and Blind Hole Repair Performance Qualification

The welder or welding operator shall perform an additional repair welding performance qualification test using a mock-up hole (refer to **Figure 4**). The repair welding qualification test hole shall be qualified by radiography according to Section 7, or shall be cross-sectioned through the centreline of the hole and

both faces shall be examined by NDE in accordance with **Section 7**. This evaluation shall include the total depth of the hole.

The repair weld qualification shall be restricted by the following essential variables for performance controls.

- a) The hole diameter used for the performance qualification test is the minimum diameter qualified. Any hole with a diameter greater than that used for the test shall be considered qualified.
- b) The depth-to-diameter ratio of the test hole shall qualify all repairs to holes with the same or smaller depth-to-diameter ratio.
- c) The performance qualification test shall have straight parallel walls. If any taper, counter-bore or other aid is used to enhance the hole configuration of the performance test, that configuration shall be considered an essential variable.

For welder performance qualification, ASME Section IX P-1 base metals may be used for the test coupon in place of the low alloy steels covered by this specification (**Table 22**).

6.5.4 ASME Section IX, Article IV — Welding data

Article IV of ASME Section IX shall apply as written.

7 Quality control requirements

7.1 General

The manufacturer shall have a quality management system that at a minimum meets the requirements of API Q1 or an equivalent international standard

This section specifies the quality control requirements for equipment manufactured to this standard.

NOTE For the purpose of this document, API Q2 and ISO 9001 are considered equivalent quality management systems to API Q1.

7.2 Measuring and testing equipment

7.2.1 General

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

7.2.2 Pressure-measuring devices

Test pressure-measuring devices shall be either pressure gauges or pressure transducers and shall be accurate to at least $\pm 0.5\%$ of full-scale range.

If pressure gauges are used in lieu of pressure transducers, they shall be selected such that the test pressure is indicated within 20% and 80% of the full-scale value.

Analog pressure-measuring devices shall be periodically recalibrated with a master pressure-measuring device or a deadweight tester at 25 %, 50 % and 75 % of full scale.

Intervals shall be established for calibrations based on repeatability and degree of usage. Calibration intervals shall be a maximum of three months until recorded calibration history can be established by the equipment manufacturer and new longer intervals in three months maximum increment can be established, not to exceed a 12-month calibration frequency.

Where pressure is recorded using a digital data acquisition system, the pressure sensor accuracy shall be equal to or better than $\pm 0.5\%$ of full-scale range of the sensor. The monitoring system shall be at least as accurate as the sensor. The update (scan) rate of the monitoring system shall be equal to or faster than 1Hz and operated in accordance with ASTM D5720-95.

7.3 Quality control personnel qualifications

7.3.1 Non-destructive examination (NDE) personnel

NDE personnel shall be qualified in accordance with ISO 9712 or ASNT SNT TC-1A.

7.3.2 Visual examination personnel

Personnel performing visual examinations shall have an annual (not to exceed 12 months) eye examination in accordance with ISO 9712 or ASNT SNT TC-1A.

7.3.3 Welding inspectors

Personnel performing visual inspection of welding operations and completed welds shall be qualified and certified to one or more of the following: CSWIP-WI-6-92, AWS QC1, or the manufacturer's documented training program.

If CSWIP-WI-6-92 is used, the allowable certifications are:

- CSWIP Certified Visual Welding Inspectors (Level 1);
- CSWIP Certified Welding Inspectors (Level 2);
- CSWIP Certified Senior Welding Inspectors (Level 3)

If AWS-QC1 is used, the allowable certifications are:

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- 1) AWS Senior Certified Welding Inspector (SCWI);
 - 2) AWS Certified Welding Inspector (CWI);
- AWS Certified Associate Welding Inspector (CAWI);

The manufacturer shall have written procedures:

- 1) Defining the In-house welding inspector certification program including training syllabus, Instructor qualification requirements, length of certification and renewal requirements;.
- 2) Defining the roles, responsibilities, authority and accountability of a welding inspector;
- 3) Defining essential welding variables and equipment monitoring;
- 4) Defining Welding, Weld NDE and PWHT audits. Internal Audits shall be performed at least annually, covering all on-site areas and shifts. Supplier Audits shall be performed in accordance with the Manufacturers written procedure for Validation of Supplier Processes

7.3.4 Other personnel

All personnel performing other quality control activities directly affecting material and product quality shall be qualified in accordance with manufacturer-documented requirements.

7.4 Quality control requirements for equipment and parts

7.4.1 General

All metallic materials which come in contact with well fluids and designed for sour service shall meet the requirements of NACE MR0175 for sour service.

7.4.2 Materials

Subsection 7.5.1 includes detailed qualification requirements for parts and qualification test coupons. It also includes heat-treatment equipment qualification requirements.

7.4.3 Quality control instructions

All quality control work shall be controlled by manufacturer's documented instructions, which include appropriate methodology and acceptance criteria.

7.4.4 Non-destructive examination (NDE)

The manufacturer shall provide written instructions for NDE activities regarding the requirements of this standard and those of all applicable referenced specifications. All NDE instructions shall be approved by the manufacturer's qualified Level III NDE examiner.

7.4.5 Acceptance status

The acceptance status of all equipment, parts and materials shall be indicated either on the equipment, parts or materials or in the records traceable to the equipment, parts or materials.

7.5 Quality control requirements for specific equipment and parts

7.5.1 Level 1 and Level 2 parts

7.5.1.1 General

Level 2 items include those exposed to wellbore fluid (except for studs and nuts, flange bolting, ring gaskets, non-metallic sealing materials, molded sealing assemblies and metallic inserts in molded assemblies; see 7.5.2 through 7.5.5).

7.5.1.2 Tensile testing

7.5.1.2.1 Level 2 Items

Methods and acceptance criteria shall be in accordance with **5.3.5.2**.

7.5.1.3 Impact testing

7.5.1.3.1 Level 2 Items

Methods and acceptance criteria shall be in accordance with **5.3.5.3**.

7.5.1.4 Hardness testing

Hardness testing methods shall be in accordance with ASTM E10, ASTM E18, ASTM E110, ASTM E384, ASTM A370, ISO 6506-1, ISO 6507-1 or ISO 6508-1..

At least one hardness test (two indentations) shall be performed on each part tested, at a location determined by the manufacturer's specifications. The hardness testing used to qualify each part shall be performed after the last heat-treatment cycle (including all stress-relieving heat-treatment cycles) and after all exterior machining operations. The actual value of the hardness test shall be stamped on the part adjacent to the test location, provided there is adequate room. It is permissible for hardness marking to be covered by other components after assembly.

When equipment is a weldment composed of different material designations, the manufacturer shall perform hardness tests on each component part of the weldment after the final heat treatment (including stress-relieving). The results of these hardness tests shall satisfy the hardness value requirements for each respective part.

Parts manufactured to NACE MR0175 shall meet the following requirement: Hardness measurements on parts manufactured from carbon low alloy and martensitic stainless type steels shall exhibit maximum values in accordance with NACE MR0175 and minimum values shall be equal to or greater than those specified in **Table 30**.

In the event that a part does not exhibit the required minimum hardness level, the part may be considered to have an acceptable hardness if the measured value satisfies the following requirements.

- a) The tensile strength, as determined from the tensile tests results, shall be used with the hardness measurements to determine the minimum acceptable hardness value for parts manufactured from the same heat.
- b) The minimum acceptable hardness value for any part shall be determined by Equation 1

$$HBW_C = \left[\frac{UTS}{UTS_{QTC}} \right] \times HBW_{QTC} \quad \text{Equation 1.}$$

where

HBW_C is the minimum acceptable Brinell hardness for the part after the final heat-treatment cycle (including stress-relieving cycles);

UTS is the minimum acceptable ultimate tensile strength specified for the applicable strength level, i.e. 70 000 psi (483 MPa), 85 000 psi (586 MPa) or 95 000 psi (655 MPa);

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UTS_{QTC} is the ultimate tensile strength determined from the QTC tensile tests;

HBW_{QTC} is the Brinell hardness value observed on the QTC.

If it is necessary to report the hardness test results in other measurement units, conversions shall be made in accordance with ASTM E140 or ISO 18265.

Table 30 — Minimum hardness requirements

API material designation	Hardness (Brinell)
60K	174 HBW
75K	197 HBW
80K	197 HBW

7.5.1.5 Dimensional verification

Critical dimensions, as defined by the manufacturer, shall be documented for each part and such documentation shall be retained by the manufacturer in accordance with 7.6. The manufacturer shall define and document the extent to which dimensions shall be verified.

7.5.1.6 Traceability

Parts and material shall be traceable to the individual heat and heat-treatment lot.

Identification shall be maintained on materials and parts, to facilitate traceability, as required by documented manufacturer requirements.

Manufacturer-documented traceability requirements shall include provisions for maintenance or replacement of identification marks and identification control records.

7.5.1.7 Chemical analysis

7.5.1.7.1 Sampling

Chemical analysis shall be performed on a heat basis.

7.5.1.7.2 Procedure

Chemical analysis shall be performed in accordance with the manufacturer's written procedure.

7.5.1.7.3 Acceptance criteria

The chemical composition shall meet the requirements of 5.3.6.

7.5.1.8 Visual examination

7.5.1.8.1 Sampling

Each part shall be visually examined.

7.5.1.8.2 Procedure

Visual examination of castings and forgings shall be performed in accordance with the manufacturer's written specification.

7.5.1.8.3 Acceptance criteria

Acceptance criteria shall be in accordance with manufacturer's written specifications.

Surfaces not wetted by well fluids and non-sealing surfaces shall be examined in accordance with the manufacturer's written specification.

7.5.1.9 Surface NDE

7.5.1.9.1 General

All accessible surfaces of each finished part shall be inspected in accordance with Section 7.

7.5.1.9.2 Surface NDE of ferromagnetic materials

All accessible surfaces wetted by the well fluid and all accessible sealing surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by either MP or LP methods.

7.5.1.9.3 Surface NDE of non-ferromagnetic materials

All accessible surfaces wetted by the well fluid of each finished part shall be inspected after final heat treatment and after final machining operations by the LP method.

7.5.1.9.4 Surface NDE of Overlay Claddings

All accessible surfaces wetted by the well fluid of each finished part shall be inspected after final heat treatment. If the cladding is to remain as-welded and not machined, no additional surface inspection shall be required after subsequent heat-treat cycles. If the cladding is final machined, the newly machined surface shall require surface inspection by the LP method.

7.5.1.9.5 Procedures

7.5.1.9.5.1 General

MP examination shall be in accordance with procedures specified in ASTM E709. Prods shall not be permitted on surfaces wetted by the well fluid or sealing surfaces.

LP examination shall be in accordance with procedures specified in ASTM E165.

7.5.1.9.5.2 Acceptance criteria for MP and LP

Inherent indications not associated with a surface rupture (i.e. magnetic permeability variations, non-metallic stringer, etc.) are not considered relevant indications.

7.5.1.9.5.3 Acceptance criteria for surfaces other than pressure-contact (metal-to-metal) sealing surfaces

The following shall apply:

- No relevant indication with a major dimension equal to or greater than 3/16 inch (5 mm).
- No more than ten relevant indications in any continuous 6 in² (40 cm²) area.

- Four or more relevant indications in a line separated by less than 1/16 inch (1.6 mm) (edge to edge) are unacceptable.

7.5.1.9.5.4 Acceptance criteria for pressure contact (metal-to-metal) sealing surfaces

There shall be no relevant indications in the pressure-contact (metal-to-metal) sealing surfaces.

7.5.1.10 Weld NDE — General

When examination is required herein, essential welding variables and equipment shall be monitored and completed weldments [a minimum of 0.500 inch (12.8 mm) of surrounding base metal] and the entire accessible weld shall be examined in accordance with the methods and acceptance criteria of this section.

7.5.1.11 Weld prep NDE — Visual examination

100 % of all surfaces prepared for welding shall be visually examined prior to initiating welding.

Examinations shall include a minimum of 0.500 inch (12.8 mm) of adjacent base metal on both sides of the weld.

Weld NDE surface preparation acceptance shall be in accordance with the manufacturer's written specification.

7.5.1.12 Post-weld visual examination

All welds shall be examined according to manufacturer's written specification.

Any undercut detected by visual examination shall be evaluated in accordance with the manufacturer's written specification.

Surface porosity and exposed slag shall not be on or within 1/8 inch (3 mm) of sealing surfaces.

7.5.1.13 Weld NDE — Surface examination (other than visual)

7.5.1.13.1 General

One hundred percent (100%) of pressure-containing welds, repair and weld metal overlay welds, and repaired fabrication welds shall be examined by either MP or LP methods after welding, post-weld heat treatment, and machining operations are completed.

Weld metal overlays that will remain in the as-welded condition shall be inspected after the final PWHT.

Repair welds to fabrication welds and to weld metal overlays shall be LP inspected both before and after the weld repair operation, and after any subsequent PWHT or machining operation.

The examination shall include 0.500 inch (12.8 mm) of adjacent base material on both sides of the weld.

7.5.1.13.2 Procedures

Methods and acceptance criteria for MP and LP examinations shall be the same as in **7.5.1.9.5** except:

a) MP examination shall reveal

- no relevant linear indications,
- no rounded indications greater than 0.125 inch (3 mm) for welds whose depth is 5/8 inch (16 mm) or less or 0.188 inch (5 mm) for welds whose depth is greater than 0.63 inch (16 mm).

b) LP examination shall reveal

- no rounded indications greater than 0.125 inch (3 mm) for welds whose depth is 0.63 inch (16 mm) or less or 0.188 inch (5 mm) for welds whose depth is greater than 0.63 inch (16 mm).

Manufacturers shall not be restricted to these criteria provided they have the means to and determine the acceptable defect size and configuration based on their stress analysis of the product. Results of the analysis shall be documented.

7.5.1.14 Repair welds

All repair welds shall be examined using the same methods and acceptance criteria used in examining the base metal (**7.5.1.9**).

Examination shall include 0.500 inch (12.8 mm) of adjacent base metal on all sides of the weld.

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Surfaces of ground-out areas for repair welds shall be examined prior to welding to ensure defect removal using the acceptance criteria for fabrication welds (7.5.1.11).

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7.5.1.15 Weld NDE — Volumetric examination of fabrication weld

7.5.1.15.1 General

One hundred percent of all pressure-containing welds shall be examined by either radiography, ultrasonic, or acoustic emission methods after all welding and post-weld heat treatment. All repair welds for which the repair is greater than 25 % of the original wall thickness or 1.00 inch (25.4 mm), whichever is less, shall be examined by either radiography, ultrasonic, or acoustic emission methods after all welding and post-weld heat treatment. Examinations shall include at least 0.500 inch (12.8 mm) of adjacent base metal on all sides of the weld.

7.5.1.15.2 Radiography

7.5.1.15.2.1 Procedure

Radiographic examinations shall be performed in accordance with procedures specified in ASTM E94, to a minimum equivalent sensitivity of 2 %. Both X-ray and gamma ray radiation sources are acceptable within the inherent thickness range limitation of each. Real-time imaging and recording/enhancement methods may be used when the manufacturer has documented proof that the methods will result in a minimum equivalent sensitivity of 2 %.

Note: Wire-type image quality indicators may be used per ASTM E747.

7.5.1.15.2.2 Acceptance criteria

The following shall not be accepted:

- a) crack, or zone of incomplete fusion, or penetration,
- b) elongated slag inclusion that has a length equal to or greater than specified in **Table 31**,
- c) group of slag inclusions in a line having an aggregate length greater than the weld thickness, t , in any total weld length $12t$, except when the distance between successive inclusions exceeds six times the length of the longest inclusion,
- d) rounded indications in excess of that specified in ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Appendix 4.

Table 31 — Weld inclusion criteria

Weld thickness t		Inclusion length	
In	(mm)	In	(mm)
< 0.76	< 19	0.25	6.4
$0.76 \leq t \leq 2.25$	$19 \leq t \leq 57$	$0.33 t$	$0.33 t$
> 2.25	> 57	0.75	19.0

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7.5.1.15.3 Ultrasonic examination

7.5.1.15.3.1 Procedure

Ultrasonic examinations shall be performed in accordance with procedures specified in ASME Boiler and Pressure Vessel Code, Section V, Article 4.

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7.5.1.15.3.2 Acceptance criteria

The following shall not be accepted:

- a) indication whose signal amplitude exceeds the reference level,
- b) linear indication interpreted as a crack, incomplete joint penetration, or incomplete fusion,
- c) slag indication with amplitude exceeding the reference level whose length exceeds that specified in **Table 31**.

NOTE If a weld joins two members having different thicknesses at the weld, t is taken as the thinner of the two thicknesses.

7.5.1.15.4 Acoustic emission examination

7.5.1.15.4.1 Procedure

Acoustic emission (AE) examinations shall be performed in accordance with procedures specified in ASTM E569. The acoustic emission examination shall be conducted throughout the duration of the hydrostatic "in-plant" test.

7.5.1.15.4.2 Acceptance criteria

Evaluation and acceptance criteria shall be as follows:

- a) During the first pressurization cycle, any rapid increase in AE events or any rapid increase in AE count rate shall require a pressure hold. If either of these conditions continues during the pressure hold, the pressure shall be immediately reduced to atmospheric pressure and the cause determined. There shall be no leakage at any time during the test.
- b) During the second pressurization cycle, the requirements of **7.5.1.15.4.2 a)** shall apply and, in addition, the following AE indications shall not be accepted:
 - 1) any AE event during any pressure hold;
 - 2) any single AE event that produces more than 500 counts, or that produces a single attribute equivalent to 500 counts;
 - 3) three or more AE events from any circular area whose diameter is equal to the weld thickness or 25 mm (1 in), whichever is greater;
 - 4) two or more AE events from any circular area (having a diameter equal to the weld thickness or 25 mm (1 in), whichever is greater) that emitted multiple AE events during the first pressurization;

Welds that produce questionable acoustic emission response signals (i.e. AE signals that cannot be interpreted by the AE examiner) shall be evaluated by radiography in accordance with **7.5.1.15.2**. If the construction of the pressure vessel does not permit interpretable radiographs to be taken, ultrasonic examination may be substituted for radiography in accordance with **7.5.1.15.3**. Final acceptance (or rejection) of such welds shall be based on the radiographic or ultrasonic results, as applicable.

7.5.1.16 Weld NDE — Hardness testing

7.5.1.16.1 Sampling

All accessible pressure-containing welds, non-pressure-containing welds and repair welds shall be hardness tested per **7.5.1.16.2**.

7.5.1.16.2 Methods

Hardness testing shall be performed in accordance with one of the following:

- a) those procedures specified in ASTM E18, ASTM E110 (Brinell) or ISO 6506-1;
- b) those procedures specified in ASTM E10, ASTM E110 (Rockwell) or ISO 6508-1;
- c) at least one hardness test shall be performed in both the weld and in the adjacent unaffected base metal after all heat treatment and machining operations. The actual value of the hardness test shall be stamped on the part adjacent to the test location. It is permissible for hardness marking to be covered by other components after assembly.

7.5.1.16.3 Acceptance criteria

Hardness values shall meet the requirements of **7.5.1.4**.

The hardness recorded in the PQR shall be the basis for acceptance if the weld is not accessible for hardness testing.

7.5.1.17 Volumetric NDE

The following requirements shall apply

a) Sampling

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

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

b) Ultrasonic examination

1) Test method

Hot-worked parts: Ultrasonic examination of hot-worked parts shall be performed in accordance with the flat-bottom-hole procedures specified in ASTM A 388 (except immersion method may be used) and ASTM E 428.

Calibration: Distance amplitude curve (DAC) shall be based on 0.063 inch (1.6 mm) flat-bottom hole for metal thicknesses through 1-1/2 inch (38.1 mm), on 0.125 inch (3.2 mm) flat-bottom hole for metal thicknesses from 1-1/2 inch (38.1 mm) through 6.00 inch (152.4 mm), and on 0.250 inch (6.35 mm) flat-bottom hole for metal thicknesses exceeding 6.00 inch (152.4 mm).

2) Acceptance criteria

The following acceptance criteria apply:

- no single indications exceeding reference distance amplitude curve;
- no multiple indications exceeding 50 % of reference distance amplitude curve.

Multiple indications are defined as two or more indications (each exceeding 50 % of the reference distance amplitude curve) within 0.500 inch (12.8 mm) of each other in any direction.

c) Radiographic examination

1) Test method

Radiographic examination of hot-worked parts shall be performed in accordance with methods specified in **7.5.1.15.2**

2) Acceptance criteria

The following acceptance criteria apply to hot-worked parts:

- no cracks, laps, or bursts;
- no elongated indications with length greater than stated in **Table 32**.

Table 32 – Weld inclusion criteria

Material thickness in (mm)	Inclusion length in (mm)
< .75 (19.0)	.25 (6.4)
.75 to 2.25 (19 to 57)	.33T (0.33T)
>2.25 (>57.0)	0.75 (19.0)

Thickness, T Inclusion length in (mm)

No group of indications in a line that have an aggregate length greater than T in a length of 12T.

7.5.2 Bolting

Studs bolts and nuts shall conform to the requirements of **4.3.2.4**.

7.5.3 Ring gaskets

Ring gaskets shall conform to the requirements of API 6A.

7.5.4 Non-metallic Sealing Materials and Molded Sealing Assemblies exposed to the wellbore

7.5.4.1 General

Testing of each batch shall be in accordance with ASTM procedures. If a suitable ASTM procedure cannot be applied, the manufacturer shall provide a written procedure for testing. Characteristics shall be defined by measurements of physical properties.

Mechanical property data shall include the following:

- a) hardness data in accordance with ASTM D1415 or ASTM D2240;
- b) tensile data in accordance with ASTM D1414 or ASTM D412;

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c) elongation data in accordance with ASTM D1414 or ASTM D412;

d) modulus data in accordance with ASTM D1414 or ASTM D412.

Acceptance shall be in accordance with manufacturer's written specifications.

7.5.4.2 Metallic inserts in molded sealing assemblies exposed to the wellbore

7.5.4.2.1 Dimensional verification

Sampling shall be in accordance with manufacturer's written requirements or ISO 2859-1, Level II 4.0 Acceptance Quality Level. .

All methods shall be in accordance with manufacturer's written requirements.

Acceptance shall be in accordance with manufacturer's written specifications.

7.5.4.2.2 Hardness testing

Sampling shall be in accordance with manufacturer's written requirements or ISO 2859-1, Level II, 4.0 Acceptance Quality Level. .

A minimum of one hardness test (two indentations) shall be performed in accordance with ASTM E10, ASTM E18, ASTM E110, ISO 6506-1 or ISO 6508-1.

Acceptance shall be in accordance with manufacturer's written requirements and NACE MR0175 (Where required).

Welding NDE shall be in accordance with manufacturer's written specifications.

7.5.5 All other well intervention pressure control equipment not covered in 7.5.1 through 7.5.6

All quality control requirements shall be documented in the manufacturer's written specifications.

7.5.6 Assembled equipment Factory Acceptance Test (FAT)

7.5.6.1 General

Assembled equipment includes Bonnet/Actuator assemblies when shipped separately from a well intervention pressure control component.

The quality control requirements for assembled equipment shall include drift tests (if applicable), pressure tests, and hydraulic operating system tests and manually operated devices.

Test in accordance with **7.5.6.6**.

After test and prior to shipment, water or water with additives test fluid should be drained and replaced with a corrosion-inhibiting fluid.

If an oil-based fluid is used the hydraulic operating system should be drained prior to shipping.

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If a water-based fluid is used the hydraulic operating system shall be flushed with a non-freezing, corrosion-inhibiting fluid in accordance with the equipment manufacturer's written procedures.

Ports shall be plugged prior to storing

7.5.6.2 Serialization

All assembled equipment that contains one or more pressure-containing or pressure-controlling components(s) shall be serialized in accordance with the manufacturer's written specifications.

7.5.6.3 Traceability record report

A report shall be prepared in which all serialized and individual-heat-traceable parts are listed as traceable to the assembly (e.g., assembly part number, serial number).

7.5.6.4 Drift test

7.5.6.4.1 Method

A drift test is required on ram well intervention pressure control devices, spools and adapters.

Pass a drift mandrel through the bore of the assembly after all pressure testing.

Drift mandrel diameter shall be in accordance with the drift diameter in Table 1 with a tolerance of $\left(\begin{smallmatrix} +0.01 \\ 0 \end{smallmatrix} \text{in} \right) \begin{smallmatrix} +0.25 \\ 0 \end{smallmatrix} \text{mm}$.

Drift mandrel gauge length shall be at least 2.00 inch (50.8 mm) longer than any cavity that intersects the bore, but not less than 12.0 inches (304.8 mm).

7.5.6.4.2 Acceptance

The drift mandrel shall pass through the bore with no external force being applied to the drift.

7.5.6.5 Pressure test equipment

A data acquisition system (System for storing and/or providing permanent copies of test information

examples include strip chart recorders, circular chart recorders, or a computer system) shall be used on all hydrostatic tests and on hydraulic control system tests. Pressure gauges used shall be as described in 7.2. The record shall identify the recording device, and shall be dated and signed.

7.5.6.6 Hydrostatic proof testing

7.5.6.6.1 General

All well intervention pressure control equipment shall be subjected to a hydrostatic proof test prior to shipment from the manufacturer's facility. Water or water with additives shall be used as the testing fluid. Any additives shall be documented in the test records.

7.5.6.6.2 In-plant Hydrostatic Proof test

Well intervention pressure control equipment shall be tested with its sealing mechanisms in the open position, if applicable.

The hydrostatic proof or shell test pressure shall be determined by the rated working pressure for the equipment. Hydrostatic proof test pressures shall be as shown in **Table 33**. For equipment with end or

outlet connections having different working pressures, the lowest rated working pressure shall be used to determine the shell test pressure.

Hydrostatic body test shall include the ring gasket areas on each end of the body.

Table 33 — Hydrostatic test pressures

Rated working pressure		Hydrostatic test pressure	
(psi)	MPa	(psi)	MPa
3 000	20.7	4 500	31.05
5 000	34.50	7 500	51.75
10 000	69.0	15 000	103.50
15 000	103.50	22 500	155.25

7.5.6.6.3 Hydraulic operating-chamber test

The hydraulic operating system test shall be tested on each assembled well intervention pressure control component.

The hydraulic operating chamber shall be tested at a minimum test pressure equal to 1.5 times the operating chamber's rated working pressure.

7.5.6.6.4 Hydrostatic proof and hydraulic operating chamber tests

The hydrostatic proof test and the hydraulic operating chamber test shall consist of three steps:

- a) an initial pressure-holding period of not less than 3 minutes;
- b) reduction of the pressure to zero;
- c) a second pressure-holding period of not less than 15 minutes.

The timing of the test shall not start until the test pressure has been stabilized within the manufacturer's specified range and the external surfaces have been thoroughly dried.

The acceptance criterion shall be zero visible leakage.

7.5.6.7 Closed Ram test

7.5.6.7.1 General

7.5.6.7.1.1 Test conditions

Each ram shall be subjected to a closed ram test after the hydrostatic proof test. The hydraulic operating system pressure used shall be equal to or less than the manufacturer's specified operating pressure. The test fluids used for all closed ram tests shall meet the requirements of **7.5.8.6.1**.

The timing of all closed ram tests shall not start until the test pressure has stabilized.

Closed ram tests shall be performed at low and high pressures, with the low-pressure test always preceding the high-pressure test.

7.5.6.7.1.2 Low-pressure test

A pressure of 200 psi to 300 psi (1.4 MPa to 2.1 MPa) shall be applied and held below the closed ram unit for a minimum of 10 minutes after stabilization.

7.5.6.7.1.3 High-pressure test

A pressure at least equal to the rated working pressure of the well intervention pressure control component shall be applied and held below the closed ram unit for a minimum of 10 minutes after stabilization.

7.5.6.7.1.4 Acceptance criterion

There shall be no visible leakage.

7.5.6.7.2 Well intervention pressure control assembly equipped with wireline ram, pipe ram, blind ram and VBR.

With the exception of the Blind Rams, these tests shall be performed with the appropriate size Test Rod for the rams being tested. VBRs shall be tested on the minimum and maximum sizes for their range.

7.5.6.7.3 Well Intervention Pressure Control assembly equipped with Shear or Shear-Blind rams

Each well intervention pressure control assembly equipped with Shear Rams or Shear-Blind Rams shall be subjected to a shearing test. The minimum size of shear specimen shall conform to below or unless otherwise specified by customer.

- The minimum size of wire for the Wireline Class Equipment shall be 7/32" cable (Material per **Table 12**)
- The minimum size of coiled tubing for the CT Class is per **Table 16**
- The minimum size of snubbing pipe for the snubbing Class is per **Table 17**

These tests shall be performed without tension and with zero ID bore pressure.

For the Shear-Blind Ram, shearing and sealing shall be achieved in a single operation. After the tube specimen (and associated internal components where specified on the purchase order) has been sheared, the Shear-Blind Ram shall remain in the fully-closed position at a hydraulic pressure not to exceed 90% of the maximum rated hydraulic operating pressure. A pressure test shall be conducted within the bore below the closed Shear-Blind Ram to the RWP of the assembly.

Documentation shall include:

- The manufacturer's shear ram and well intervention pressure control component configurations
- The pipe/tubing/wire description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API Specification for that sample.
- Record of wellbore pressure and operator closing and opening pressure throughout the test;
- Document the operator hydraulic closing and opening areas.
- Document the shear pressure, i.e. the net pressure at the point of shear taking into account opening pressure/area and closing pressure/area.
- Document condition of all ram packers as they are removed after tests.

Hydraulic/Manual ram-locking system

The closed ram test for each well intervention pressure control component equipped with a hydraulic or a manual ram-locking system shall be pressure-tested with the locking system engaged. This test shall apply to each included ram that is designed to operate with the ram-locking system. The ram component shall be tested in accordance with **7.5.6.7.1.2** and **7.5.6.7.1.3** after the rams are closed, the locks engaged and then all operating pressure(s) released.

7.5.6.7.4 Well Intervention pressure control assembly equipped with Slip or Pipe-Slip Rams

Each well intervention pressure control assembly equipped with a Slip Ram or Pipe-Slip Ram shall be subjected to the following tests:

- a) For coiled tubing equipment, Slip and Pipe-Slip Ram tests shall be performed in accordance with **4.7.3.13.8**, **4.7.3.13.9** (only pipe-light test is required) and **4.7.3.13.10**. The hydraulic pressure to be applied during this test shall not exceed the effective hydraulic actuator pressure. The OD size, wall thickness and yield strength of the coiled tubing to be used should follow the size specified in **Table 11** or as specified by the purchaser. If the purchase order specifies that the well intervention pressure control be assembled for an OD tube size different from the OD size of coiled tubing stated in **Table 11**, it is acceptable to perform the Factory Acceptance Test with the OD size, wall thickness and yield strength of coiled tubing stipulated by the purchaser.
- b) For snubbing equipment, Slip Ram tests shall be performed in accordance with **4.7.3.13.4**, **4.7.3.13.9** and **4.7.3.13.10** (only pipe-light test is required). The OD size, wall thickness and

yield strength of the jointed pipe to be used should follow the size, weight and grade as specified in **Table 11** or as specified by the purchaser. If the purchase order specifies that the well intervention pressure control be assembled for an OD tube size different from the OD size of jointed tube stated in **Table 11**, it is acceptable to perform the Factory Acceptance Test with the OD size, weight and grade of tubing stipulated by the purchaser.

Documentation shall include:

- The manufacturer's slip and/or pipe-slip ram and intervention pressure control component configurations
- For the Coiled Tubing Class the coiled tubing description (nominal OD size, wall thickness, and grade), actual OD, wall thickness, mechanical properties, and impact properties as specified in API Specification 5ST.
- For the Snubbing Class the pipe description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API Specification 5CT or 5DP
- Record of wellbore pressure and operator closing and opening pressure throughout the test;
- Document the operator hydraulic closing and opening areas.
- digital record of hydraulic actuator pressure from start to end of each test, including documentation of test period where axial load is retained using only the ram locks (hydraulic actuator pressure is bled to zero)
- Record of wellbore pressure and operator closing and opening pressure throughout the test;
- Document the operator hydraulic closing and opening areas.

7.6 Requirements for quality control records

7.6.1 General

The quality control records required by this standard are those documents and records necessary to substantiate that all materials and equipment made to this standard do conform to the specified requirements.

7.6.2 NACE records requirements

Records required to substantiate conformance of equipment to NACE requirements shall be in addition to those described in other sections of this standard, unless the records required by this standard also satisfy the NACE MR0175 requirements.

7.6.3 Records control

Records required by this standard shall be legible, identifiable, retrievable and protected from damage, deterioration or loss.

Records required by this standard shall be retained by the manufacturer for a minimum of ten years following the date of manufacture as marked on the equipment associated with the records.

The manufacturer shall document and retain all records for each batch of raw material used in the manufacture of ram packers and seals. Records shall be retained for a minimum of five years.

All records required by this standard shall be signed and dated. Computer-stored records shall contain the originator's personal code.

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7.6.4 Records to be maintained by manufacturer

7.6.4.1 Records

The manufacturer shall retain all documents and records as required in **Section 4** through **Section 7**.

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7.6.4.2 Parts or components covered in 7.5.1

The following records shall be retained:

- a) weldPQR ;
- b) welder qualification record;
- c) material test records:
 - 1) chemical analysis;
 - 2) tensile tests (QTC);
 - 3) impact tests (QTC, as required);
 - 4) hardness tests (QTC);
- d) NDE personnel qualification records;
- e) NDE records:
 - 1) surface NDE records;
 - 2) full penetration fabrication;
 - 3) weld volumetric NDE records;
 - 4) repair weld NDE records;
- f) hardness test records;
- g) welding process records:
 - 1) welder identification;
 - 2) weld procedures;
 - 3) filler materials;
 - 4) post-weld heat treatments;
- h) heat treatment records:
 - 1) actual temperature;
 - 2) actual times at temperature;
- i) volumetric NDE records;
- j) hydrostatic pressure test records;
- k) critical dimensions as defined by the manufacturer.

7.6.4.3 Bolting

The manufacturer shall retain records as specified in **API Spec 20E** and **API Spec 20F** for Class C (**Table 7**) Bolting.

7.6.4.4 Non-metallic sealing materials and molded sealing assemblies

The manufacturer shall retain a certification of compliance for non-metallic sealing materials and molded sealing assemblies to manufacturer's written requirements.

7.6.4.5 Assembled equipment

The following records shall be retained:

- a) pressure test records
- b) drift test record

7.6.5 Records to be furnished to original purchaser upon product delivery

A manufacturer's certificate of conformance stating that equipment conforms to the current edition of this standard shall be furnished to the purchaser. Additionally, a data book per **Annex D** shall be furnished unless otherwise specified by the purchaser.

8 Marking requirements

8.1 General

All equipment, as listed in Section 1, manufactured in accordance with this standard shall be marked in accordance with the procedure and requirements of this section and **Table 34**.

Equipment shall be stamped on the product "API 16B".

8.2 Types of identification stamping

8.2.1 Metallic components

8.2.1.1 Low-stress-area marking

For identification on low-stress areas (such as nameplates, outside diameters of flanges, etc.), the use of sharp "V" stamping is acceptable.

8.2.1.2 High-stress-area marking

For identification on high-stress areas, dot, vibration or round "V" stamping is acceptable. Sharp "V" stamping is allowed in high-stress areas only if subsequent stress-relieving is performed to the component.

8.2.1.3 Weld metal overlays

When equipment has weld metal-overlaid ring grooves, the ring gasket type and number shall be followed by "CRA" to designate a corrosion-resistant alloy or "SST" to designate an austenitic stainless steel.

8.2.2 Non-metallic components

8.2.2.1 Wellbore non-metallic components

For identification of wellbore non-metallic components, such as ram packers and seals, the manufacturer shall have a written procedure for affixing the required codification to the product or its package.

8.2.2.2 Non-wellbore non-metallic components

Identification of non-wellbore non-metallic components, such as elastomeric seals used in ram actuation systems, shall be in accordance with the manufacturer's written specification.

8.3 Specific codification requirements of equipment

8.3.1 Gaskets

Ring gaskets shall be marked in accordance with API 6A.

8.3.2 Bolting

Class C **bolting** shall be marked in accordance with API 20E or API 20F.

Table 34 — Marking requirements and location

Marking	Ram Pressure Control Component	OECs (integral & loose) ^d	Ram blocks	Ram seals & Outer seals
API 16B	body	Mfr's specification	Mfr's specification	Mfr's specification
Mfr's name or mark	body	Mfr's specification		Mfr's specification
Intervention Designation e.g WL, CT, SB	body		Mfr's specification	Mfr's specification
Serial number	body		Mfr's specification	
Size designation (Table 1)	Nameplate and/or body & connection OD ^a	Mfr's specification		
Rated working pressure (Table 2)	Nameplate and/or body & connection OD ^a	Mfr's specification		
Temperature rating (Table 3)	Nameplate and/or body	Mfr's specification		
Mfr's part number	body	Mfr's specification	Mfr's specification	Mfr's specification
Date of manufacture	Nameplate and/or body			Mfr's specification
Hydr OS rated working pressure	Nameplate and/or body			
Hydraulic open & close ports	Mfr's specification			
Ring groove designation (if applicable)	Connection OD ^{a, b, c}	Mfr's specification ^c		
Service	Nameplate and/or body			

Table 35 — Marking Requirements for non-metallic sealing materials

Description
Compound hardness (Durometer)
Generic type of compound (see ASTM D 1418)
Date of manufacture (see 8.4.3)
Lot/serial number (in accordance with manufacturer's spec)
Temperature class (see Table 4)
Date of expiry

Table 36 — Elastomer compound marking code

Common name/ trade name	Chemical name	Code ASTM D 1418
Butyl	Isobutylene, Isoprene	IIR
	Epichlorohydrin	CO
	Epichlorohydrin-ethylene oxide	ECO
Kel-F ^a	Chlorofluoro elastomer	CFM
Hypalon ^a	Chlorosulfonated polyethylene	CSM
EPR	Ethylene-propylene copolymer	EPM
EPT	Ethylene-propylene diene monomer	EPDM
Viton ^a	Fluoro elastomer	FKM
Natural rubber	Polyisoprene	NR
Isoprene (natural or synthetic)	Polyisoprene	IR
Nitrile rubber	Butadiene-acrylonitrile	NBR
HNBR	Hydrogenated Acrylonitrile-butadiene	HNBR
Acrylic	Polyacrylic	ACM
Diene rubber	Polybutadiene	BR
Neoprene ^a	Polychloroprene	CR
Vistanex ^a	Polyisobutylene	IM
Thiokol	Polysulfide	—
Silicone	Polysiloxanes	Si
SBR (GR-S)	Styrene-butadiene	SBR
Urethane	Diisocyanates + polyols	—

^a This is the trade name of a suitable product available commercially. This information is given for the convenience of users of this standard and does not constitute an endorsement by API of this product. Equivalent products may be used if they can be shown to lead to the same results.

8.4 Marking Designations:

8.4.1 Compound Hardness:

Marking will contain the Durometer of the elastomer

8.4.2 Generic Type of Compound:

Marking will state the compound code or common name as stated in ASTM D1418, or state the full compound name in order to clearly state what the elastomer base is.

8.4.3 Date of Manufacture:

The date of manufacture shall contain the month and year. The date should be in a four-digit format with the first two digits being the month and the next two the year. (Example: 0422 would be April 2022.)

8.4.4 Lot/Serial Number

The lot/serial number will be in accordance to the manufacturers specification and contain information for traceability of the part.

8.4.5 Temperature Class

The temperature class marking can contain the three-digit code found in **Table 4**

8.4.6 Date of Expiry:

The date of Expiry shall contain the month and year. This can include numerical format or written. Example May 2022 can be expressed as 0522, 05/2022, or May 2022.

9 Storing and shipping

9.1 Storing for periods greater than 30 days

9.1.1 Draining after testing

If not already performed in **7.5.6.1**, all equipment shall be drained after testing and prior to storage.

9.1.2 Rust prevention

Prior to storage, parts and equipment shall have exposed metallic surfaces protected with a rust preventative which will not become fluid at temperatures below 125 °F (50 °C).

9.1.3 Connection-surface protection

All connection faces and ring gasket grooves shall be protected with durable covers.

9.1.4 Hydraulic operating system

If a water-based fluid is used the hydraulic operating system shall be flushed with a non-freezing, corrosion-inhibiting fluid in accordance with the equipment manufacturer's written procedures. Ports shall be plugged prior to storing. Equipment may be stored with customer specified control fluid to avoid contamination with corrosion inhibiting fluid.

NOTE Mixing of OEM control fluids may create highly caustic compounds. These compounds can cause extreme damage to lip seal elastomers.

9.1.5 Elastomeric seals

Elastomeric seals shall be stored in accordance with the manufacturer's written procedures.

9.1.6 Ring gaskets

Loose ring gaskets shall be wrapped or boxed for storage and shipping.

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9.2 Shipping

All equipment shall be shipped in accordance with the manufacturer's written procedures.

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Annex A (informative)

Purchasing guidelines

A.1 General

This annex provides recommended guidelines for enquiry and purchase of equipment covered by the scope of API 16B

A.2 Well Intervention well pressure control Components

A.2.1 Size designation

The size designation consists of the vertical through-bore dimension. A list of standard sizes is included in **Table 1**.

A.2.2 Service conditions

A.2.2.1 Rated working pressure

The rated working pressure is determined by the lowest pressure rating of all integral end or outlet connections. Rated working pressures for equipment covered by the scope of API 16B are given in **4.2.1**.

A.2.2.2 Temperature ratings

A.2.2.2.1 General

Minimum temperature is the lowest ambient temperature to which the equipment may be subjected. Maximum temperature is the highest temperature of the fluid that may flow through the equipment.

A.2.2.2.2 Metallic materials

Metallic parts will be designed to operate in the temperature ratings, which should be designated by the purchaser. These ratings can be found in **Table 3**.

A.2.2.2.3 Wellbore elastomeric materials

The purchaser should provide the temperature range for wellbore elastomeric materials.

A.2.2.2.4 All other elastomeric seals

The purchaser should provide the temperature range for all other elastomeric materials .

A.2.3 Outlet connections

The purchaser should determine the number, location, size, pressure and temperature ratings for all outlet connections. It should be noted that the pressure rating for the equipment is determined by the lowest pressure rating of all end or outlet connections.

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A.2.4 Equipment details/data book

A data book should be supplied upon the request of the purchaser, and should contain the following information:

Assembly drawings, actual overall package dimensions, pressure rating, end connection/outlet description, mass, centre of gravity, list of materials for components defined in 7.5.1 and the location of their use;

The table below outlines contents for the construction of the Manufacturing Data Book (MDB) that shall be provided and recorded in order to provide the minimum traceability requirements for maintenance and remanufacturing of pressure control equipment manufactured under API-16B.

Table A1 — Manufacturing Data Book (MDB)

<u>Document Contents</u>	<u>Delivered to Client</u>	<u>Maintained by Manufacturer</u>
Date of Manufacturing	✓	✓
Purchase order /sales order number	✓	✓
Date of FAT	✓	✓
Part and Serial Numbers of equipment	✓	✓
Design Verification Report	Available for review	✓
3 rd Party Review Certificate	When in Purchase Order	
3 rd Party Type Approval Certificate	When in Purchase Order	✓
Material Mill Certs (including the following):		
a) Chemical Analysis	✓	✓
b) Tensile tests (QTC)	✓	✓
c) Impact tests (QTC as required)	✓	✓
d) Hardness tests (QTC)	✓	✓
e) NDE Reports	✓	✓
f) Heat Treatment (Q&T, etc.)	✓	✓
Material Specification Number	✓	✓
WPS/PQR 3 rd Party or Customer Review Records	As required on Purchase Order	✓
NDE Records:		
a) Surface NDE Records	✓	✓
b) Volumetric NDE records	✓	✓
c) Repair weld NDE records	✓	✓
d) Final Hardness Records	✓	✓
Inspector Qualification Records	As Per Purchase Order	✓
Welding Process Records		
a) Welder ID	✓	✓
b) Filler Metal	✓	✓
c) Heat and/or batch number	✓	✓
d) WPS #	✓	✓
e) PWHT Charts	✓	✓

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f) Total remaining PWHT time (per PQR)	✓	✓
g) Weld Maps	✓	✓

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Manufacturing Data Book (MDB) continued.

<u>Document Contents</u>	<u>Delivered to Client</u>	<u>Maintained by Manufacturer</u>
Welder Qualification Records	As Per Purchase Order	✓
Test Report(s), Pressure Testing and FAT		
a) Pressure test records	✓	✓
Certificate of Conformance	✓	✓
a) include specification to which equipment is certified to		

Annex B (normative)

Failure Reporting

B.1 Manufacturer's Requirements

B.2.1 Manufacturer's Internal Requirements

- B.2.1.1 All significant problems experienced with equipment manufactured to this specification noted during its manufacture, testing or use shall be formally communicated to the individual or group within the manufacturer's organization responsible for the design and specification documents.
- B.2.1.2 The manufacturer shall have a written procedure that describes forms and procedures for making this type of communication and shall maintain records of progressive design, material changes, or other corrective actions taken for each model and size of the equipment.

B.2.2 Manufacturer's External Requirements

- B.2.2.1 All failures experienced with equipment manufactured to this specification that prevent the equipment from meeting the functional requirements shall be reported to the manufacturer in writing. Upon verification of the failure by the manufacturer, the failure shall be reported in writing to every known equipment owner within 3 weeks.
- B.2.2.2 The manufacturer shall communicate any design changes resulting from a malfunction or failure history to every known equipment owner of the affected equipment. That notice shall be within 30 days after the design change.

Annex C (informative) **Conversion of US Customary units to the SI system (metric)**

C.1 General

The purpose of this annex is to document the rules for conversion of US Customary (USC) units into the SI system (metric).

The rules of conversion and rounding are based upon the rules defined in ASTM SI 10:1997[2]. The units obtained by application of the conversion rules in this annex may be different from the results that would be obtained by exact conversion of the units in API 16B. In general, the conversion procedure is to multiply the USC value by a conversion factor that is more accurate than the original units; the result is then rounded to the appropriate number of significant digits. The number of significant digits retained should be such that accuracy is neither sacrificed nor exaggerated. According to the rules of ASTM SI 10, the estimate of intended precision should never be smaller than the accuracy of measurement and should usually be smaller than one-tenth the tolerance, if one exists. After estimating the precision of the dimension, the converted dimension should be rounded to a minimum number of significant digits so that a unit of the last place is equal to or smaller than the converted precision.

NOTE See also, for information, ISO 31 (all parts).

C.2 Conversion rules

USC dimensions are converted from the dimensional tables of API 16B in the following manner:

- a) First convert from decimal inch to exact fraction. This is done to account for the fact that API design originated in the fractional inch system. Therefore, a dimension of 7.06 in the tables actually means $7 \frac{1}{16}$ in or 7.0625 in.
- b) The next step is to multiply the resulting exact decimal equivalent of the fractional-inch dimension by 25.4 mm to obtain the exact millimeter dimension. Example:
 $7 \frac{1}{16}$ in = 7.0625 in = 179.3875 mm.
- c) The next step is the rounding process for the particular dimension. Rounding rules differ for different dimensions, depending on the function of the dimension and involves several steps.
 - 1) Determine the precision required of the USC dimension. The precision should normally be smaller than one-tenth of the tolerance range. For example, a dimension with a ± 0.015 in tolerance would require a converted dimension precision of $\frac{1}{10} \times 0.030$ in $\times 25.4$ mm/in = 0.0762 mm. Therefore, the precision of the converted dimension should be smaller than the 0.0762 mm in this example.
 - 2) In accordance with good industry practice, the converted dimension should be rounded to units that are multiples of 1, 2 or 5, e.g. 0.01; 0.02; 0.05; 0.1; 0.2 or 0.5. As in the previous example, the 0.076 2 mm would be rounded down to 0.05 mm increments.
 - 3) During the rounding process, for critical or interface dimensions, the absolute extremes of the converted (SI) value should not fall outside the absolute extremes of the USC values.

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Example: 7 1/16 in + 0.031 / 0 in bore

The precision of the converted dimension should be
 $1/10 \times 1/32 \text{ in} \times 25.4 \text{ mm/in} = 0.079375 \text{ mm} \approx 0.05 \text{ mm}.$

For the minimum extreme: 7 1/16 in = 7.0625 in = 179.3875 mm \approx 179.40 mm.

For the maximum extreme: 7 1/16 + 1/32 in = 7.093 75 in = 180.181 25 mm \approx 180.15 mm.

C.3 Pressure ratings

Pressure ratings in the SI system are expressed in megapascals (MPa).

The pressures in API Specification 16B are required to be measured within an accuracy of $\pm 0.5\%$ of full scale. For a 5 000 psi rating, this would be $\pm 25 \text{ psi}$ ($\pm 0.172 \text{ MPa}$). Since one-tenth of the tolerance is 5 psi (0.034 474 MPa), the converted dimension should be rounded to the nearest $\pm 0.02 \text{ MPa}$. Thus, 5 000 psi is rounded to 34.48 MPa. API pressure ratings are converted as shown in Table D1.

Table D1 — Pressure ratings

USC values		Converted (SI) values		Precision	Rounded SI values	
nominal	max.	nominal	max.		nominal	max.
psi	psi	MPa	MPa	MPa	MPa	MPa
3 000	3 015	20.684 271	20.787 692	0.01	20.68	20.77
5 000	5 025	34.473 785	34.646 154	0.02	34.48	34.64
10 000	10 050	68.947 570	69.292 308	0.02	68.94	69.26
15 000	15 075	103.421 355	103.938 462	0.05	103.40	103.85

C.4 Nominal sizes

Nominal bore sizes for API drill-through equipment have a tolerance range of 0.031 in. Following the same rules as for the pressure ratings, the converted dimensions should be rounded upward to the nearest 0.05 mm. The nominal bore sizes for API Specification 16B equipment are in accordance with Table D2.

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Table D2 — Nominal sizes

Size in	USC values		Converted (SI) values		Precision mm	Rounded SI values	
	min. in	max. in	min. Mm	max. mm		min. mm	max. mm
2 9/16	2.562 5	2.593 5	65.087 5	65.874 9	0.05	65.10	65.85
3.00	76.20	3.031 0	76.200 0	76.987 4	0.05	76.20	76.99
3 1/16	3.062 5	3.093 5	77.787 5	78.574 9	0.05	77.80	78.55
4 1/16	4.062 5	4.093 5	103.187 5	103.974 9	0.05	103.20	103.95
4 ½	4.500 0	4.531 0	114.300 0	115.087 4	0.05	114.30	115.09
5	5.000 0	5.031 0	127.000 0	127.787 4	0.05	127.00	127.79
5 1/8	5.125	5.156 0	130.175 0	130.962 4	0.05	130.18	130.97
5 ½	5.500	5.531 0	139.700 0	140.487 4	0.05	139.70	140.49
6 3/8	6.375	6.406 0	161.925 0	162.712 4	0.05	161.93	162.71
7 1/16	7.062 5	7.093 5	179.387 5	180.174 9	0.05	179.40	180.15
7 3/8	7.375	7.406	187.325 0	188.112 4	0.05	187.33	188.11
9	9.000	9.031	228.600 0	229.387 4	0.05	228.60	229.35
11	11.000	11.031	279.400 0	280.187 4	0.05	279.40	280.15
13 5/8	13.625	13.656	346.075 0	346.862 4	0.05	346.10	346.85

C.5 Conversion factors

C.5.1 Length

1 inch (in) = 25.4 millimetres (mm), exactly.

C.5.2 Pressure/stress

1 pound per square inch (psi) = 0.006894757 megapascals (MPa).

C.5.3 Impact energy

1 foot-pound (ft-lb) = 1.355818 joules (J).

C.5.4 Torque

1 foot-pound (ft-lb) = 1.355818 newton metres (N·m).

C.5.5 Force

1 pound-force (lbf) = 4.448222 newtons (N).

C.5.6 Mass

1 pound-mass (lb) = 0.4535924 kilograms (kg).

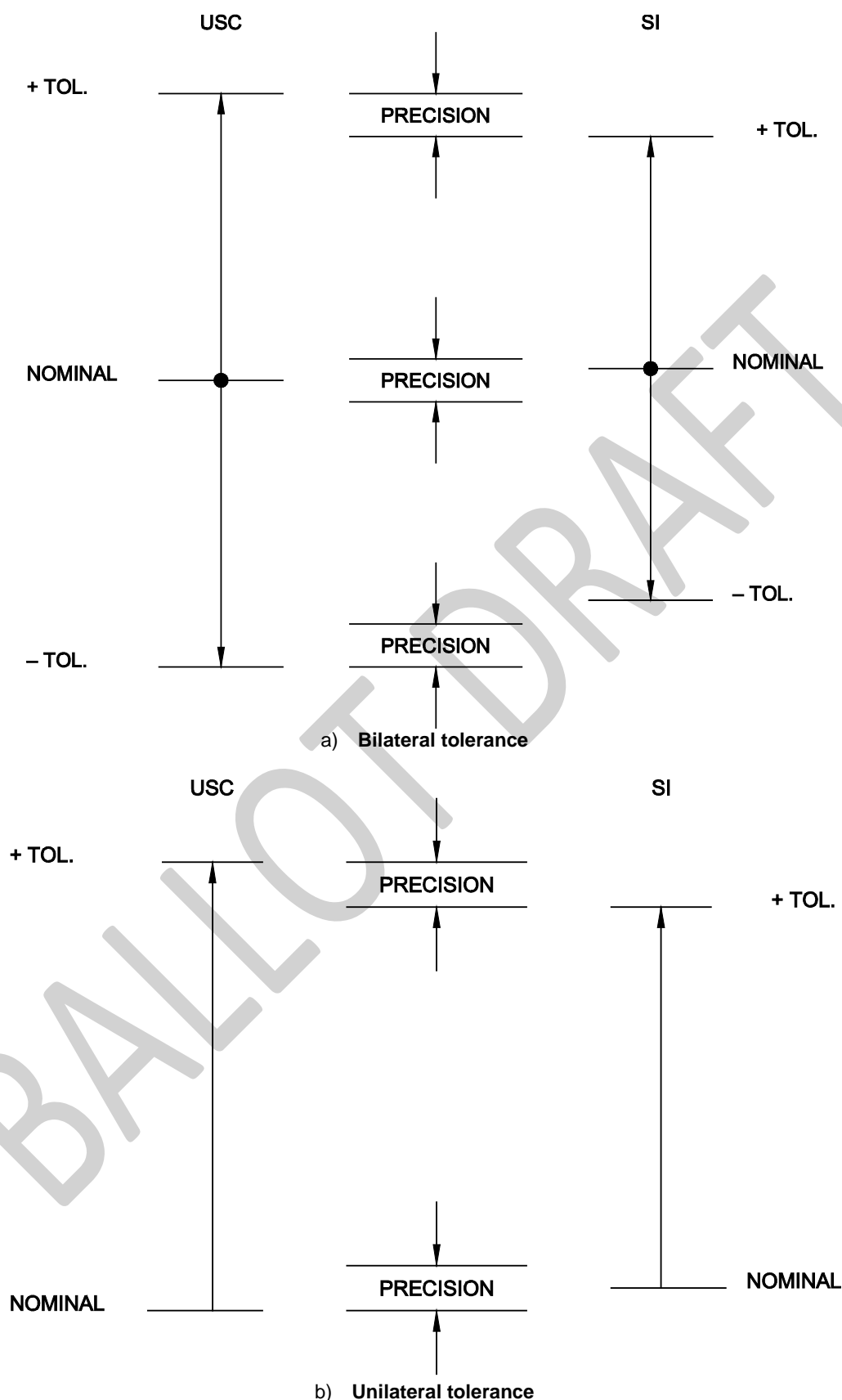


Figure 9 — Metric conversions

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Annex D (Normative)

Minimum Requirements for Certificate of Conformance (COC)

D.1 General

This annex provides the minimum requirements for the Certificate of Conformance for equipment covered by the scope of API 16B. Format changes are allowed.

D.2 Certificate Requirements

D.2.1 Company Information

The Certificate of Conformance shall contain the name and contact details of the manufacturing company from whom it was issued.

D.2.2 Certificate Issue Date

The Certificate of Conformance shall contain the date when it is issued.

D.2.3 Customer Information

The certificate of Conformance shall contain the name of the customer and the relevant purchase order number.

D.2.4 Additional Tracking Information

Additional tracking information may be included for company internal purposes, such as work order or certificate number

D.2.5 Statement of Conformance

The certificate shall contain a statement that confirms that all listed equipment has been manufactured in conformance with this specification.

D.2.6 Additional Endorsements

The certificate may indicate applicable additional endorsements, such as conformance with NACE or other industry standards.

D.2.7 List of Equipment

The Certificate shall list the equipment being certified, The list shall contain, at a minimum:

- Part number: the assembly or component part number of each piece of equipment shall be provided;
- Revision: the revision identifier of each piece of equipment as manufactured shall be provided;
- Description: a description of each piece of equipment, such as serial, batch, or heat number, shall be provided;
- Quantity: The quantity of each part number addressed by the COC.

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D.2.8 Ratings

The certificate shall include a list of applicable ratings, including a minimum of:

- Rated working pressure;
- Rated temperature of metallic components;
- Environmental limits, according to NACE MR0175/ISO 15156, based on the rated working pressure and maximum temperature rating of metallic components
- Design temperature of non-metallic components;
- Additional Environmental Limits for Non-Metallic Components

D.2.9 Record Retention

The certificate shall state the manufacturer's record retention policy.

D.2.10 Statement of Record Review

The certificate shall contain a statement from the company's authorized representative verifying that all relevant records have been reviewed and found to be in conformance to the applicable standard.

D.2.11 Company Endorsement

The certificate shall be endorsed by a company's authorized representative, including, at minimum, the name, signature, title, and date of the signature.

D.3 Example of Certificate of Conformance

Figure E.1 Contains an example of certificate of conformance:

Company Logo

Company Name:
Company Address:
Company telephone number:

Certificate of Conformance

Certificate Issue Date:	
Customer:	
Cutomer Purchase Order	
Work Order No.:	
Certificate Number:	

This certificate conforms that the equipment requested per the above purchase order and listed below has been manufactured in conformance with:

- API Specification 16B, “Specification for Coiled Tubing, Snubbing and Wireline Well Intervention Equipment” 1st Edition

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The Certification is Related to the Following Ratings:

Rated Working Pressure:

Design Temperature (minimum to maximum):

Sour Service according to NACE MR0175/ISO 15156: (Y/N?):

Provide full environmental limits defined by NACE MR0175/ISO 15156 service base on the maximum rated working pressure and maximum rated working temperature for the assembly. The following individual parameters may or may not apply, depending on the alloys of construction (see NACE MR0175/ISO 15156 for applicability for the individual alloys used in the assembly):

- Partial pressure H₂S (max.)
- Partial pressure H₂S + CO₂ (max)

Other Limitations:

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C. List of Certified Equipment:

Item	Assembly or Part No.	PR	Qty.	Description	Serial Numbers(s)
1					
2					
3					

Certificate of Conformance Approval

Signature

Signature

Name:

Name:

Title:

Title:

Date:

Date:

Control Document No. Revision Date/Level

Figure E.1 – Example Certificate of Conformance

Bibliography

- [1] API Specification 7 – 39th edition, *Specification for rotary drill stem elements* ¹⁾
- [2] API Recommended Practice 16ST, Coiled Tubing Well Control Equipment Systems
- [3] IEEE/ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*
- [4] ISO 31 (all parts), *Quantities and units*
- [5] ASME Boiler and Pressure Vessel Code Section V, Article 5, *UT Examination Methods for Materials and Fabrication*
- [6] ASTM D471, Standard Test Method for Rubber Property — Effect of Liquids
- [7] ASTM A453, Standard Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels
- [8] ASTM E 92, *Standard Test Method for Vickers Hardness of Metallic Materials*
- [9] AWS D17.1 Specification for Fusion Welding for Aerospace
- [10] AWS QC1 Standard for AWS Certification of Welding Inspectors
- [11] SAE AMS-H-6875, Heat Treatment of Steel Raw Materials

