Specification for Drill-through Equipment

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

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1 Scope

This specification defines the requirements for performance, design, materials, testing and inspection, welding, marking, handling, storing, and shipping of drill-through equipment used for drilling for oil and gas. It also defines service conditions in terms of pressure, temperature, and wellbore fluids for which the equipment is designed.

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

a) ram blowout preventers;

b) ram blocks, packers, and top seals;

c) annular blowout preventers;

d) annular packing units;

e) hydraulic wellbore connectors (wellhead, riser, or LMRP);

f) drilling spools and spacer spools;

g) adapters;

h) mandrels (for wellbore connectors);

i) loose connections;

j) clamps.

Dimensional interchangeability is limited to end and outlet connections.

A simplified example of drill-through equipment defined by this specification is shown in Figures 1 and 2.

Repair and remanufacture of 16A equipment is covered in API 16AR, *Standard for Repair and Remanufacturing of Drill-through Equipment*.

This specification does not apply to field use or field testing of drill-through equipment.

If a product is supplied bearing the API Monogram and manufactured at a facility licensed by API, the requirements of Annex A apply.

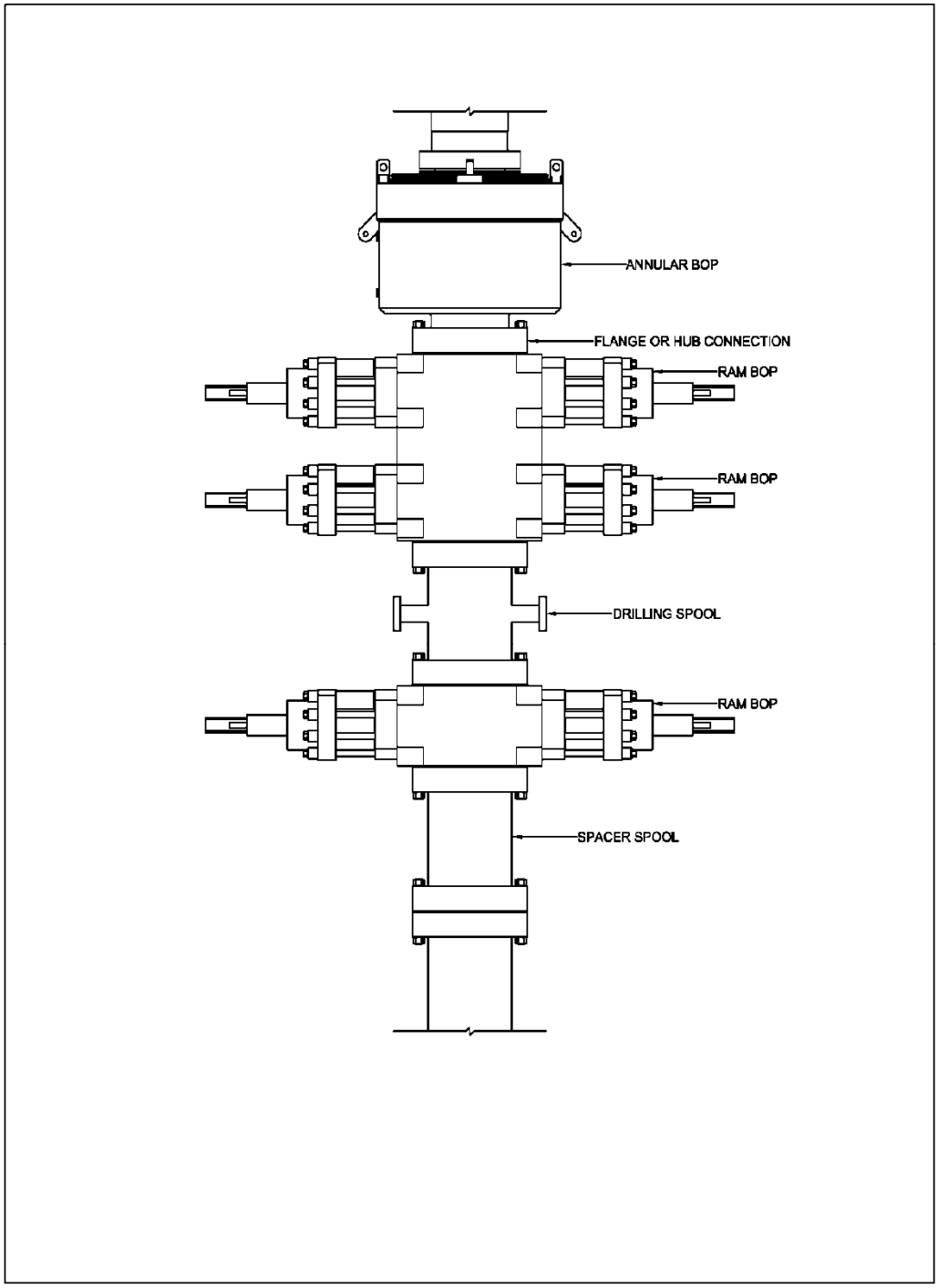

Figure 1—Simplified Example of Surface Drill-through Equipment

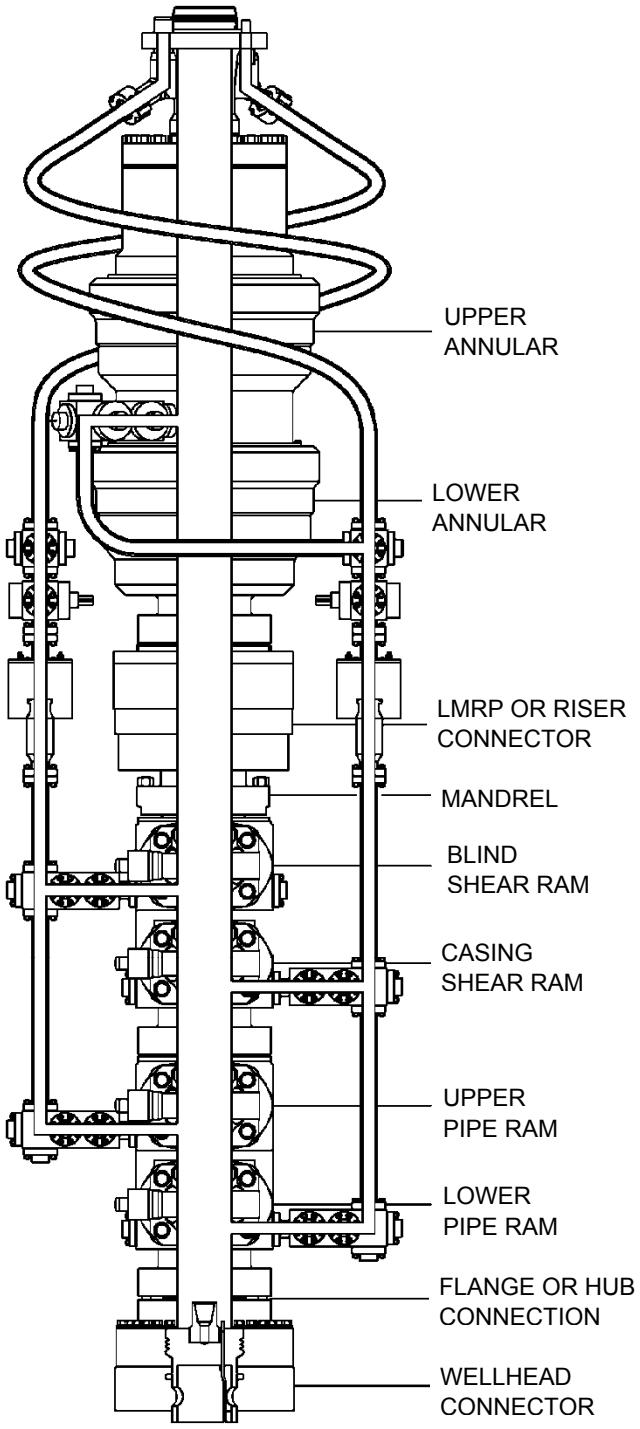

Figure 2—Simplified Example of Subsea Drill-through Equipment

2 Normative References

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

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

API Specification 5DP, *Specification for Drill Pipe*

API Specification 6A, *Specification for Wellhead and Christmas Tree Equipment, 20th edition, April 2011*

API Technical Report 6AF2, *Capabilities of API Flanges Under Combinations of Load*

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

API Specification 7-1, *Specification for Rotary Drill Stem Elements*

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 TR 6MET, *Metallic Material Limits for Wellhead Equipment*

ASME [1] Boiler and Pressure Vessel Code, Section V, *UT Examination Methods for Materials and Fabrication*

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 VIII, Division 2, Annex 5-F, *Experimental Stress and Fatigue Analysis*

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

ASTM [2] A388, *Standard Practice for Ultrasonic Examination of Steel Forgings*

ASTM D412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers—Tension*

ASTM D471, *Standard Test Method for Rubber Property—Effect of Liquids*

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*

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 Examination*

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[1] American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016

[2] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428

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

ASTM E140, *Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness*

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Examination for General Industry*

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

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

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

ASTM E428, *Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing*

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 [3], *Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing*

AWS D17.1/D17.1M [4], *Specification for Fusion Welding for Aerospace Applications*

AWS QC1, *Standard for AWS Certification of Welding Inspectors*

CSWIP-WI-6-92 [5], *Requirements for the Certification of Visual Welding Inspectors (Level 1), Welding Inspectors (Level 2) and Senior Welding Inspectors (Level 3) (fusion welding) in accordance with the requirements of BS EN ISO 176371:2011*

ISO 2859-1 [6], *Sampling procedures for inspection by attributes — Part 1: Sampling schemes 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*

ISO 6892, *Metallic Materials — Tensile Testing at Ambient Temperature*

ISO 9712, *Nondestructive Testing — Qualification and Certification of NDT Personnel*

ISO 18265, *Metallic Materials — Conversion of Hardness Values*

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[3] American Society for Nondestructive Testing, PO Box 28518, 1711 Arlingate Lane, Columbus OH 43228

[4] American Welding Society, 8669 NW 36th Street, #130, Miami, FL 33166

[5] TWI Certification Ltd, Granta Park, Great Abington, Cambridge, CB21 6AL, United Kingdom

[6] International Organization for Standardization, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland

NACE MR0175/ISO 15156 [7], *Petroleum and Natural Gas Industries—Materials for Use in H_2S-containing Environments in Oil and Gas Production, Parts 1, 2 and 3*

SAE AMS2750 [8], *Pyrometry*

3 Terms, Definitions, Acronyms, and Abbreviations

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, equipment, processes, or services

3.1.2
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

3.1.3
annular blowout preventer
Blowout preventer that uses an annular-shaped elastomeric sealing element to seal the space between the tubular and the wellbore or an open hole

3.1.4
blind connection
End or outlet connection with no center bore, used to completely close off an outlet

3.1.5
blind shear ram
Closing and sealing component in a ram blowout preventer that first shears the tubular in the wellbore and then seals off the bore or acts as a blind ram if there is no tubular in the wellbore

3.1.6
blind ram
Closing and sealing component in a ram blowout preventer that seals the open wellbore

3.1.7
blowout preventer
BOP
Equipment installed at the wellhead or wellhead assemblies to contain wellbore fluids, either in the annular space between the casing and the tubulars or in an open hole during drilling, completion, testing, or workover operations

3.1.8
blowout preventer stack
BOP stack
Complete assembly of well control equipment, including preventers, spools, valves, and nipples, connected to the top of the wellhead or wellhead assemblies

3.1.9
body
portion of equipment between end connections, with or without internal parts, that contains wellbore pressure

[7] NACE International, 15835 Park Ten Place, Houston, TX 77084
[8] SAE International, 400 Commonwealth Drive, Warrendale, PA 15096

3.1.10
bolting
All threaded fasteners, including studs, tap-end studs, double-ended studs, headed bolts, cap screws, screws, and nuts

3.1.11
calibration
Comparison to a standard of known accuracy and making any needed adjustment(s)

3.1.12
cast *(verb)*
To pour molten metal into a mold to produce an object of desired shape

3.1.13
casting *(noun)*
Object at or near finished shape obtained by solidification of a molten metal in a mold

3.1.14
Certificate of Conformance
COC
Document in which the manufacturer certifies that the assembly or part is in conformance to the mentioned standard(s), specifications, and guidelines in accordance with the original product definition

3.1.15
chemical analysis
Determination of the chemical composition of material

3.1.16
clamp *(noun)*
Device with internal angled shoulders used to fasten mating hubs

3.1.17
clamping load
Axial load applied to clamp hubs by the clamp due to bolt tightening

3.1.18
closing ratio
Area of the operator piston exposed to the close operating pressure, divided by the cross-sectional area of the piston shaft exposed to wellbore pressure

3.1.19
closure bolting
Bolting used to assemble or join wellbore pressure-containing parts, including end and outlet connections

NOTE Examples of closure bolting include flange bolting, bonnet bolting, end connection bolting on BOPs, ram door bolting, and hub clamp bolting.

3.1.20
conformance
Satisfying all of the requirements of the referenced specification, specification section, or document

3.1.21
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/ISO 15156; see Clause 2).

3.1.22
corrosion-resistant ring groove
Ring groove lined with a CRA or an austenitic stainless steel to resist metal-loss corrosion

3.1.23
critical areas
Part(s) of a product that require specific operational control in service life; includes sealing surfaces and locations of high stress and strain under static and/or cycling loads

3.1.24
critical dimension
Dimension(s) identified by the manufacturer as requiring verification and documentation

3.1.25
data acquisition system
System for capturing and storing data

NOTE Examples include strip chart recorders, circular chart recorders, or computer systems.

3.1.26
date of manufacture
Date of the manufacturer's final acceptance of finished equipment

3.1.27
design validation results
Document or dataset created and maintained that provides objective evidence of activities performed, results achieved, or statements made during the design validation

3.1.28
drilling spool
Pressure-containing piece of equipment having end connections and outlets, used below or between drill-through equipment

3.1.29
end connection
Integral male or female thread, clamp hub end connector, flange (studded or through-bolted), or any other means used to join together equipment that contains or controls pressure

3.1.30
equipment
Components or assemblies to which this specification is applicable

3.1.31
exposed bolting
Bolting exposed directly to a sour environment or that is buried, insulated, equipped with flange protectors, or is otherwise denied open atmosphere or open seawater exposure

3.1.32
extended range
Range outside the rated range in which the manufacturer defines the operational characteristics based on test data

3.1.33
fabrication weld
Weld joining two or more parts

3.1.34
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

3.1.35
forging *(noun)*
Shaped metal part formed by the forging method

3.1.36
full penetration weld
Weld that extends throughout the complete wall section of the parts joined

3.1.37
gasket-retaining load
Portion of the clamping load required to offset the separating force the gasket exerts on the hubs when pressurized

3.1.38
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

3.1.39
heat treatment
heat treating
Specified, timed sequence of controlled heating and cooling of materials for the purpose of changing physical or mechanical properties

3.1.40
heat treatment load
— For batch furnaces: material placed on loading or carry devices and moved as a batch through one heat treat cycle

— For continuous furnaces: group of pieces of material with the same nominal size that is moved sequentially through the heat treatment process using the same process parameters

3.1.41
hot-work *(verb)*
Deform metal plastically at a temperature above the recrystallization temperature

3.1.42
hub
Protruding rim with an external angled shoulder and a sealing mechanism used to join pressure-containing equipment

3.1.43
hub face separation
Occurs when all preload is lost between the two hubs, flanges, or OEC faces, and the two faces have lost contact from OD to ID or ID to OD

3.1.44
hydraulic connector
Hydraulically actuated drill-through equipment that locks and seals on end connections

3.1.45
indication
Visual sign of cracks, pits, or other abnormalities found during nondestructive examination

3.1.46
integral *(adjective)*
⟨Parts⟩ joined by the forging, casting, or welding process

3.1.47
leakage
Visible passage of fluid during pressurization or a hold period from the inside to the outside of the pressure-containment area of the equipment being tested

3.1.48
linear indication
Liquid penetrant or magnetic particle examination indication whose length is equal to or greater than three times its width

3.1.49
loose connection
Flange (studded or open-face), hub connection, or other end connection used to join together equipment, but not integral to the equipment

3.1.50
manufacturing data book
MDB
Composite file of records from a traceable API product that includes records associated with the original API product manufacturing, including certification records as required by this specification

3.1.51
non-pressure-containing weld
Weld whose failure will not reduce the pressure-containing integrity of the component

3.1.52
non-sealing shear ram
Closing component in a ram blowout preventer that is capable of shearing or cutting certain tubulars, but does not seal

3.1.53
original equipment manufacturer
OEM
Design owner or manufacturer of the traceable assembled equipment, single equipment unit, or component part

3.1.54
other end connection
OEC
Connection that is not specified in an API specification or standard

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

3.1.55
outlet connection
Clamp hub end connector and flange, studded or through bolted, or any other end connection with a bore that intersects the vertical drill-through bore

3.1.56
part
Individual piece used in the assembly of a single unit of equipment

3.1.57
performance requirement level
PR
Designation determined by the extent of testing successfully performed in accordance with minimum performance criteria identified by this specification

3.1.58
pipe ram
Closing and sealing component in a ram blowout preventer that seals around tubulars in the wellbore

3.1.59
post-weld heat treatment
PWHT
Heat treatment subsequent to welding, including stress relief

3.1.60
pressure
Ratio of force to the area over which that force is distributed (i.e. pound force to an area (in^2), measured in "psi", etc.)

absolute pressure
Internal pressure that the equipment is designed to contain and/or control, or that is zero-referenced against a perfect vacuum; measured in "psia"

differential pressure
Difference in pressure between any two points (p1 and p2); measured in "psid"

gauge pressure
Measured relative to the ambient pressure (e.g. atmospheric for surface application, hydrostatic for subsea application), measured in "psig"

3.1.61
pressure-containing part
Part exposed to wellbore fluids whose failure to function as intended would result in a release of wellbore fluid to the environment

NOTE 1 Examples include bodies and bonnets.

NOTE 2 Examples of items that are not included are operating cylinders and cylinder heads.

3.1.62
pressure-containing weld
Weld whose absence or failure will reduce or compromise the pressure-containing integrity of the component

3.1.63
pressure-controlling bolting
Bolting used to assemble or join pressure-controlling part(s)

NOTE Examples include bolting on ram, seat or seal retainer bolting, shear ram blade bolting

3.1.64
pressure-controlling part
Part intended to control or regulate the movement of wellbore fluids

NOTE Examples include packing elements, rams, and replaceable seats within a pressure-containing part.

3.1.65
pressure end load
Axial load resulting from internal pressure applied to the area defined by the maximum seal diameter

3.1.66
pressure-retaining bolting
Bolting used to assemble or join pressure-retaining parts whose failure would result in a release of wellbore fluid to the environment

NOTE Examples are studs and nuts on top of a hydraulic connector, and clamp bolts.

3.1.67
pressure-retaining part
Part not exposed to wellbore fluids whose failure to function as intended will result in a release of wellbore fluid to the environment

NOTE An example is a clamp.

3.1.68
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

3.1.69
product family
Model or type of specific equipment listed in Section 1 of this specification

3.1.70
ram blowout preventer
Blowout preventer that uses metal blocks assembled with elastomer seals to seal off pressure on a wellbore, with or without tubulars in the bore

3.1.71
rated range
Range of tubulars that can be sealed up to the full rated working pressure of the BOP

3.1.72
rated working pressure
Maximum internal pressure that the equipment is designed to contain and/or control on surface

3.1.73
record *(noun)*
Retrievable document or dataset created that provides objective evidence of activities performed, results achieved, or statements made

3.1.74
relevant indication
Surface NDE indication (liquid penetrant or magnetic particle examination) with a major dimension greater than 1.6 mm (0.062 in)

NOTE Inherent indications not associated with a surface rupture are considered non-relevant indications.

3.1.75
remanufacture
Process of disassembly, reassembly, and testing of drill-through equipment, with or without the replacement of parts, in which machining, welding, heat treatment, or other manufacturing operation is employed

3.1.76
repair weld
Welding performed to correct a nonconformance

3.1.77
reportable
Test performed and the results documented

3.1.78
rounded indication
— For liquid penetrant or magnetic particle examination: any indication that is approximately circular or elliptical and whose length is less than three times its width

— For radiographic examination: any indication with a maximum length of three times the width or less on the radiograph.

NOTE Indications may be circular, elliptical, conical, or irregular in shape, and may have tails. When evaluating the size of an indication, the tail is included.

3.1.79
serialization
Assignment of a unique code to individual parts and/or pieces of equipment to maintain records

3.1.80
spacer spool
Pressure-containing piece of equipment having end connections, used below or between drill-through equipment

NOTE A spool is used to provide separation between two components with equal-sized end connections.

3.1.81
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.

3.1.82
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 different-temperature fluids, convection, or conduction.

3.1.83
stress relief
Controlled heating of material to a predetermined temperature for the purpose of reducing any residual stresses

3.1.84
studded connection
Connection in which thread-anchored studs are screwed into tapped holes

3.1.85
surface finish
Ra
Measurement of the average roughness of a surface

3.1.86
test series

Group of tests at the same load condition (i.e. rated, extreme, survival) that are related to each other in some manner, such as capacity or type of test

EXAMPLE A Rated Capacity Test Series comprises all the tests that are conducted to a load level that corresponds to a rated capacity rating.

3.1.87
trepan *(verb)*
Produce a hole through a part by boring a narrow band or groove around the circumference of the hole and removing the solid central core of material

3.1.88
utility bolting
All bolting that is required to mount equipment and accessories to the drill-through equipment that is not closure bolting, pressure retaining, or pressure controlling

NOTE Examples include bolting on lifting eyes, pad eyes (non-welded), wear bushing, nameplate, clamps for tubing, guards.

3.1.89
variable bore ram
VBR
Closing and sealing component in a ram blowout preventer that is capable of sealing on a range of tubular sizes

3.1.90
visual examination
Examination of parts and equipment for visible defects in material and workmanship

3.1.91
volumetric nondestructive examination
Examination for internal material defects by radiography, acoustic emission, or ultrasonic testing

3.1.92
weld groove (weld prep)
Area between two metals to be joined that has been prepared to receive weld filler metal; also known as “weld prep”

3.1.93
weld *(verb)*
Act of fusing materials, with or without the addition of filler materials

3.1.94
welding
Application of any one of a group of welding processes that applies heat energy sufficient to melt and join one or more pieces of metal through localized fusion and coalescence

3.1.95
welding procedure specification
WPS
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.

3.1.96
weldment
Portion or area of a component on which welding has been performed

NOTE A weldment includes the weld metal, the heat-affected zone (HAZ), and the base metal unaffected by the heat of welding.

3.1.97
wrought structure
Structure that contains no cast dendritic structure

3.1.98
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 The term is expressed in newtons per square millimeter (pounds per square inch) of loaded area.

NOTE 2 All yield strengths specified in this standard are considered as being the 0.2 % yield offset strength in accordance with ISO 6892 or ASTM A370.

3.2 Acronyms and Abbreviations

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

AE	acoustic emission
ANSI	American National Standards Institute
API	American Petroleum Institute
AQL	acceptance quality level
ASME	American Society of Mechanical Engineers
ASNT	American Society for Non-destructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BOP	blowout preventer
BSL	bolting specification level
CAWI	certified associate welding inspector
COC	certificate of conformance
CRA	corrosion-resistant alloy
CSO	complete shut-off
CWI	certified welding inspector
CSWIP	certification scheme for welding inspection personnel
DAC	distance amplitude curve
DHT	dehydrogenization heat treatments
ER	equivalent round
FAT	factory acceptance test
FCAW	flux-cored arc welding
HAZ	heat-affected zone

ID	inside diameter
ISR	intermediate stress relief
LP	liquid penetrant
LMP	Larsen-Miller parameter
LMRP	lower marine riser package
LVDT	linear variable displacement transformer
MDB	manufacturing data book
MOPFLPS	minimum operator pressure for low pressure sealing
MP	magnetic particle
MT	magnetic particle test
NACE	National Association of Corrosion Engineers
NDE	nondestructive examination
OD	outside diameter
OEC	other end connection
OEM	original equipment manufacturer
OS	operating system
PQR	procedure qualification record
PR	performance requirement
PT	penetrant test
PWHT	post-weld heat treatment
QTC	qualification test coupon
SAW	submerged arc welding
SCWI	senior certified welding inspector
SMAW	shielded metal arc welding
SR	supplemental requirement
SST	[austenitic] stainless steel
VBR	variable bore ram
WPS	welding procedure specification

4 Design Requirements

4.1 Size Designation

Equipment to which this specification is applicable shall have a vertical through-bore dimension corresponding with the size designation as shown in Table 1.

Table 1—Equipment Size

Nominal Bore Size Designation		Minimum Drift Mandrel Diameter	
mm	(in)	mm	(in)
179	7 1/16	178.61	7.032
228	9	227.84	8.970
279	11	278.64	10.970
346	13 5/8	345.31	13.595
425	16 3/4	424.69	16.720
476	18 3/4	475.49	18.720
527	20 3/4	526.29	20.720
540	21 1/4	538.99	21.220
680	26 3/4	678.69	26.720
762	30	761.24	29.970
NOTE 1 tolerance on drift mandrel diameter is +0.25/ -0.00 mm (+0.010 / -0.000 in)			
NOTE 2 nominal bore size tolerance +0.79 / -0.00 mm (+0.031 / -0.000 in)			

4.2 Service Conditions

4.2.1 Rated Working Pressure

Equipment to which this specification is applicable shall be rated in only the rated working pressures shown in Table 2.

Table 2—Equipment Rated Working Pressures

MPa	psia
6.9	1,000
13.8	2,000
20.7	3,000
34.5	5,000
69.0	10,000
103.4	15,000
138.0	20,000
172.4	25,000
206.8	30,000

The rated working pressure shall be the maximum internal pressure that the equipment is designed to contain and or control on surface.

4.2.2 Temperature Ratings

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	
	°C	°F
T-75/250	– 59 to 121	– 75 to 250
T-75/350	– 59 to 177	– 75 to 350
T-20/250	– 29 to 121	– 20 to 250
T-20/350	– 29 to 177	– 20 to 350
T-0/250	– 18 to 121	0 to 250
T-0/350	– 18 to 177	0 to 350
NOTE Information on strength of materials at elevated temperatures is found in API 6A and API 6MET.		

Equipment shall be designed for wellbore elastomeric materials to operate within the temperature classifications of Table 4.

Low temperature shall be the lowest temperature to which the equipment may be subjected.

Continuous elevated temperature limit shall be the minimum fluid temperature achieved per Table 4 over a 10 pressure cycle period.

Extreme temperature limit shall be the maximum fluid temperature allowed in a one hour period.

The overall combined temperature classification shall be designated by a three-digit code as defined in Table 4

Table 4—Temperature Ratings for Nonmetallic Sealing Materials

Low Temperature Limit (first digit)			Continuous Elevated Temperature Limit[a] (second digit)			Extreme Temperature Limit (third digit)		
Code	Temperature		Code	Temperature		Code	Temperature	
	°C	°F		°C	°F		°C	°F
A	– 26	– 15	A	66	150	A	82	180
B	– 18	0	B	82	180	B	93	200
C	– 12	10	C	99	210	C	104	220
D	– 7	20	D	116	240	D	121	250
E	– 1	30	E	132	270	E	149	300
F	4	40	F	149	300	F	177	350
G	Other	Other	G	Other	Other	G	Other	Other

[a] not required for PR1

EXAMPLE Material "FDE" has a low temperature rating of 40 °F, a continuous elevated temperature rating of 240 °F, and an extreme temperature limit of 300 ° F.

All other elastomeric seals shall be designed to operate within the temperatures of the manufacturer's written specifications.

4.2.3 Retained Fluid Ratings

All metallic materials that come in contact with well fluids shall meet the requirements of NACE MR0175 /ISO 15156 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 conform to the dimensional requirements of API 6A prior to assembly and testing.

Dimensions shall apply to machining dimensions and shall not apply after test or after flange and ring gasket makeup.

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

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

Type 6B and API 6BX flange connections shall be designed for use in the combination of size designation and pressure ratings shown in Table 5.

4.3.1.2 API Type 6B Flange Connections

The type 6B flange shall have a through-bolted or studded design.

Type 6B flange connections shall have a ring joint type and not be designed for face-to-face make-up.

NOTE 1 The connection make-up bolting force reacts on the metallic gasket.

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

Rated Working Pressure	Flange Size Range mm (in)		
MPa (psi)	Type 6B	Type 6BX	Dual Segmented
13.8 (2,000)	52 to 540 (2 1/16 to 21 1/4)	679 to 762 (26 3/4 to 30)	—
20.7 (3,000)	52 to 527 (2 1/16 to 20 3/4)	679 to 762 (26 3/4 to 30)	—
34.5 (5,000)	52 to 279 (2 1/16 to 11)	346 to 540 (13 5/8 to 21 1/4)	35 to 103 x 108 (1 3/8 to 4 1/16 x 4 1/4)
69.0 (10,000)	—	46 to 540 (1 13/16 to 21 1/4)	—
103.5 (15,000)	—	46 to 476 (1 13/16 to 18 3/4)	—
138.0 (20,000)	—	46 to 346 (1 13/16 to 13 5/8)	—

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

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

4.3.1.3 API Type 6BX Flange Connections

The type 6BX flange shall be of the through-bolted or studded design.

Type 6BX flanges shall be of the ring joint type and are designed with a raised face.

NOTE 1 Depending on tolerances, the connection makeup 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.

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

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

NOTE 2 Other weld preparations may be employed when the strength of the overlay alloy equals or exceeds the strength of the base material.

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.

NOTE Type 6B and type 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 to conform to API 6A. The thread form of the tapped hole shall conform to the requirements of API 6A. The minimum depth of the full threads in the hole shall be equal to the diameter of the stud, and the maximum depth 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 conform to 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 conform to the requirements of API 6A. The minimum depth of the full threads in the hole shall be equal to the diameter of the stud, and the maximum depth shall be in accordance with the manufacturer's written specification.

4.3.3 Bolting

4.3.3.1 Bolting for Land Service

4.3.3.1.1 General

Manufacturers (OEM) shall have a documented procedure for the qualification of bolting manufacturers that satisfies the requirements of API 20E and API 20F in accordance with Table 6. Exposed bolting shall meet the hardness requirements of NACE MR0175/ISO 15156. Manufacturers (OEM) shall have documented specifications that include the thread form and dimensions of studs, nuts, and bolts. When plating or coating is specified, API 20E plating and coating requirements shall be required.

Table 6—Bolting Requirement

	Material	Land[1]	Offshore[2]
Pressure-controlling Bolting	Alloy steel and carbon steel	API 20E BSL-1[3]	API 20E BSL-2[3]
	Stainless steel and CRA	API 20F BSL-2	API 20F BSL-2
Closure Bolting	Alloy steel and carbon steel	API 20E BSL-2[3]	API 20E BSL-3[3]
	Stainless steel and CRA	API 20F BSL-2	API 20F BSL-3
Pressure-retaining Bolting	Alloy steel and carbon steel	API 20E BSL-2[3]	API 20E BSL-3[3]
	Stainless steel and CRA	API 20F BSL-2	API 20F BSL-3
Utility Bolting	Alloy steel and carbon steel	Mfg. Spec.[4]	Mfg. Spec.[4]
	Stainless steel and CRA	Mfg. Spec.[4]	Mfg. Spec.[4]

NOTE:
(1) General requirements listed in 4.3.3.1 apply to all bolting
(2) General requirements listed in 4.3.3.2 apply to all bolting
(3) Need to conform to API 6A for material class and material testing
(4) Based on manufacturer's written specification

Bolting manufactured from proprietary materials shall conform to API 20E or API 20F, with the exception that the materials meet the manufacturer's written specifications for chemical composition and mechanical properties.

Refer to Table 6 for bolting requirements.

4.3.3.1.2 Pressure-controlling Bolting

Alloy steel and carbon steel bolting shall be in conformance with API 20E BSL-1 minimum and API 6A (for material class and mechanical testing).

Stainless steel and CRA bolting shall be in conformance with API 20F BSL-2 minimum.

4.3.3.1.3 Closure Bolting

Alloy steel and carbon steel closure bolting shall be conformance with API 20E BSL-2 minimum and API 6A (for material class and mechanical testing).

Stainless steel and CRA closure bolting shall be in conformance with API 20F BSL-2 minimum.

4.3.3.1.4 Pressure-retaining Bolting

Alloy steel and carbon steel pressure–retaining bolting shall be in conformance with API 20E BSL-2 minimum and API 6A (for material class and mechanical testing).

Stainless steel and CRA pressure–retaining bolting shall be in conformance with API 20F BSL-2 minimum.

4.3.3.1.5 Utility Bolting

Alloy steel and carbon steel bolting shall be in conformance with the manufacturer's specification.

Stainless steel and CRA bolting shall be in conformance with the manufacturer's specification.

4.3.3.2 Bolting for Offshore Surface and Subsea Service

4.3.3.2.1 General

Manufacturers (OEM) shall have a documented procedure for the qualification of bolting manufacturers that follows the requirements of API 20E and API 20F.

Bolting manufactured from alloy steel or carbon steel shall be limited to 34 HRC maximum due to concerns about hydrogen embrittlement.

Exposed bolting shall meet the requirements of NACE MR0175/ISO 15156. Manufacturers (OEM) shall have documented specifications that include the thread form and dimensions of studs, nuts, and bolts.

When plating or coating is specified, API 20E plating and coating requirements shall be required.

Bolting manufactured from proprietary materials shall conform to the manufacturer's written specification and the requirements of API 20E or API 20F, with the exception that the material meet the manufacturer's specified chemical composition and mechanical properties.

Refer to Table 6 for bolting requirements.

4.3.3.2.2 Pressure-controlling Bolting

Alloy steel and carbon steel bolting shall conform to API 20E BSL-2 minimum and API 6A (for material class and mechanical testing).

Stainless steel and CRA bolting shall conform to API 20F BSL-2 minimum and API 6A (for material class and mechanical testing).

Bolting that attaches the shear ram blade to the ram block shall conform to:

— the requirements of API 20E BSL-3 or API 20F BSL3 and API 6A as appropriate for the material type;

— the manufacturer's written specification and requirements for the chemical composition and mechanical properties.

4.3.3.2.3 Closure Bolting

Alloy steel and carbon steel closure bolting shall conform to API 20E BSL-3 and API 6A (for material class and mechanical testing).

Stainless steel and CRA closure bolting shall conform to API 20F BSL-3 and API 6A (for material class and mechanical testing).

4.3.3.2.4 Pressure–retaining Bolting

Alloy steel and carbon steel pressure–retaining bolting shall conform to API 20E BSL-3 minimum and API 6A (for material class and mechanical testing).

Stainless steel and CRA pressure–retaining bolting shall conform to API 20F BSL-3 minimum.

4.3.3.2.5 Utility Bolting

Alloy steel and carbon steel bolting shall conform to the manufacturer's specifications.

Stainless steel and CRA bolting shall conform to the manufacturer's specifications.

4.3.4 Hub End and Outlet Connections

4.3.4.1 General

End and outlet hubs (Type 16B and Type 16BX) shall be in accordance with this specification.

NOTE Type 16B and Type 16BX hubs may be used as integral connections.

Type 16B and Type 16BX hubs integral to drill-through equipment shall not contain test connections. Type 16B and Type 16BX hubs are designed for use in the combination of designated sizes and pressure ranges shown in Table 7.

Table 7—Pressure Ratings and Size Ranges of Type 16B and 16BX Hubs

Pressure Rating MPa (psi)	Type 16B mm (in)	Type 16BX mm (in)
13.8 (2,000)	179 (7 1/16), 425 (16 3/4), 540 (21 1/4)	—
20.7 (3,000)	279 (11), 346 (13 5/8), 425 (16 3/4)	—
34.5 (5,000)	—	52 to 540 (2 1/16 to 21 1/4)
69.0 (10,000)	—	46 to 540 (1 13/16 to 21 1/4)
103.5 (15,000)	—	46 to 476 (1 13/16 to 18 3/4)
138.0 (20,000)	—	46 to 279 (1 13/16 to 11)

4.3.4.2 Type 16B Hubs

Type 16B hubs shall be of the ring joint type and designed for face-to-face makeup. The type RX ring gasket shall be used for these connections.

In order to accomplish a face-to-face makeup, the special type SR ring grooves shall be used as listed in Table 8 and Table 9.

Dimensions for type 16B integral hubs shall conform to Table 8 or Table 9, and to Figure 3.

Dimensions for type 16B blind hubs shall conform to Table 8 or Table 9, and to Figure 4.

Type 16B hubs shall use type RX gaskets in accordance with 4.3.6.

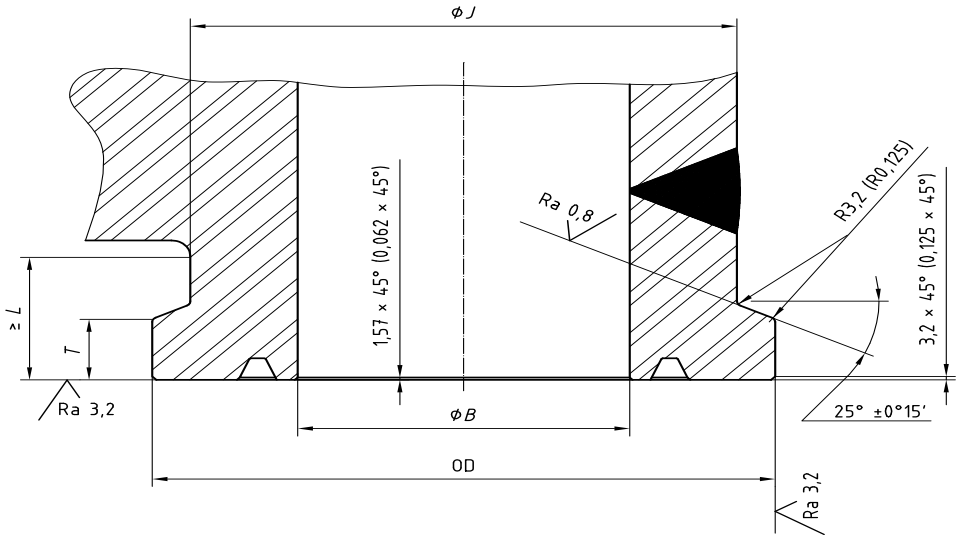
NOTE 1 Type 16B hub connections may be manufactured with corrosion-resistant overlays in the ring grooves.

Table 8—Type 16B Integral Hub Connections for 13.8 MPa (2,000 psi) Rated Working Pressure

Nominal Size mm (in)	Bore *B* mm (in)	Outside Diameter OD mm (in)	Total Thickness *T* mm (in)	Large Diameter of Neck *J* mm (in)	Minimum Neck Length *L* mm (in)	Ring Groove Number	Clamp Number
179 (7 1/16)	179.40 (7.062)	263.52 (10.375)	36.64 (1.443)	225.40 (8.875)	63.5 (2.50)	SR-45	25
425 (16 3/4)	425.45 (16.750)	517.52 (20.375)	32.22 (1.269)	482.60 (19.000)	79.5 (3.13)	SR-65	12
540 (21 1/4)	539.75 (21.250)	669.92 (26.375)	47.54 (1.872)	622.30 (24.500)	127.0 (5.00)	SR-73	18
Tolerance m	+0.79 0	+0.13 -0.13	+0.0 -0.25	+0.0 -0.79	-.1.52		
(in)	(+0.031) (-0)	(+0.005) (-0.005)	(+0) (-0.010)	(+0) (-0.031)	(-0.06)		

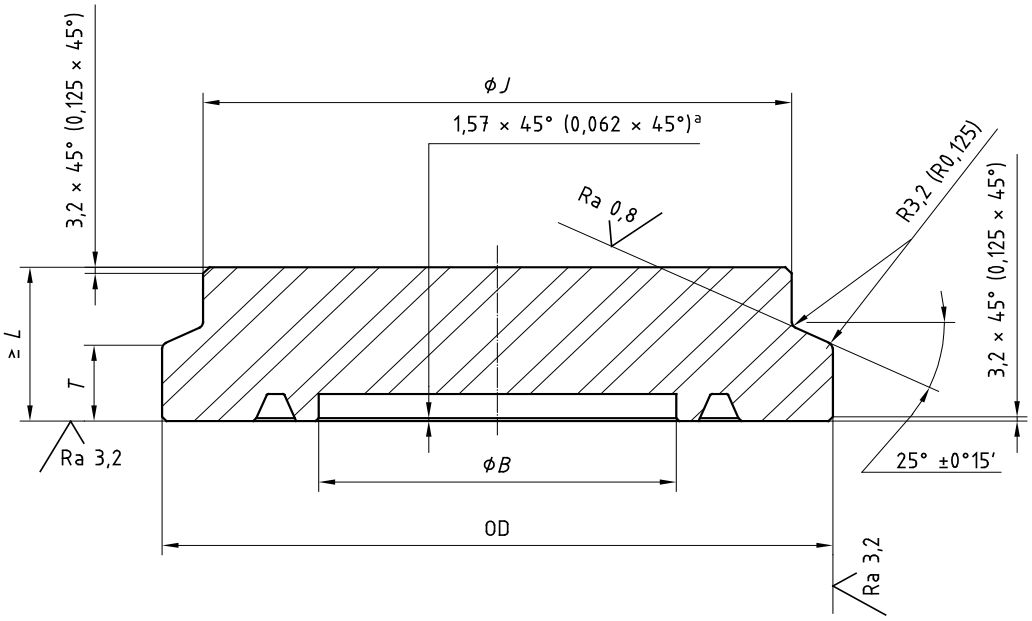
Table 9—Type 16B Integral Hub Connections for 20.7 MPa (3,000 psi) Rated Working Pressure

Nominal Size mm (in)	Bore *B* mm (in)	Outside Diameter OD mm (in)	Total Thickness *T* mm (in)	Large Diameter of Neck *J* mm (in)	Minimum Neck Length *L* mm (in)	Ring Groove Number	Clamp Number
279 (11)	279.40 (11.000)	396.88 (15.626)	35.52 (1.399)	355.60 (14.000)	79.5 (3.13)	SR-53	9
346 (13 5/8)	346.10 (13.625)	466.72 (18.375)	33.92 (1.336)	425.45 (16.750)	81.0 (3.19)	SR-57	11
425 (16 3/4)	425.45 (16.750)	539.76 (21.250)	37.04 (1.459)	498.45 (19.625)	93.4 (3.68)	SR-65	14
Tolerance mm	+0.79 0	+0.13 -0.13	+0 -0.25	+0.0 -0.79	-.1.52		
(in)	(+0.031) (-0)	(+0.005) (-0.005)	(+0) (-0.010)	(+0) (-0.031)	(-0.06)		



Dimensions in millimeters (inches) / Surface roughness in micrometers

Figure 3—Type 16B and 16BX Integral Hub Connections



Dimensions in millimeters (inches) / Surface roughness in micrometers

NOTE 1 For 13.8 MPa (2,000 psi) and 20.7 MPa (3,000 psi) type 16B blind hubs, refer to Table 8 and Table 9 for hub dimensions, ring groove dimensions, and tolerances. If corrosion-resistant inlay is used in ring grooves, refer to Table 10 for rough machining detail.

NOTE 2 For 34.5 MPa (5,000 psi), 69.00 MPa (10,000 psi), 103.5 MPa (15,000 psi), and 138,00 MPa (20,000 psi) type 16BX blind hubs, refer to Table 12, Table 13, Table 14, or Table 15 for hub dimensions, ring groove dimensions, and tolerances. If corrosion-resistant inlay is used in ring grooves, refer to API 6A for rough machining details.

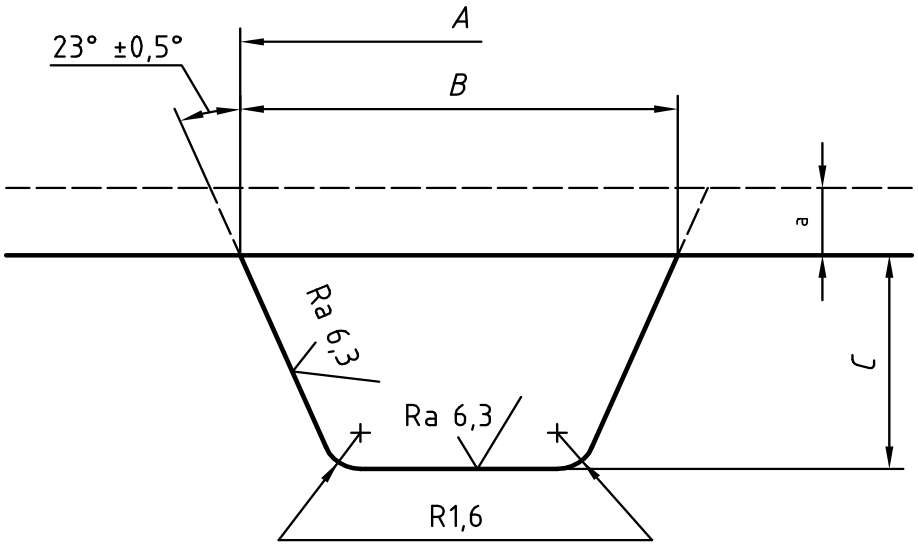
[a]The counterbore of a type 16B or type 16BX blind hub is optional. If the counterbore is used, the depth of the counterbore shall not exceed the dimension and tolerance of E or C as shown in the appropriate ring groove dimension table.

Figure 4—Type 16B and 16BX Blind Hubs

Prior to overlay, the ring groove shall be prepared as specified in Table 10 and Figure 5.

Table 10—Rough Machining of Type SR Ring Grooves

Ring Groove Number	Outside Diameter of Groove *A*		Width of Groove *B*		Depth of Groove *C*	
	mm	(in)	mm	(in)	mm	(in)
SR-45	237	(9.4)	24	(1.0)	18	(0.7)
SR-53	350	(13.8)	24	(1.0)	18	(0.7)
SR-57	406	(16.0)	24	(1.0)	18	(0.7)
SR-65	495	(19.5)	24	(1.0)	18	(0.7)
SR-73	612	(24.1)	27	(1.1)	21	(0.9)
Tolerance	+7 / 0	(+0.3) / (0)	+7 / 0	(+0.3) / (0)	+7 / 0	(+0.3) / (0)



Dimensions in millimeters (inches) / Surface roughness in micrometers

Figure 5—Rough Machining of Type SR Ring Grooves

Dimensions for ring grooves shall conform to Table 11 and Figure 6. All 23° surfaces of ring grooves shall have a surface finish no rougher than *Ra* = 1.6 μm [63 μin (micro-inch) RMS.

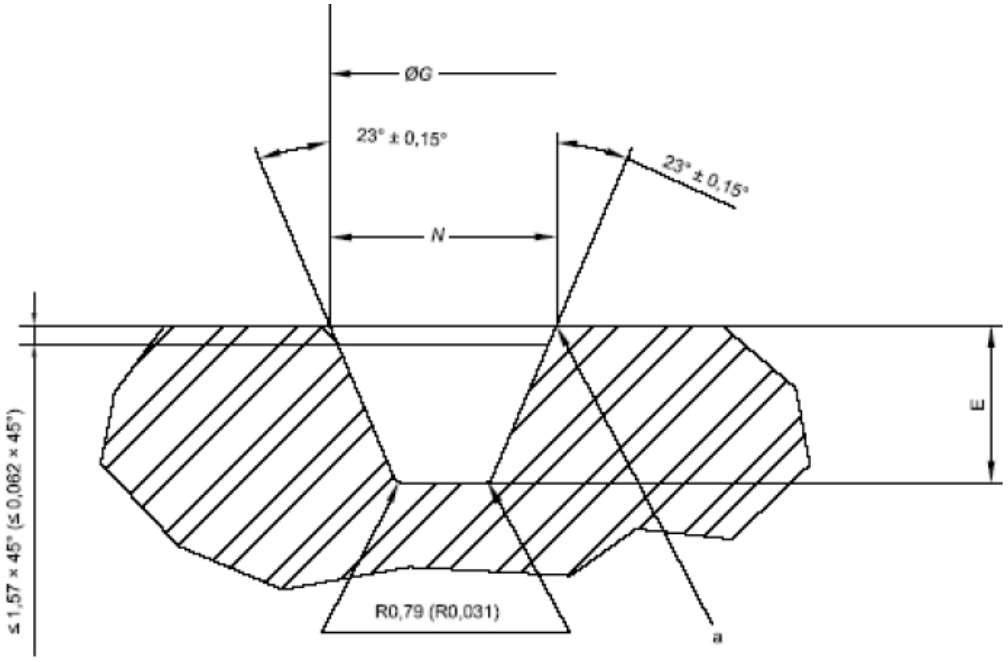
NOTE 2 Allow 3.2 mm ($^1/_8$ in) or greater for final machining of overlay.

NOTE 3 Other weld preparations may be employed when the strength of the overlay alloy equals or exceeds the strength of the base metal.

Dimensions shall apply to machining dimensions and shall not apply to post-test or post-hub and ring gasket makeup.

Table 11—Finish of Machining of Type SR Ring Grooves

Ring Groove Number	Outside Diameter of Groove *G*		Width of Groove *N*		Depth of Groove *E*	
	mm	(in)	mm	(in)	mm	(in)
SR-45	228.27	(8.987)	16.97	(0.668)	14.28	(0.562)
SR-53	340.49	(13.405)	16.97	(0.668)	14.28	(0.562)
SR-57	397.13	(15.635)	16.97	(0.668)	14.28	(0.562)
SR-65	486.03	(19.135)	16.97	(0.668)	14.28	(0.562)
SR-73	603.33	(23.753)	19.92	(0.784)	17.48	(0.688)
Tolerance	+0.09 / -0.0	(+0.004) / (-0.0)	+0.09 / -0.0	(+0.004) / (-0.0)	+0.38 / -0.0	(+0.016) / (-0.0)



All ring groove surfaces shall have a surface finish no rougher than 63 micro-inch RMS.

[a] Break Sharp Corner

Dimensions in millimeters (inches)

Figure 6—Finish Machining of Type SR Ring Grooves

4.3.4.3 Type 16BX Hubs

Type 16BX hubs shall be of the ring joint type and are designed for face-to-face makeup. Type BX ring gaskets shall be used for these connections.

Dimensions for type 16BX integral hubs shall conform to Table 12, Table 13, Table 14, or Table 15, and Figure 3.

Dimensions for type 16BX blind hubs shall conform to Table 12, Table 13, Table 14, or Table 15, and Figure 4.

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

Type 16BX hubs shall use type BX gaskets in accordance with 4.3.6.

NOTE 1 Type 16BX hubs may be manufactured with corrosion-resistant overlays in the ring grooves.

NOTE 2 Other weld preparations may be employed when the strength of the overlay alloy equals or exceeds the strength of the base material.

NOTE 3 The counterbore in a type 16BX blind hub is optional.

NOTE 4 Friction inhibits makeup and assists in holding the connection at operating and test conditions.

NOTE 5 The coefficient of friction stated here is that used for clamp and hub design. This specification is not applicable to materials or coatings which have different coefficients of friction.

If the counterbore is used, the depth of the counterbore shall not exceed the dimension and tolerance of the ring groove depth, C or E, as shown in the appropriate ring groove dimension table.

Table 12—Type 16BX Integral Hub Connections for 34.5 MPa (5,000 psi) Rated Working Pressure

Nominal Size mm (in)	Bore *B* mm (in)	Outside Diameter OD mm (in)	Total Thickness *T* mm (in)	Large Diameter of Neck *J* mm (in)	Minimum Neck Length *L* mm (in)	Ring Groove Number	Clamp Number
52 (2 1/16)	52.40 (2.063)	127.78 (5.031)	29.60 (1.166)	92.85 (3.656)	56.3 (2.22)	BX-152	1
65 (2 9/16)	65.10 (2.563)	146.84 (5.781)	29.60 (1.166)	111.90 (4.406)	57.6 (2.27)	BX-153	2
79 (3 1/8)	77.80 (3.063)	160.32 (6.312)	29.60 (1.166)	125.40 (4.938)	59.9 (2.36)	BX-154	4
103 (4 1/16)	103.20 (4.063)	193.68 (7.625)	30.40 (1.197)	158.75 (6.250)	60.4 (2.38)	BX-155	5
130 (5 1/8)	130.20 (5.125)	276.23 (10.875)	37.06 (1.459)	234.95 (9.250)	85.85 (3.38)	BX-169	7
178 (7 1/16)	179.40 (7.063)	336.54 (13.250)	41.18 (1.622)	295.25 (11.625)	85.8 (3.38)	BX-156	8
228 (9)	228.60 (9.000)	336.54 (13.250)	41.18 (1.622)	295.25 (11.625)	85.8 (3.38)	BX-157	8
279 (11)	279.40 (11.000)	412.76 (16.250)	42.00 (1.654)	371.45 (14.625)	104.9 (4.13)	BX-158	10
346 (13 5/8)	346.10 (13.625)	523.88 (20.625)	47.52 (1.871)	482.60 (19.000)	123.9 (4.88)	BX-160	13
425 (16 3/4)	425.45 (16.750)	650.88 (25.625)	45.16 (1.778)	609.60 (24.000)	139.7 (5.50)	BX-162	19
540 (21 1/4)	539.75 (21.250)	793.76 (31.250)	92.20 (3.630)	708.00 (27.875)	171.4 (6.75)	BX-165	27
Tolerance mm	+0.79 -0	+0.13 -0.13	+0 -0.25	+0.0 -0.79	-1.52		
(in)	(+0.031) (-0)	(+0.005) (-0.005)	(+0) (-0.010)	(+0) (-0.031)	(-0.06)		

Table 13—Type 16BX Integral Hub Connections for 69.0 MPa (10,000 psi) Rated Working Pressure

Nominal Size mm (in)	Bore *B* mm (in)	Outside Diameter OD mm (in)	Total Thickness *T* mm (in)	Large Diameter of Neck *J* mm (in)	Minimum Neck Length *L* mm (in)	Ring Groove Number	Clamp Number
46 (1 13/16)	46.05 (1.813)	127.78 (5.031)	29.60 (1.166)	92.85 (3.656)	56.3 (2.22)	BX-151	1
52 (2 1/16)	52.40 (2.063)	146.84 (5.781)	29.60 (1.166)	111.90 (4.406)	57.6 (2.27)	BX-152	2
65 (2 9/16)	65.10 (2.563)	160.32 (6.312)	29.60 (1.166)	125.40 (4.938)	59.9 (2.36)	BX-153	4
78 (3 1/16)	77.80 (3.093)	193.68 (7.625)	30.40 (1.197)	158.75 (6.250)	60.4 (2.38)	BX-154	5
103 (4 1/16)	103.20 (4.063)	214.30 (8.437)	33.26 (1.310)	173.00 (6.812)	71.6 (2.82)	BX-155	6
130 (5 1/8)	130.20 (5.125)	276.23 (10.875)	37.06 (1.459)	234.95 (9.250)	85.85 (3.38)	BX-169	7
178 (7 1/16)	179.40 (7.063)	412.76 (16.250)	41.98 (1.653)	371.45 (14.625)	104.9 (4.13)	BX-156	10
228 (9)	228.60 (9.000)	412.76 (16.250)	41.98 (1.653)	371.45 (14.625)	104.9 (4.13)	BX-157	10
279 (11)	279.40 (11.000)	523.88 (20.625)	51.68 (2.035)	473.05 (18.625)	120.6 (4.75)	BX-158	22
346 (13 5/8)	346.10 (13.625)	565.16 (22.250)	58.64 (2.309)	523.85 (20.625)	134.8 (5.31)	BX-159	15
425 (16 3/4)	425.45 (16.750)	711.20 (28.000)	76.32 (3.005)	635.00 (25.000)	156.7 (6.17)	BX-162	28
476 (18 3/4)	476.25 (18.750)	793.76 (31.250)	92.20 (3.630)	708.00 (27.875)	171.4 (6.75)	BX-164	27
540 (21 1/4)	539.75 (21.250)	863.60 (34.000)	101.72 (4.005)	774.70 (30.500)	208.7 (8.22)	BX-166	26
Tolerance mm	+0.79 -0	+0.13 -0.13	+0.0 -0.25	+0.0 -0.79	-.1.52		
 (in)	(+0.031) (-0)	(+0.005) (-0.005)	(+0) (-0.010)	(+0) (-0.031)	(-0.06)		

Table 14—Type 16BX Integral Hub Connections for 103.5 MPa (15,000 psi) Rated Working Pressure

Nominal Size mm (in)	Bore *B* mm (in)	Outside Diameter OD mm (in)	Total Thickness *T* mm (in)	Large Diameter of Neck *J* mm (in)	Minimum Neck Length *L* mm (in)	Ring Groove Number	Clamp Number
46 (1 13/16)	46.05 (1.813)	146.84 (5.781)	29.60 (1.166)	111.90 (4.406)	57.6 (2.27)	BX-151	2
52 (2 1/16)	52.40 (2.063)	155.58 (6.125)	41.18 (1.622)	114.30 (4.500)	81.7 (3.22)	BX-152	3
65 (2 9/16)	65.10 (2.563)	155.58 (6.125)	41.18 (1.622)	114.30 (4.500)	81.7 (3.22)	BX-153	3
78 (3 1/16)	77.80 (3.063)	214.30 (8.437)	33.26 (1.310)	173.00 (6.812)	71.6 (2.82)	BX-154	6
103 (4 1/16)	103.20 (4.063)	336.54 (13.250)	41.18 (1.622)	295.25 (11.625)	85.8 (3.38)	BX-155	8
130 (5 1/8)	130.20 (5.125)	336.54 (13.250)	41.18 (1.622)	295.25 (11.625)	85.8 (3.38)	BX-169	8
179 (7 1/16)	179.40 (7.063)	523.90 (20.626)	51.68 (2.035)	473.05 (18.625)	120.6 (4.75)	BX-156	22
279 (11)	279.40 (11.000)	565.16 (22.250)	58.64 (2.309)	523.85 (20.625)	134.8 (5.31)	BX-158	15
346 (13 5/8)	346.10 (13.625)	711.20 (28.000)	76.32 (3.005)	635.00 (25.000)	156.7 (6.17)	BX-159	28
476 (18 3/4)	476.25 (18.750)	863.60 (34.000)	101.72 (4.005)	774.70 (30.500)	208.7 (8.22)	BX-164	26
Tolerance mm	+0.79 -0	+0.13 -0.13	+0.0 -0.25	+0.0 -0.79	-1.52		
 (in)	(+0.031) (-0)	(+0.005) (-0.005)	(+0) (-0.010)	(+0) (-0.031)	(-0.06)		

Table 15—Type 16BX Integral Hub Connections for 138.0 MPa (20,000 psi) Rated Working Pressure

Nominal Size	Bore	Outside Diameter	Total Thickness	Large Diameter of Neck	Minimum Neck Length	Ring Groove Number	Clamp Number
	B	OD	*T*	*J*	*L*		
mm (in)	mm (in)	mm (in)	mm (in)	mm (in)	mm (in)		
46 (1 13/16)	46.05 (1.813)	155.58 (6.125)	41.18 (1.622)	114.30 (4.500)	81.7 (3.22)	BX-151	3
52 (2 1/16)	52.40 (2.063)	155.58 (6.125)	41.18 (1.622)	114.30 (4.500)	81.7 (3.22)	BX-152	3
65 (2 9/16)	65.10 (2.563)	214.30 (8.437)	33.26 (1.310)	173.00 (6.812)	71.6 (2.82)	BX-153	6
78 (3 1/16)	77.80 (3.063)	336.54 (13.250)	41.18 (1.622)	295.25 (11.625)	85.8 (3.38)	BX-154	8
103 (4 1/16)	103.20 (4.063)	412.76 (16.250)	41.98 (1.653)	371.45 (14.625)	104.9 (4.13)	BX-155	10
179 (7 1/16)	179.40 (7.063)	565.16 (22.250)	58.64 (2.309)	523.85 (20.625)	134.8 (5.31)	BX-156	15
279 (11)	279.40 (11.000)	711.20 (28.000)	76.32 (3.005)	635.00 (25.000)	171.4 (6.17)	BX-158	28
Tolerance mm	+0.79 -0	+0.13 -0.13	-0.0 -0.25	-0.0 -0.79	-.1.52		
(in)	(+0.031) (-0)	(+0.005) (-0.005)	(+0) (-0.010)	(+0) (-0.031)	(-0.06)		

The dimensions shall apply to machining dimensions and shall not apply to post-test or post-hub and ring gasket makeup.

Consideration shall be given to the application to determine the appropriate use of blind or target flanges.

The coefficient of friction shall be considered and shall be + 0.1 at makeup and − 0.1 while operating.

Prior to overlay, the ring grooves shall be rough machined to conform to API 6A.

If materials with other coefficients of friction are used, the manufacturer shall include those coefficients in the design.

4.3.5 Clamps

4.3.5.1 General

This subsection provides the minimum design, material, and dimensional requirements for clamps that shall be used in conjunction with type 16B and type 16BX hubs conforming to 4.3.4.

4.3.5.2 Design

Clamps shall be designed for use in the combination of designated size ranges and pressure ratings shown in Table 16. Clamps shall be designated by the clamp number shown in Table 16.

Clamp connectors shall be designed according to 4.4.2. Each clamp shall be designed for the highest loading that may be induced by any hub it is intended to fit.

Table 16—Clamps for Type 16B and 16BX Hub Connections

Clamp No.	Hub				Clamp No.	Hub			
	Designated Size A		Working Pressure			Designated Size A		Working Pressure	
	mm	(in)	MPa	(psi)		mm	(in)	MPa	(psi)
1	46	(1 13/16)	68.95	(10,000)	10	103	(4 1/16)	137.9	(20,000)
	52	(2 1/16)	34.45	(5,000)		179	(7 1/16)	68.95	(10,000)
2	46	(1 13/16)	103.4	(15,000)		228	(9)	68.95	(10,000)
	52	(2 1/16)	68.95	(10,000)		279	(11)	34.45	(5,000)
	65	(2 9/16)	34.45	(5,000)	11	346	(13 5/8)	20.68	(3,000)
3	46	(1 13/16)	137.9	(20,000)	12	425	(16 3/4)	13.79	(2,000)
	52	(2 1/16)	103.4	(15,000)	13	346	(13 5/8)	34.45	(5,000)
	52	(2 1/16)	137.9	(20,000)	14	425	(16 3/4)	20.68	(3,000)
	65	(2 9/16)	103.4	(15,000)	15	179	(7 1/16)	137.9	(20,000)
4	65	(2 9/16)	68.95	(10,000)		279	(11)	103.4	(15,000)
	79	(3 1/8)	34.45	(5,000)		346	(13 5/8)	68.95	(10,000)
5	78	(3 1/16)	68.95	(10,000)	18	540	(21 1/4)	13.79	(2,000)
	103	(4 1/16)	34.45	(5,000)	19	425	(16 3/4)	34.45	(5,000)
6	65	(2 9/16)	137.9	(20,000)	22	179	(7 1/16)	103.4	(15,000)
	78	(3 1/16)	103.4	(15,000)		279	(11)	68.95	(10,000)
	103	(4 1/16)	68.95	(10,000)	25	179	(7 1/16)	13.79	(2,000)
7	130	(5 1/8)	34.45	(5,000)	26	476	(18 3/4)	103.4	(15,000)
	130	(5 1/8)	68.95	(10,000)		540	(21 1/4)	68.95	(10,000)
8	78	(3 1/16)	137.9	(20,000)	27	476	(18 3/4)	68.95	(10,000)
	103	(4 1/16)	103.4	(15,000)		540	(21 1/4)	34.45	(5,000)
	130	(5 1/8)	103.4	(15,000)	28	279	(11)	137.9	(20,000)
	179	(7 1/16)	34.45	(5,000)		346	(13 5/8)	103.4	(15,000)
	228	(9)	34.45	(5,000)		425	(16 3/4)	68.95	(10,000)
9	279	(11)	20.68	(3,000)					

The clamp bore shall provide a minimum of 3 mm (0.125 in) radial clearance around the hub neck in the made-up condition on all hubs it is designed to fit.

All clamps shall have one or more bolts at each connecting point.

Spherical-face heavy hexagonal nuts or spherical washers shall be used to minimize potential bending in bolts.

Clamp-bolting stresses shall conform to 4.4.2. Torque values and lubricant for clamp bolting shall be determined by the manufacturer to assure sufficient preload in the connection. Stresses shall be calculated at makeup, operating, and test conditions. The coefficient of friction shall be considered and shall be $+0.1$ at makeup and -0.1 while operating.

NOTE 1 Friction inhibits makeup and assists in holding the connection at operating and test conditions.

NOTE 2 The coefficient of friction stated here is that used for clamp and hub design. This specification is not applicable to materials or coatings that have different coefficients of friction.

If materials with other coefficients of friction are used, the manufacturer shall include those coefficients in the design.

Makeup stresses are directly proportional to the bolt loads and shall be determined based on the greater of:

- the bolt load required to seat the gasket and bring the hub faces into contact, or
- the bolt load required to retain the sum of the rated working pressure end load and the gasket retaining load.

Makeup of the clamp shall be sufficient such that the hub faces meet and there is no change in facial separation at the hub OD at rated working pressure.

Operating stresses shall be determined using the stresses resulting from the sum of the rated working pressure end load and the gasket-retaining load.

Test condition stresses shall be determined using the stresses resulting from the sum of the test pressure end load and the gasket-retaining load.

The stresses shall be determined using the outside diameter of the gasket as the sealing diameter.

All clamps shall have grooves in their bores with angles of 25° ± 0°15’ to fit type 16B and type 16BX hubs (see Figure 7).

All 25° surfaces in clamp grooves shall have a surface finish *Ra* of 0.8 μm (32 μin RMS) or less.

4.3.5.3 Material

Clamps shall be manufactured from material conforming to this specification. Material requirements of NACE MR0175/ISO 15156 are not necessary.

Bolting shall conform to 4.3.3.

Material for washers shall meet the manufacturer's written material specification.

4.3.6 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. See Table 17 for a summary of groove and gasket usage.

4.3.7 Blowout Preventers and Drilling Spools

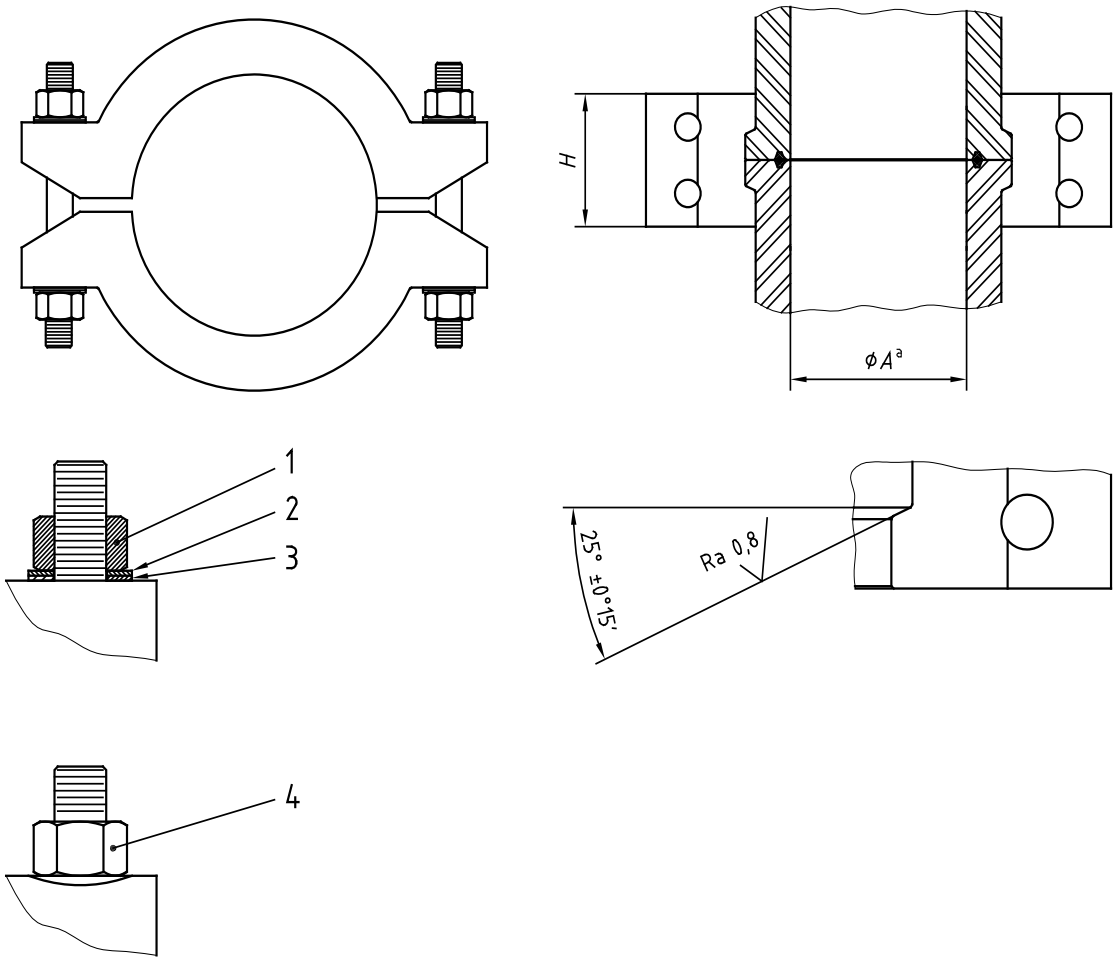
4.3.7.1 Dimensions

Blowout preventers and drilling spools shall be identified by the size designation shown in Table 1.

The end-to-end dimension for blowout preventers, drilling spools, and spacer spools shall be the overall height from the bottom face of the bottom connection to the top face of the top connection. This dimension shall be in accordance with the manufacturer's written specifications.

Blowout preventers, drilling spools, and spacer spools shall have a cylindrical passage (bore) through the body, including end connections. The drill-through diameter shall conform to the size designation and shall allow passage of a drift with a diameter, as shown in Table 1.

Surface roughness in micrometers



Key

1 Nut
2 Outer washer
3 Inner washer
4 Spherical nut

[a] Size designation as specified in Table 16

Maximum height (H) of clamp is H = 2L – 0.12 in

NOTE Dimension L can be found on the appropriate hub table (see Tables 12 through 15)

Figure 7—Clamps for Type 16B and 16BX Hub Connections

Table 17—Ring Gasket Numbers for API 6A/16A Equipment

Ring Number	Designated Size		Rated Working Pressure		Ring Number	Designated Size		Rated Working Pressure	
	mm	(in)	MPa	(psi)		mm	(in)	MPa	(psi)
Type 6B Integral Flange Connections					BX 159	346	(13 5/8)	103.5	(15,000)
R or RX 45	179	(7 1/16)	13.8	(2,000)	BX 164	476	(18 3/4)		
R or RX 49	228	(9)			BX 156	179	(7 1/16)	138	(20,000)
R or RX 53	279	(11)			BX 157	228	(9)		
R or RX 57	346	(13 5/8)			BX 158	279	(11)		
R or RX 65	425	(16 3/4)			BX 159	346	(13 5/8)		
R or RX 73	540	(21 1/4)			**Type 16B Integral Hub Connections**				
R or RX 45	179	(7 1/16)	20.7	(3,000)	RX 45	179	(7 1/16)	13.8	(2,000)
R or RX 49	228	(9)			RX 65	425	(16 3/4)		
R or RX 53	279	(11)			RX 73	540	(21 1/4)		
R or RX 57	346	(13 5/8)			RX 53	279	(11)	20.7	(3,000)
R or RX 66	425	(16 3/4)			RX 57	346	(13 5/8)		
R or RX 74	527	(20 3/4)			RX 65	425	(16 3/4)		
R or RX 46	179	(7 1/16)	34.5	(5,000)	**Type 16BX Integral Hub Connections**				
R or RX 50	228	(9)			BX-169	130	(5 1/8)	34.5	(5,000)
R or RX 54	279	(11)			BX 156	179	(7 1/16)		
Type 6BX Integral Flange Connections					BX 157	228	(9)		
BX 167	679	(26 3/4)	13.8	(2,000)	BX 158	279	(11)		
BX 303	762	(30)			BX 160	346	(13 5/8)		
BX 168	679	(26 3/4)	20.7	(3,000)	BX 162	425	(16 3/4)		
BX 303	762	(30)			BX 165	540	(21 1/4)		
BX 160	346	(13 5/8)	34.5	(5,000)	BX-169	130	(5 1/8)	69	(10,000)
BX 162	425	(16 3/4)			BX 156	179	(7 1/16)		
BX 163	476	(18 3/4)			BX 157	228	(9)		
BX 165	540	(21 1/4)			BX 158	279	(11)		
BX 156	179	(7 1/16)	69	(10,000)	BX 159	346	(13 5/8)		
BX 157	228	(9)			BX 162	425	(16 3/4)		
BX 158	279	(11)			BX 164	476	(18 3/4)		
BX 159	346	(13 5/8)			BX 166	540	(21 1/4)		
BX 162	425	(16 3/4)			BX-169	130	(5 1/8)	103.5	(15,000)
BX 164	476	(18 3/4)			BX 156	179	(7 1/16)		
BX 166	540	(21 1/4)			BX 158	279	(11)		
BX 156	179	(7 1/16)	103.5	(15,000)	BX 159	346	(13 5/8)		
BX 157	228	(9)			BX 164	476	(18 3/4)		
BX 158	279	(11)			BX 156	179	(7 1/16)	138	(20,000)
					BX 158	279	(11)		

4.3.7.2 Design

Design methods shall conform to 4.4.

End connections on all equipment within the scope of this specification shall conform to the requirements of 4.3.1, 4.3.2, 4.3.4, or 4.3.9.

Outlet connections shall conform to the requirements of 4.3.1, 4.3.2, 4.3.4, or 4.3.9. The number of outlets is optional.

4.3.7.3 Material

Material used for pressure-containing parts shall conform to Section 5.

Closure bolting shall conform to 4.3.3, and other parts shall conform to the manufacturer's written specification.

4.3.8 Weld Neck Hubs

This specification is not applicable to weld neck hubs.

4.3.9 Other End Connections (OECs)

4.3.9.1 General

This subsection provides requirements for other end connections that may be used for joining drill-through equipment and that 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.

4.3.9.2 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.

4.3.9.3 Materials

OEC materials shall meet the requirements of Section 5.

4.3.9.4 Testing

Equipment utilizing OECs shall successfully complete the tests required in Section 7.

4.3.10 Blind Connections

4.3.10.1 Flanges

Type 6B and 6BX blind flanges shall conform to the dimensional requirements of API 6A.

4.3.10.2 Hubs

Dimensions of 16B and 16BX blind hubs shall conform to Figure 4 and Table 8, Table 9, Table 12, Table 13, Table 14, or Table 15, in accordance with applicable size and pressure rating.

4.3.10.3 Other End Connections (OECs)

The design and configuration of blind OECs shall conform to 4.3.9.2, 4.3.9.3, and 4.3.9.4.

4.3.11 Adapters

End connections shall meet the requirements of 4.3.1, 4.3.2, 4.3.4, or 4.3.9.

NOTE Length of adapters is not addressed in this specification.

4.3.12 Hydraulic Connectors

4.3.12.1 Dimensions

Hydraulic connectors shall be identified by the designated size in Table 1.

The end-to-end dimensions for hydraulic connectors shall include both the overall height and the height from the internal face (which connects to the wellhead or blowout-preventer mandrel) to the face of the top end connection. These dimensions are not standardized and shall conform to the manufacturer's written specifications.

The bore diameter shall conform to the minimum bore dimension of the end connections as shown in Table 1.

4.3.12.2 Design

Design methods shall conform to 4.4.

There shall be no hub face separation of the connection face when locked with manufacturer's recommended operating pressure and tested at rated working pressure.

NOTE Maximum recommended latching pressure may be used.

4.3.12.3 Connections

The top connection shall conform to the requirements of 4.3.1, 4.3.2, 4.3.4, or 4.3.9.

The bottom connection shall lock and seal on the adapter or wellhead as specified by the manufacturer.

4.3.12.4 Gasket Retention Mechanism

A gasket retention mechanism shall be provided.

NOTE This mechanism may be hydraulic or mechanical.

4.3.12.5 Position Indicator

A position-indicating device shall be provided to visually show if the connector is locked or unlocked.

4.3.12.6 Material

Material shall conform to the requirements of Section 5.

4.3.12.7 Locks

Hydraulic connectors shall be designed to include primary and secondary unlocking functionality.

4.3.13 Test, Vent, Injection, and Gauge Connections

Sealing and porting of flanges, hubs, and OECs shall conform to the requirements of API 6A and is only permitted in blind flanges and test stumps.

4.4 Design Methods

4.4.1 End and Outlet Connections

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

End and outlet connections to the wellbore shall be integral.

4.4.2 Pressure-containing, Pressure-controlling, or Pressure-retaining Parts

4.4.2.1 General

Parts or members shall be designed in accordance with one or more of the methods given in 4.4.2.1 to 4.4.2.4

If equipment is being designed to operate where higher-than-normal atmospheric (14.7 psi) differential pressures (psid) exist, the differential pressure of the intended service shall be considered in the design verification analysis and validation of the equipment. Particular care should be given to identifying trapped voids in the equipment and analyzing the effects of those voids on the system in an externally pressurized environment.

NOTE 1 Validation testing may be performed with text fixtures.

NOTE 2 This specification is not applicable to fatigue analysis and localized bearing stress values. Design decisions based only on the allowable methods shown may not be sufficient for all service conditions.

4.4.2.2 Design Methodology

The design methodology described in API 6X shall be used.

NOTE The use of von Mises equivalent stress is permitted.

4.4.2.3 Distortion Energy Theory

NOTE 1 Distortion energy theory, also known as von Mises Law, may be used for design calculations. Rules for the consideration of discontinuities and stress concentrations are beyond the scope of this method.

NOTE 2 This design methodology for the basic pressure vessel wall thickness may be sized by combining triaxial stresses based on hydrostatic test pressure, and is limited by the following criterion:

$$S_e = S_y \quad (1)$$

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.

4.4.2.4 Experimental Stress Analysis

NOTE Application of experimental stress analysis as described in ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, may be used.

4.4.3 Closure Bolting

The maximum tensile stress for closure 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:

$$S_{a = 0.83\ S_y} \text{ and} \quad (2)$$

$$S_{b = 1.0\ S_y} \quad (3)$$

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.

4.4.4 Other Parts

Other parts shall be designed to satisfy the manufacturer's written specifications and the service conditions defined in 4.2.

4.4.5 Hydraulic Connectors

The manufacturer shall document the capacity for the hydraulic connector in a chart format that provides a relationship of the internal pressure versus bending moment at various tension/compression levels. Effects of preload, pressure end load, ability to maintain a seal, and hub separation shall be defined. It is recommended that the capacity chart is generated using 3-D finite element analysis.

Additionally, for PR2 requirements, the capacity chart shall include the rated capacities with a design factor of 1.5, extreme capacity with a design factor of 1.25, and survival capacity with a design factor of 1. The design methodology shall be per section 4.4.

NOTE 1 The number of tension/compression lines and magnitude of external tension/compression applied can vary depending on the application.

NOTE 2 An example of a connector capacity chart is shown in Figure 8.

The capacity chart shall be validated by physical testing as described in the section 4.5.

The capacity chart shall be based on the capabilities of the connector assembly and the test wellhead, mandrel, or test stump; the end connection can be excluded.

4.4.6 Clamps

The manufacturer shall document the load/capacity for the clamp connection using the format for API flanges in API 6AF2.

The documented load capacity shall relate pressure to the allowable bending moment for various tensions.

The manufacturer shall state whether the limitation is in the stress level of the clamp or of the hub. Analytical design methods shall conform to 4.4. The manufacturer shall state which part of the connection contains the stress limitations or leakage limitations that form the basis for the graphs.

4.4.7 Other End Connections and LMRP mandrels

The manufacturer shall document the load/capacity for the OEC and LMRP mandrels using the format used for API flanges in API 6AF2.

The documented load capacity shall relate pressure to the allowable bending moment for various tensions.

The manufacturer shall state which part of the connection contains the stress limitations that form the basis for the graphs. Analytical design methods shall conform to 4.4.

4.4.8 Test Stumps

Test stumps shall be designed in accordance with API 6X and manufacturer's specifications.

4.5 Design Validation

4.5.1 General

All parts of the equipment and the entire assembly shall be fully design validated in accordance with the manufacturer's written specifications and/or other internationally recognized standards.

Design validation shall be documented as required in 4.6.

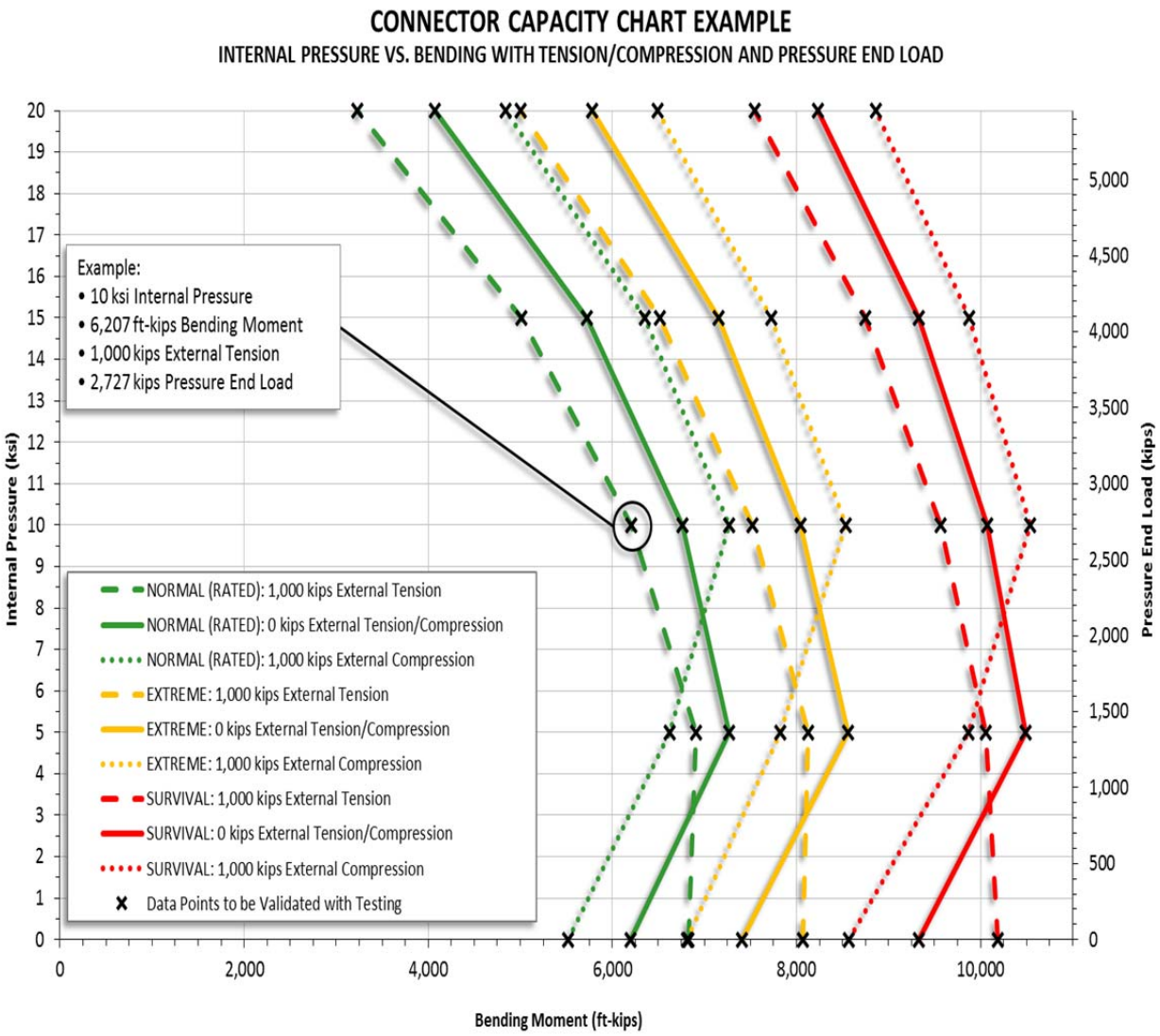


Figure 8—Connector Capacity Chart

4.5.2 Blowout Preventers

Tests of the operating characteristics for blowout preventers shall conform to 4.7.

4.5.3 Hydraulic Connectors

Tests of the operating characteristics for hydraulic connectors shall conform to 4.7.

4.5.4 Annular Packer Units

Tests on annular packing units shall conform to 4.7.

Design temperature validation on annular packing units shall conform to 4.7.

The manufacturer shall maintain documentation that identifies the essential variables related to the manufacture of elastomer components, raw materials, and molded seals. Changes to essential variables shall require revalidation according to this specification. The minimum essential variables evaluated for inclusion in the documentation are:

— compound or compound components;

— manufacturing process;

— compound vendors;

— metallic insert design;

— bonding agents and application;

— mold design.

4.5.5 Ram Blocks, Packers, and Top Seals

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

Design temperature validation on ram packers and top seals shall conform to 4.7.

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

— compound or compound components;

— manufacturing process;

— compound vendors;

— metallic insert design;

— bonding agents and application;

— mold design.

4.5.6 OECs

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 and development documentation shall be reviewed and verified by a technical authority other than the individual who created the original design.

4.6.3 Design Validation

The following shall be included in the design validation documentation:

— design validation test procedures;

— documentation for measuring and testing equipment, including calibration verification;

— traceability for the equipment subject to design validation;

— design validation results.

4.6.4 Documentation Retention

Documents required in accordance with Section 4 shall be retained for 10 years after the last unit of that model, size, and rated working pressure is manufactured.

4.7 Tests for BOP and Hydraulic Connector 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 two performance requirement levels documented in the tables below: PR1 and PR2. The performance requirement (PR) level is determined by the extent of testing successfully performed in accordance with minimum performance criterion indicated in the tables below. If PR2 testing has been completed, it also meets the requirement of a PR1 test.

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 or 4.9.

4.7.1.2 Procedure

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

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 3.45 MPa (500 psi), whichever is less.

4.7.2 Testing Requirements and Minimum Performance Criteria

4.7.2.1 Ram BOP Qualification

Ram BOPs shall be hydrostatic proof tested in accordance with 7.5.7.6 prior to PR1 or PR2 qualification testing.

Ram BOPs shall be tested in accordance with Table 18. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

Table 18—Required Tests and Performance Criteria for Ram BOPs

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Ram access	4.7.3.11[a]	4.7.3.12	200 cycles with 10 pressure cycles	200 cycles with 10 pressure cycles
Fatigue	4.7.3.3	4.7.3.4	Reportable	52 pressure cycles
Ram locking	4.7.3.13[a]	4.7.3.14	1 locking pressure cycle	52 locking pressure cycles
Low temperature	4.7.3.15	4.7.3.15	3 pressure cycles	3 pressure cycles
Continuous operating temperature	N/A	4.7.3.16	N/A	10 pressure cycles
Extreme high temperature	4.7.3.17	4.7.3.17	1 hour hold time	1 hour hold time

[a] Only one test is required for a product family of functionally similar design to qualify for PR1.

NOTE Test results may be used to qualify other Ram BOPs provided all the following criteria are met (except as noted in Table 18, Note a):

— the rated working pressure is equal to, or lower than, the equipment tested;

— the rated working pressure is lowered by only changing the end connections;

— the temperature rating is within the qualified temperature range;

— seal geometry (excluding ram seals) and ram cavity cross section as applied is identical.

4.7.2.2 Ram Blocks, Packers, and Top Seals Qualification

4.7.2.2.1 Fixed Bore Pipe Rams and Blind Rams

Pipe sizes required to be tested for qualification are listed in Table 19 unless otherwise noted in the specified design validation test.

Table 19—Test Mandrel Pipe Size(s) for Ram Testing

Nominal Size Designation		PR 1 Nominal Pipe Size(s)		PR2 Nominal Pipe Size(s)	
mm	(in)	mm	(in)	mm	(in)
179	7 1/16	89	3 1/2	89	3 1/2
228	9	89	3 1/2	89	3 1/2
279	11	127	5	127	5
346	13 5/8	127	5	127	5
425	16 3/4	127	5	127	5
476	18 3/4	127	5	127 and one size ≥ 273	5 and one size ≥ 10 3/4
527	20 3/4	127	5	127 and one size ≥ 273	5 and one size ≥ 10 3/4
540	21 1/4	127	5	127 and one size ≥ 273	5 and one size ≥ 10 3/4
680	26 3/4	127	5	127 and one size ≥ 273	5 and one size ≥ 10 3/4
762	30	127	5	127 and one size ≥ 273	5 and one size ≥ 10 3/4

Fixed bore pipe rams and blind rams shall be tested in accordance with Table 20. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

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

— no essential variables have changed as specified in 4.5.5, other than those dimensional changes required to accommodate a different pipe size;

— the rated working pressure is equal to, or lower than, the equipment tested;

— the temperature rating is within the qualified temperature range.

Table 20—Required Tests and Performance Criteria for Fixed Bore Pipe Rams and Blind Rams

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Sealing Characteristics	4.7.3.1[d]	4.7.3.2[d]	Reportable	Reportable
Fatigue	4.7.3.3	4.7.3.4	Reportable	52 pressure cycles
Stripping	4.7.3.5 [a, b, c]	4.7.3.6 [a, b]	Reportable	500 ft
Hang-off	4.7.3.9 [a, b, e]	4.7.3.10 [a, b, e]	Reportable	Reportable
Low Temperature	4.7.3.15	4.7.3.15	3 pressure cycles	3 pressure cycles
Continuous High Temperature	N/A	4.7.3.16	N/A	10 pressure cycles
Extreme High Temperature	4.7.3.17	4.7.3.17	1 hour hold time	1 hour hold time

[a] Not applicable to blind rams if tested separate from fixed bore pipe rams.
[b] Test is not applicable to casing rams designed for tubular sizes as defined in API 5CT.
[c] Qualifies all rated working pressures of the product tested and qualifies all equipment size designations of the product tested.
[d] 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.
[e] Applicable to equipment sizes 11 in and larger.

4.7.2.2.2 Variable Bore Pipe Rams

Variable bore rams shall be tested in accordance with Table 21. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

Table 21—Required Tests and Performance Criteria for Variable Bore Pipe Rams

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Sealing Characteristics	4.7.3.1[d]	4.7.3.2[d]	Reportable	Reportable
Fatigue	4.7.3.3	4.7.3.4[b]	Reportable	28 pressure cycles
Stripping	4.7.3.5[c]	4.7.3.6[c]	Reportable	Reportable
Hang-off	4.7.3.9[a, e]	4.7.3.10[e]	Reportable	Reportable
Low Temperature	4.7.3.15	4.7.3.15	3 pressure cycles	3 pressure cycles
Continuous High Temperature	N/A	4.7.3.16	N/A	10 pressure cycles
Extreme High Temperature	4.7.3.17	4.7.3.17	1 hour hold time	1 hour hold time

[a] Hang-off on minimum pipe size shall be reported as zero if no testing on the minimum pipe size is performed.
[b] The fatigue test shall alternate between the minimum and maximum pipe sizes every seven pressure cycles.
[c] Qualifies all rated working pressures of the product tested.
[d] 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.
[e] Applicable only to equipment sizes 11 in and larger.

For variable bore pipe rams, the minimum and maximum pipe sizes for that product shall be tested unless otherwise noted in the specified design validation test. Table 21 criteria shall be achieved on both the minimum and maximum pipe sizes for the variable bore pipe ram design being tested.

NOTE Test results may be used to qualify other variable bore ram assemblies, provided all the following criteria are met:

— no essential variables have changed as specified in 4.5.5;

— the rated working pressure is equal to, or lower than, the equipment tested;

— the temperature rating is within the qualified temperature range.

4.7.2.2.3 Blind Shear Rams

Blind shear rams shall be tested in accordance with Table 22. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved (Table 23).

Table 22—Required Tests and Performance Criteria for Blind Shear Rams

Test	PR1 Section	PR2 Section	PR 1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Sealing Characteristics	4.7.3.1[a]	4.7.3.2[a]	Reportable	Reportable
Fatigue	4.7.3.3	4.7.3.4	Reportable	52 pressure cycles
Shear with Seal	4.7.3.7	4.7.3.8.1	3 complete shear and seal tests	3 complete shear and seal tests
Shearing Range	N/A	4.7.3.8.2	N/A	Reportable
Off-center Shearing	N/A	4.7.3.8.3	N/A	Reportable
Shear Side-load Testing	N/A	4.7.3.8.4	N/A	Reportable
Low Temperature	4.7.3.15	4.7.3.15	3 pressure cycles	3 pressure cycles
Continuous High Temperature	N/A	4.7.3.16	N/A	10 pressure cycles
Extreme High Temperature	4.7.3.17	4.7.3.17	1 hour hold time	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.				

NOTE Test results may be used to qualify other blind shear ram assemblies provided:

— No essential variables have changed as specified in 4.5.5;

— The rated working pressure is equal to, or lower than, the equipment tested;

— The temperature rating is within the qualified temperature range;

— The same shear blade geometry is used.

Table 23—Shear Pipe Requirements

BOP Size	PR1 Shear Pipe (Minimum)	PR2 Shear Pipe (Minimum)
179 mm (7 1/16 in)	3 1/2 in 13.3 lb/ft Grade E-75	3 1/2 in 13.3 lb/ft Grade E-75
228 (9 in)	3 1/2 in 13.3 lb/ft Grade G105	3 1/2 in 13.3 lb/ft Grade G105
279 mm (11 in)	5 in 19.5 lb/ft Grade G105	5 in 19.5 lb/ft Grade G105
346 mm (13 5/8 in)	5 in 19.5 lb/ft Grade G-105	5 in 19.5 lb/ft Grade G-105
425 (16 3/4 in) and larger size designations	5 in 19.5 lb/ft Grade G-105	5 1/2 in 24.7 lb/ft Grade S135
NOTE A larger diameter, higher-grade, or heavier-weight pipe may be used.		

4.7.2.2.4 Non-sealing Shear Rams

Non-sealing shear rams shall be tested in accordance with Table 24. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

Table 24—Required Tests and Performance Criteria for Non-Sealing Shear Rams

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Shearing Test	4.7.3.7	4.7.3.8.1	3 complete shear tests	3 complete shear tests
Shearing Range	N/A	4.7.3.8.2	N/A	Reportable
Shearing Side-load testing	N/A	4.7.3.8.3	N/A	Reportable
Off-center Shearing	N/A	4.7.3.8.4	N/A	Reportable

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

— The rated working pressure is equal to, or lower than, the equipment tested.

— The same shear blade geometry is used.

4.7.2.3 Annular BOP Qualification Test Requirements:

Annular BOPs shall be tested in accordance with Table 25. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

Table 25—Required Tests and Performance Criteria for Annular BOPs

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Packer Access	4.7.3.23[a]	4.7.3.23[a]	Reportable	60 cycles with 3 pressure cycles
Fatigue	4.7.3.21[b]	4.7.3.22[b]	Reportable	26 pressure cycles
Low Temperature	4.7.3.26[b]	4.7.3.27[b]	3 pressure cycles	3 pressure cycles
Continuous Operating Temperature	N/A	4.7.3.28[b]	N/A	10 pressure cycles
Extreme High Temperature	4.7.3.29[b]	4.7.3.29[b]	1 hour hold time	1 hour hold time

[a] Only one test is required for a product family of functionally similar design.
[b] Test is to evaluate the nonmetallic sealing components of the annular BOP, excluding the packing unit, at the temperature rating.

NOTE Test results may be used to qualify other annular BOP assemblies provided:

— The rated working pressure is equal to, or lower than, the equipment tested.

— The rated working pressure is lowered by only changing the end connections.

— The temperature rating is within the qualified temperature range.

4.7.2.4 Annular Packing Units Qualification Tests

Test mandrel pipe sizes shall conform to Table 26. Annular packers shall be tested in accordance with Table 27. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

Table 26—Test Mandrel Pipe Size(s) for Annular Packers

Nominal Size Designation		PR 1 Nominal Pipe Size(s)		PR2 Nominal Pipe Size(s)	
mm	(in)	mm	(in)	mm	(in)
179	(7 1/16)	89	(3 1/2)	89	(3 1/2)
228	(9)	89	(3 1/2)	89	(3 1/2)
279	(11)	127	(5)	Minimum and Maximum[a]	Minimum and Maximum[a]
346	(13 5/8)	127	(5)	Minimum and Maximum[a]	Minimum and Maximum[a]
425	(16 3/4)	127	(5)	Minimum and Maximum[a]	Minimum and Maximum[a]
476 and above	(18 3/4 and above)	127	(5)	Minimum and Maximum[a]	Minimum and Maximum[a]

[a] Minimum and Maximum is the mandrel size range of the annular packing unit at the rated working pressure as determined by the manufacturer.

Table 27—Required Tests and Performance Criteria for Annular Packers

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Sealing Characteristics	4.7.3.18	4.7.3.19	Reportable	Reportable
Fatigue	4.7.3.21	4.7.3.22[a]	Reportable	26 pressure cycles
Extended Range Operational Characteristics	N/A	4.7.3.20	N/A	Optional Test
Stripping	4.7.3.24	4.7.3.25[b]	Reportable	50 stripping cycles
Low Temperature	4.7.3.26	4.7.3.27	3 pressure cycles	3 pressure cycles
Continuous High Temperature	N/A	4.7.3.28	N/A	10 pressure cycles
Extreme High Temperature	4.7.3.29	4.7.3.29	1 hour hold time	1 hour hold time
Low Temperature Drift Characteristics	N/A	4.7.3.30	N/A	Reportable

[a] The fatigue test shall be performed on both the minimum and maximum pipe sizes.
[b] Test is not applicable to casing packers designed for tubular sizes as defined in API 5CT.

NOTE Test results can be used to qualify other annular packers assemblies provided:

— No essential variables have changed as specified in 4.5.4;

— The rated working pressure is equal to, or lower than, the equipment tested;

— The temperature rating is within the qualified temperature range.

4.7.2.5 Hydraulic Connector Qualification Tests

Hydraulic connectors shall be tested in accordance with Table 28. The indicated tests shall be performed and the minimum performance criteria for the applied PR level shall be achieved.

Table 28—Required Tests and Performance Criteria for Hydraulic Connectors

Test	PR1 Section	PR2 Section	PR1 Minimum Performance Criteria	PR2 Minimum Performance Criteria
Locking	4.7.3.31	4.7.3.31	Reportable	Reportable
Sealing mechanism	4.7.3.32	4.7.3.32	Reportable	24 pressure cycles
Combined loading	N/A	4.7.3.33	N/A	Reportable
Gasket	N/A	4.7.3.34	N/A	Reportable

4.7.3 Design Validation Tests

4.7.3.1 PR 1 Test of Sealing Characteristics, Ram-type BOP

4.7.3.1.1 PR 1 Ram Closure Against Zero Initial Wellbore Pressure

4.7.3.1.1.1 Purpose

NOTE 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

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) Disengage any automatic locking system on the ram closing device.

b) Close the rams using the manufacturer's recommended closing pressure.

c) Initially apply 3.45 MPa (500 psi) wellbore pressure, 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 3.45 MPa (500 psi) above the previous step, and again reduce the closing 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 preventer. The wellbore pressure increment shall be 3.45 MPa (500 psi) until the wellbore pressure exceeds 34.45 MPa (5,000 psi). Thereafter, the wellbore pressure increment shall be 6.89 MPa (1,000 psi).

4.7.3.1.2 PR1 Ram Closure Against Elevated Wellbore Pressure, Ram-type BOP

4.7.3.1.2.1 Purpose

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

4.7.3.1.2.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

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

b) Close the preventer with the 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 3.45 MPa (500 psi) 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 the preventer.

h) Repeat steps a through h, increasing the wellbore pressure to the rated working pressure of the preventer.

4.7.3.1.3 PR1 Sealing Characteristics Documentation, Ram-type BOP

Documentation for PR1 sealing characteristics shall include:

— Record of equipment used (e.g. BOP model, operator size and 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 PR2 Test of Sealing Characteristics, Ram-type BOP

4.7.3.2.1 PR2 Minimum Operator Pressure for Low-Pressure Sealing (MOPFLPS) Against Zero Wellbore Pressure

4.7.3.2.1.1 Purpose

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

4.7.3.2.1.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) Close rams at lowest expected closing pressure required to achieve a seal.

b) Attempt a 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure test with a hold period of 5 minutes.

c) If the test is unsuccessful, bleed all wellbore pressure and increase closing pressure.

d) Repeat steps b and 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 PR2 Minimum Operator Pressure for Low-Pressure Sealing (MOPFLPS) at Elevated Wellbore Pressure

4.7.3.2.2.1 Purpose

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

4.7.3.2.2.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) Pressurize wellbore above and below rams to 6.9 MPa (1,000 psi) +3.5 MPa (500 psi) or +5 % of the rated wellbore pressure, whichever is less -0 MPa (0 psi).

b) Close rams (on mandrel, if applicable) with MOPFLPS obtained in 4.7.3.2.1.1, 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 1.4 MPa to 2.1 MPa (200 psi to 300 psi) 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 steps b through 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 steps a through f, increasing the wellbore pressure in increments until it equals the rated working pressure of the preventer. The wellbore pressure increment shall be determined to result in a minimum of five approximately equally-spaced data points.

NOTE For equipment rated at 6.9 MPa (1,000 psi), no additional steps are necessary. For 13.8 MPa (2,000 psi) and 20.7 MPa (3,000 psi) equipment, repeat using 6.9 MPa (1,000 psi) increments up to working pressure.

4.7.3.2.3 PR2 Wellbore Pressure Assist

4.7.3.2.3.1 Purpose

NOTE 1 This test is to quantify the effect of wellbore pressure assist on maintaining a seal.

NOTE 2 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

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) Close rams at the 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 PR2 Sealing Characteristics Documentation

Documentation for PR2 sealing characteristics shall include:

Record of equipment used (e.g. BOP model, operator size and type, ram assembly);

Record of test results, including, at a minimum:

— MOPFLPS at zero wellbore pressure;

— Table of MOPFLPS at elevated wellbore pressures;

— Wellbore pressure–assist results at which leakage occurred.

4.7.3.3 PR1 Fatigue Test, Ram-type BOP

4.7.3.3.1 Purpose

NOTE This test determines the ability of the ram packers and 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 BOP for pipe ram tests. No test mandrel is required in blind/shear ram tests.

b) Close and open the rams seven times using the manufacturer's recommended operating pressure. On every seventh closure, pressure-test the rams at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and the full rated working pressure of the BOP. 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 minutes.

c) Repeat step b until the rams fail a pressure test, or until 546 openings and closings have been completed (78 pressure tests).

d) The ram blocks shall be MP or LP inspected after testing.

e) Document any observed wear following the test.

f) The ram blocks shall be MP or LP inspected after testing.

NOTE Ram locking device failure may be repaired during fatigue testing.

4.7.3.3.3 PR1 Fatigue Test Documentation, Ram-type BOP

Fatigue test documentation shall include:

— Record of equipment used (e.g. BOP model, operator size and type, ram assembly)

— Magnetic particle (MP) or liquid penetrant (LP) inspection of ram blocks, after testing, in accordance with the 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 PR2 Fatigue Test, Ram-type BOP

4.7.3.4.1 Purpose

NOTE This test determines the ability of the ram packers and 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 BOP for pipe ram tests. No test mandrel is required in blind/shear ram tests.

b) Close and open the rams seven times using the manufacturer's recommended operating pressure. On every seventh closure, pressure-test the rams at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and the full rated working pressure of the BOP. The operating pressure for this step shall be consistent until minimum performance criteria have been achieved, except during a MOPFLPS test.

c) On every pressure test, 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 minutes.

d) On the initial pressure cycle and every seventh pressure cycle thereafter:

   — perform a MOPFLPS test in accordance with 4.7.3.2.1.2;

   — after completion of each MOPFLPS test, vent wellbore pressure;

   — return the opening pressure to the recommended pressure reference in 4.7.3.4.2b;

   — proceed with the wellbore test to full rated working pressure, with the operating pressure and the locks engaged.

NOTE 1 For example, test on the first cycle, eighth cycle, 15th cycle, up to the 78th cycle.

e) For VBRs, alternate between the minimum and maximum pipe size every seventh pressure cycle.

f) Repeat steps b through d until the rams fail a pressure test or until 546 openings and closings have been completed (78 pressure tests).

g) The ram blocks shall be MP or LP inspected.

h) Document any observed wear following the test.

NOTE 2 Ram Locking Device failure may be repaired during fatigue testing unless test is also qualifying ram locking device.

NOTE 3 Minimum performance requirements can be found on tables 18, 20, 21, and 22.

4.7.3.4.3 PR2 Fatigue Test Documentation, Ram-type BOP

Fatigue test documentation shall include:

— Record of equipment used (e.g. BOP 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, operator closing pressure and MOPFLOPSs throughout the test.

4.7.3.5 PR1 Test for Stripping Life, Ram-type BOP

4.7.3.5.1 Purpose

NOTE This test determines the ability of the ram packers and seals to control wellbore pressure while running drill pipe through the closed rams without exceeding a leak rate of 3.8 liter/minute (1 gal/minute).

4.7.3.5.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) Measure and record the durometer hardness of the packer rubber.

b) Install test mandrel. For 279 mm (11 in) blowout preventers and larger, install a 127 mm (5 in) OD (no tool joint) test mandrel; for 228 mm (9 in) blowout preventers and smaller, install a 88.9 mm (3 1/2 in) OD test mandrel (no tool joint). When testing variable bore rams, if the mandrel size falls outside the specified operating range of the ram, use the mandrel size closest to the size recommended above.

c) Determine the initial closing pressure by adding 0.69 MPa (100 psi) (frictional effects) to the manufacturer's minimum recommended closing pressure for 6.89 MPa (1,000 psi) wellbore pressure. After closing on the test mandrel, using this pressure and applying 6.89 MPa (1,000 psi) wellbore pressure, reduce the closing pressure until the preventer leak rate is less than 3.8 l/minute (1 gal/minute) (to wet the test mandrel wall).

d) Reciprocate the test mandrel at a speed of approximately 600 mm/s (2 ft/s) until an equivalent of 9.1 m (30 ft) of pipe has been lubricated through the packer seals.

e) Bleed off wellbore pressure, and open the ram.

f) As the severity of the leak increases, raise the closing pressure, as needed, to the manufacturer's recommended value, and repeat d through f.

g) Repeat the steps above until the leak rate exceeds 3.8 l/minute (1 gal/minute) or an equivalent of 3,048 m (10,000 ft) of pipe has passed through the packer seals.

h) Document any wear on all ram packers as they are removed during the tests.

4.7.3.5.3 PR1 Stripping Test Documentation, Ram-type BOP

Documentation shall include:

— Diameter of test mandrel used;

— Record of reciprocating speed;

— Equivalent length of pipe stripped or 3,048 m (10,000 ft), whichever is attained first;

— Record of wellbore pressure and operator closing pressure throughout the test;

— Document condition of all ram packers as they are removed after tests.

4.7.3.6 PR2 Test for Stripping Life, Ram-type BOP

4.7.3.6.1 Purpose

NOTE This test determines the ability of the ram packers and seals to control wellbore pressure while running drill pipe through the closed rams without exceeding a leak rate of 3.8 liters/minute (1 gal/minute).

4.7.3.6.2 Protocol

Fixed-bore rams shall use a 127 mm (5 in) test mandrel for 279 mm (11 in) and larger blowout preventers. Fixed-bore rams shall use an 88.9 mm (3 1/2 in) test mandrel for blowout preventers smaller than 279 mm (11 in). 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.

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) Determine the initial closing pressure by adding 0.69 MPa (100 psi) (frictional effects) to the manufacturer's minimum recommended closing pressure for 6.89 MPa (1,000 psi) wellbore pressure. After closing on the test mandrel, using this pressure and applying 6.89 MPa (1,000 psi) wellbore pressure, reduce the closing pressure until the preventer leak rate is less than 3.8 l/minute (1.0 gal/minute) (to wet the test mandrel wall).

b) Reciprocate the test mandrel at a speed of approximately 600 mm/s (2 ft/s) until an equivalent of 9.1 m (30 ft) of pipe has been lubricated through the packer seals.

c) Bleed off wellbore pressure, and open the ram.

d) Close the ram with previously used closing pressure.

e) Repeat steps b through d. As the leak rate increases, raise the closing pressure, as needed, not to exceed the maximum operating pressure, until the leak rate exceeds 3.8 l/minute (1.0 gal/minute) or an equivalent of 3,048 m (10,000 ft) of pipe has passed through the packer seals.

4.7.3.6.3 PR2 Stripping Test Documentation, Ram-type BOP

Documentation shall include:

— Diameter of test mandrel used—include diameter and length of external upset, if applicable;

— 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 PR1 Shear Ram Test (With or Without Seal)

4.7.3.7.1 Purpose

NOTE This test determines the shearing and sealing capabilities for selected drill pipe samples.

4.7.3.7.2 Protocol

The test protocol shall be as follows:

a) Install a new set of ram packers onto the blocks. Record the durometer of the seals.

b) Suspend a section [approximately 1.2 m (4 ft) in length] of drill pipe as specified in Table 23 as appropriate for the preventer size vertically above the preventer, and lower it into the wellbore. It is permitted to loosely guide the portion of the pipe below and or above the rams to prevent excessive bending of the pipe during shearing.

c) Set the closing unit manifold pressure to the manufacturer’s recommended pressure for shearing. Close the rams and shear the pipe in a single operation.

d) The pressure at which the pipe is sheared will be obvious from the rapid pressure change at the instant of shearing.

e) Raise the wellbore pressure to 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 3 minutes, examining for leaks.

f) Raise the wellbore pressure to the maximum rated working pressure of the preventer and again examine for leaks during 3 minutes.

g) Reduce the wellbore pressure to zero, open the rams, and inspect and document any wear on the preventer.

h) Repeat the above step[s for two additional samples of drill pipe. Ram packers may be replaced as necessary.

NOTE Steps d through f are only applicable to blind shear rams.

4.7.3.7.3 PR1 Shear Ram Test Documentation, Ram-type BOP

Documentation shall include:

— Manufacturer's shear ram and BOP configurations;

— Actual operating pressure required to shear the pipe;

— Pipe description (size, mass, and grade), actual pipe tensile properties, and impact properties as specified in API 5DP;

— Document if the packers were replaced;

— Shear ram seal durometer.

4.7.3.8 PR2 Shear Ram Test (With or Without Seal), Ram-type BOP

4.7.3.8.1 PR2 Shear and Seal test

4.7.3.8.1.1 Purpose

NOTE This test determines the shearing and sealing capabilities (for rams with seal) for selected pipe samples.

4.7.3.8.1.2 Protocol

The test protocol shall be as follows:

The pipe used for the shear test as a minimum shall be in accordance with Table 23. Ram seals may be replaced between shear tests.

a) Install a new set of ram packers onto the blocks. Record shear ram seal durometer measurement data in test records.

b) Suspend a section [a minimum of 1.2 m (4 ft) in length] of drill pipe as specified in Table 23 as appropriate for the preventer size above the preventer and lower it into the wellbore. Testing shall be performed without axial loading of the pipe. Disable ram locks.

c) Set closing unit manifold pressure to maximum rated working pressure for the operator. Close the rams and shear the pipe in a single operation.

d) Bleed down closing pressure to shear pressure.

e) Raise the wellbore pressure to 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 3 minutes, examining for leaks.

NOTE 1 Increase closing pressure if wellbore seal cannot be obtained.

f) Raise the wellbore pressure to maximum rated working pressure of preventer and hold for 10 minutes after stabilization, examining for leaks.

NOTE 2 Increase closing pressure if wellbore seal cannot be obtained.

g) Reduce the wellbore pressure to zero, open the rams, and inspect.

h) Repeat the above steps for two additional samples of drill pipe. For the final shear test sample, the bottom of the pipe shall be constrained from moving downward.

NOTE 3 Steps d through g are applicable to blind shear rams.

4.7.3.8.1.3 PR2 Shear Ram Test Documentation

Documentation shall include:

— The manufacturer's shear ram and blowout preventer configurations;

— The pipe description (nominal size, weight, and grade), actual OD, actual ID, mechanical properties, and impact properties as specified in API 5DP;

— Record of wellbore pressure and operator closing and opening pressure throughout the test;

— Operator hydraulic closing and opening areas for both shearing and sealing;

— The maximum closing pressure required to shear and seal;

— The net effective shear force, F_{eff} (i.e. the maximum net force required to shear and seal, taking into account opening pressure/area and closing pressure/area);

$$F_{eff} = (P_c \times A_c) - (P_o \times A_o) \quad (4)$$

Where F_{eff} is the net effective shear or seal force
P_C is the closing pressure
P_O is the opening pressure
A_C is the closing area
A_O is the opening area

— Condition of all ram packers as they are removed after tests;

— Shear and seal pressure and corresponding shear and seal force.

4.7.3.8.2 PR2 Shearing Diametrical Design Range Test

4.7.3.8.2.1 Purpose

NOTE 1 This test determines the ability of a shear ram to shear a diametrical design range of tubular and effect a seal (for blind shear rams) without mechanically binding the ram.

NOTE 2 The shearing operator pressure is outside of the purpose of this test.

NOTE 3 Ram components may be changed between individual tests.

4.7.3.8.2.2 Protocol

The test protocol shall be as follows:

The tubular used for this test shall be designated by the equipment manufacturer and selected from API 5CT or API 5DP. The equipment manufacturer shall demonstrate that the shear rams can shear and seal (for blind shear rams) the wellbore for a specified minimum/maximum outer diameter and maximum wall thickness.

a) Suspend a section [a minimum of 1.2 m (4 ft) in length] of tubular vertically above the preventer and lower it into the wellbore. Testing shall be performed without axial loading of the tubular, 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 tubular in a single operation.

c) Raise the wellbore pressure to 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 5 minutes after stabilization, examining for leaks.

d) Raise the wellbore pressure to the maximum rated working pressure of the preventer and hold for 10 minutes after stabilization, examining for leaks.

e) Reduce the wellbore pressure to zero, open the rams, and inspect.

NOTE Steps c through e are only applicable to blind shear rams.

4.7.3.8.2.3 PR2 Shearing Diametrical Design Range Documentation

Documentation shall include:

— The manufacturer's shear ram and blowout preventer configurations;

— The pipe description (nominal size and grade), actual OD, actual ID;

— Record of wellbore pressure and operator closing and opening pressure throughout the test.

4.7.3.8.3 PR2 Diametrical Off-center Shearing Test

4.7.3.8.3.1 Purpose

NOTE 1 This test determines the ability for the shear rams to shear the tubular sample, and seal (sealing only required for blind shear 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.

NOTE 2 There is not a requirement to restrain the pipe against the side of the wellbore in this test.

4.7.3.8.3.2 Protocol

The test protocol shall be as follows:

The pipe used for this test shall be designated by the equipment manufacturer. The equipment manufacturer shall demonstrate that the shear rams can shear and seal (sealing only required for blind shear rams) the wellbore for a specified minimum outer diameter.

a) Suspend a section [a minimum of 1.2 m (4 ft) in length] of drill pipe vertically above the preventer and lower it into the wellbore. Testing shall be performed without axial loading of the pipe, with the pipe 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 in a single operation.

c) Raise the wellbore pressure to 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 5 minutes after stabilization, examining for leaks.

d) Raise the wellbore pressure to the maximum rated working pressure of the preventer and hold for 10 minutes after stabilization, examining for leaks.

e) Reduce the wellbore pressure to zero, open the rams, and inspect.

NOTE Steps c through e are only applicable to blind shear rams.

4.7.3.8.3.3 PR2 Diametrical Off-Center Shearing Documentation

Documentation shall include:

— The manufacturer's shear ram and blowout preventer configurations;

— The tubular description (nominal size and grade), actual OD, actual ID;

— Record of wellbore pressure and operator closing and opening pressure throughout the test.

4.7.3.8.4 PR2 Shearing Side Load

4.7.3.8.4.1 Purpose

NOTE 1 This test determines the side load force the shear rams can resist and still shear and seal the wellbore (sealing only required for blind shear 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 is initially in contact with the side of the wellbore (perpendicular to the axis of the ram.)

NOTE 2 It is only necessary to perform one shear test with side load.

4.7.3.8.4.2 Protocol

The pipe used for this shear test shall be as specified in Table 23. The manufacturer shall validate through testing the side load force that the shear rams can resist when the shearable 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, then seal (sealing only required for blind shear 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 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 5 minutes after stabilization, examining for leaks.
d) Perform a high wellbore pressure test at the maximum rated working pressure of the preventer and hold for 10 minutes after stabilization, examining for leaks.
e) Reduce the wellbore pressure to zero, open the rams, and inspect.

4.7.3.8.4.3 PR2 Shearing Side Load Documentation

Documentation shall include:

— The manufacturer's shear ram and blowout preventer configurations;

— 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;

— The tubular description (nominal size, grade), actual OD, actual ID, actual mechanical properties, and impact properties as specified in API 5DP;

— Record of wellbore pressure and operator closing and opening pressure throughout the test.

4.7.3.9 PR1 Hang-off Test, Ram-type BOP

4.7.3.9.1 Purpose

NOTE This test determines the ability of the fixed or variable ram assembly to maintain a 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and full rated working pressure seal while supporting drill-pipe loads.

4.7.3.9.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test protocol shall be as follows:

a) The ram blocks, a simulated 18° API tool-joint mandrel, and rubber packer metal inserts shall be inspected and the results recorded. The dimensional and hardness specifications of the simulated tool joint(s) used shall be in accordance with API 5DP.

   The inspection shall include:

   — MP inspection of ram blocks;

   — hardness measurement of the ram packer steel segments;

   — hardness measurement of ram blocks;

   — hardness measurement of the simulated tool joint;

   — durometer measurements on the ram packer.

b) Raise the simulated tool-joint so that the 18° taper is immediately above the ram blocks. Close the ram on the pipe with the manufacturer's recommended closing pressure. Lower the pipe with the rams closed until the tool joint lands on the ram assembly.

c) Perform a low wellbore pressure test at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 3 minutes after stabilization, examining for leaks.

d) Perform a high wellbore pressure test at the maximum rated working pressure of the preventer and hold for 3 minutes after stabilization, examining for leaks.

e) Bleed wellbore pressure to zero psi, increase the load incrementally, and repeat for each load increment until either the rams leak or a 2.7 MN (600,000 lb) load is reached for 125 mm (5 in) or larger pipe, or a 2.0 MN (450,000 lb) load is reached for pipe less than 125 mm (5 in).

f) Repeat the above steps using only the locking mechanism provided with the preventer to maintain the closed position.

g) Document any wear or deformation of the ram blocks, simulated tool-joint, and the metal inserts of the ram packer.

4.7.3.9.3 PR1 Hang-off Documentation, Ram-type BOP

Documentation shall include:

— The ram and blowout preventer configurations used;

— Nondestructive examination (NDE) of ram blocks in accordance with manufacturer's written procedure;

— Load at which the leak developed or 600,000 lb for 5 in and larger pipe, or 450,000 lb for pipe smaller than 5 in (whichever is less);

— Record of wellbore pressure, and operator closing pressure and hang-off load throughout the test;

— Diameter of test mandrel used; include diameter and length of external upset, if applicable.

4.7.3.10 PR2 Hang-off Test, Ram-type BOP

4.7.3.10.1 Purpose

NOTE 1 This test determines the ability of the fixed or variable ram assembly to maintain a 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and full rated working pressure seal while supporting drill-pipe loads.

NOTE 2 The test mandrel may or may not include external upset.

4.7.3.10.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

This test shall apply to 279 mm (11 in) and larger blowout preventers. Any hang-off test performed with a variable bore ram shall use drill pipe diameter sizes of the minimum and the maximum diameter designed for that ram.

The test joint shall have an 18° API simulated tool-joint in accordance with API 5DP.

The test protocol shall be as follows:

a) Raise the simulated tool-joint so that the 18° taper is immediately above the ram blocks. Close the ram on the pipe with the manufacturer's recommended closing pressure. Lower the pipe with the rams closed until the tool-joint lands on the ram assembly.

b) Perform a low wellbore pressure test at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 3 minutes after stabilization, examining for leaks.

c) Perform a high wellbore pressure test at the maximum rated working pressure of the preventer and hold for 3 minutes after stabilization, examining for leaks.

d) Bleed the wellbore pressure to zero psi, increase the hang-off load incrementally, and repeat Step b for each load increment until the minimum performance criteria of tables 20 and 21 are met.

e) Additionally, perform Steps a through c with the ram locking device engaged and zero closing pressure.

4.7.3.10.3 PR2 Hang-off Test Documentation, Ram-type BOP

Documentation shall include:

— The highest successful load increment before a leak developed.

— The ram and blowout preventer configurations used, including locking mechanism.

— A record of wellbore pressure, operator closing area and closing pressure, and hang-off load throughout the test;

— The diameter of the test mandrel used; include diameter and length of external upset, if applicable.

Any wear or deformation of the ram blocks, simulated tool joint, and the metal inserts of the ram packer shall be documented.

The inspection shall include:

— Nondestructive examination (NDE) of ram blocks in accordance with the manufacturer's written procedure;

— Hardness measurement of the ram packer metallic inserts (for VBRs);

NOTE Only required if hang-off load is applied to metallic inserts.

— Hardness measurement of ram blocks;

— Hardness measurement of the simulated tool joint;

4.7.3.11 PR1 Ram Access Test, Ram-type BOP

4.7.3.11.1 Purpose

NOTE This test determines the ability of the blowout preventer to undergo repeated ram and/or ram packer changes without affecting operational characteristics.

4.7.3.11.2 Protocol

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.

NOTE 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 the ram. Open access points to the extent required for ram removal.

b) Perform the manufacturer's recommended procedure for closing all ram-access points.

c) Repeat the above steps a total of 200 times. Every 20th time, pressure-test the BOP to rated working pressure for a minimum 3 minutes hold after pressure stabilization.

4.7.3.11.3 PR1 Ram Access Documentation, Ram-type BOP

Documentation shall include:

— The ram and blowout preventer 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.

4.7.3.12 PR 2 Ram Access Test, Ram-type BOP

4.7.3.12.1 Purpose

NOTE This test determines the ability of the blowout preventer to undergo repeated ram and/or ram packer changes without affecting operational characteristics.

4.7.3.12.2 Protocol

NOTE 1 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.

NOTE 2 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 the ram. Open access points to the extent required for ram removal.

b) Perform the manufacturer's recommended procedure for closing all ram-access points.

c) Repeat the above steps a total of 200 times. Every 20th time, pressure-test the BOP to rated working pressure for a minimum 3 minutes hold after pressure stabilization.

4.7.3.12.3 PR2 Ram Access Test Documentation, Ram-type BOP

Documentation shall include the

— The ram and blowout preventer 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.

4.7.3.13 PR1 Ram Locking Device Test, Ram-type BOP

4.7.3.13.1 Purpose

NOTE This test determines the ability of the blowout preventer's ram-locking device to maintain a wellbore pressure seal after removing the closing and/or locking pressure(s).

4.7.3.13.2 Protocol

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

A 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and full rated working pressure test shall be performed.

4.7.3.13.3 PR1 Ram Locking Device Documentation, Ram-type BOP

Documentation shall include:

— The ram and blowout preventer configurations used;

— Record of wellbore pressure and operator closing pressure throughout the test;

— The number of locking cycles obtained.

4.7.3.14 PR2 Ram Locking Device Test, Ram-type BOP

4.7.3.14.1 Purpose

NOTE This test determines the ability of the blowout preventer's ram-locking device to maintain a wellbore pressure seal after removing the closing and/or locking pressure(s).

4.7.3.14.2 Protocol

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

A 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and full rated working pressure tests shall be performed.

4.7.3.14.3 PR2 Ram Locking Device Documentation

Documentation shall include:

— The ram and blowout preventer configurations used;

— Record of wellbore pressure and operator closing pressure throughout the test;

— The number of locking cycles obtained.

4.7.3.15 PR1 and PR2 Low Temperature Design Validation, Ram-type BOP

4.7.3.15.1 Purpose

NOTE This test determines the ability of the nonmetallic seals and molded sealing assemblies used as pressure-controlling and/or pressure-containing parts to maintain a wellbore pressure seal after repeated closings and openings at the minimum rated temperature of the nonmetallic sealing components.

4.7.3.15.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

The test shall not be started until the 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. For PR2 testing, the test shall not be started until the BOP assembly and wellbore temperature is at or below the test temperature.

The test protocol shall be as follows:

a) Open the BOP and begin the cooling cycle. Continue the cooling until the test fluid temperature is reached and has stabilized.

b) Close and open the BOP up to seven times using the manufacturer's recommended operating pressure.

c) With test fluid at or below test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 3 minutes after pressure stabilization.

d) Apply the full rated working pressure of the BOP and hold for a minimum of 3 minutes after pressure stabilization for PR1, and a minimum of 10 minutes after pressure stabilization for PR2.

e) Bleed off the wellbore pressure.

f) Repeat steps b through e twice more, for a total of three pressure-test cycles.

4.7.3.15.3 PR1 and PR2 Low Temperature Design Validation Documentation, Ram-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, operator size and type, ram assembly);

— Record of wellbore pressure and operator closing pressure throughout the tests;

— Record of wellbore temperature throughout the test.

4.7.3.16 PR2 Continuous Operating Temperature Design Validation, Ram-type BOP

4.7.3.16.1 Purpose

NOTE 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 nonmetallic sealing components.

4.7.3.16.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

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 BOP and begin the heating cycle. Continue the heating until the test fluid temperature is reached and has stabilized.

b) Close and open the BOP three times using the manufacturer's recommended operating pressure.

c) With test fluid at or above test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 5 minutes after pressure stabilization.

d) Apply the full rated working pressure of the BOP and hold for a minimum of 10 minutes after pressure stabilization.

e) Bleed off the wellbore pressure and open the ram BOP.

f) Repeat steps b through e until the minimum acceptance criteria are met. See Tables 18, 20, 21, and 22.

4.7.3.16.3 PR2 Continuous Operating Temperature Test Documentation, Ram-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, operator size and type, ram assembly);

— Record of wellbore pressure and operator closing pressure throughout the tests;

— Record of wellbore temperature throughout the test.

4.7.3.17 PR1 and PR2 Extreme High Temperature Design Validation, Ram-type BOP

4.7.3.17.1 Purpose

NOTE This test determines the ability of the nonmetallic seals and molded sealing assemblies used as pressure-controlling and/or pressure-containing parts to maintain a wellbore pressure seal at the extreme temperature of the nonmetallic 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.

4.7.3.17.2 Protocol

NOTE When testing VBRs, the packer may be changed between tests on minimum and maximum pipe sizes.

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 BOP and begin the heating cycle. Continue the heating until the test fluid temperature is reached and has stabilized.

b) With the test fluid at or above test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 3 minutes after pressure stabilization.

c) Apply the full rated working pressure of the BOP and hold for a minimum of 60 minutes after pressure stabilization.

d) Bleed off the wellbore pressure.

4.7.3.17.3 PR1 and PR2 Extreme High Temperature Test Documentation, Ram-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, operator size and type, ram assembly);

— Record of wellbore pressure and operator closing pressure throughout the tests;

— Record of wellbore temperature throughout the test.

4.7.3.18 PR1 Test for Annular Sealing Characteristics, Annular BOP

4.7.3.18.1 Constant Wellbore Pressure Test

4.7.3.18.1.1 Purpose

NOTE This test determines the operator closing pressure required to maintain a wellbore pressure seal on a specified test mandrel as a function of wellbore pressures up to full rated working pressure of the blowout preventer.

4.7.3.18.1.2 Protocol

The test shall be conducted on the designated drill pipe sizes; see Table 26.

The test protocol shall be as follows:

a) Close the preventer using the manufacturer's recommended closing pressure.

b) Apply 3.45 MPa (500 psi) wellbore pressure.

c) Lower the closing pressure until a leak develops.

d) Bleed off the wellbore pressure and open the preventer.

e) Repeat steps a through d, increasing wellbore pressure in a minimum of 10 approximately equal pressure increments until wellbore pressure equals the rated working pressure of the preventer.

4.7.3.18.2 Constant Closing Pressure Test

4.7.3.18.2.1 Purpose

NOTE This test determines the maximum wellbore pressure obtainable, up to the rated working pressure, for a given closing pressure when closing on a test mandrel.

4.7.3.18.2.2 Protocol

The test shall be conducted on the designated drill pipe sizes; see Table 26.

The test protocol shall be as follows:

a) Apply 3.45 MPa (500 psi) closing pressure.

b) Apply increasing wellbore pressure until a leak occurs or wellbore pressure equals the rated working pressure of the preventer.

c) Bleed off wellbore pressure and open the preventer.

d) Repeat steps a through c, increasing closing pressure 0.69 MPa (100 psi) each time until closing pressure reaches the level recommended by the manufacturer.

4.7.3.18.3 PR1 Full Closure Pressure Test, Open Hole

4.7.3.18.3.1 Purpose

NOTE 1 This test determines the operator closing pressure required to seal on the open hole at one-half of rated working pressure.

The maximum number of flexing cycles required to achieve full closure at room temperature shall be specified in the manufacturer's written procedure.

NOTE 2 This test is only necessary for annular packing elements rated for complete shut-off (CSO) operation.

4.7.3.18.3.2 Protocol

This test shall be conducted without drill pipe in the wellbore.

The test protocol shall be as follows:

a) Close the preventer using the pressure recommended by the manufacturer.

b) Apply wellbore pressure of 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 3 minutes. If leakage occurs, increase the closing pressure as needed. Do not exceed the manufacturer’s recommended maximum operating pressure.

c) Following a successful low-pressure test, raise wellbore pressure to one-half the rated working pressure of BOP. Hold the pressure for 3 minutes. If leakage occurs, increase closing pressure as needed. Do not exceed the manufacturer’s recommended maximum operating pressure.

4.7.3.18.4 PR1 Sealing Characteristics Documentation, Annular BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, annular packer assembly, test mandrel);

— Record of wellbore pressure vs. operator closing pressure throughout each test;

— The number of flexing cycles required to achieve full closure at room temperature for the “Open Hole Constant Closing” pressure test;

— The closing pressure required to maintain a wellbore pressure seal on the specified test mandrel as a function of wellbore pressures up to full rated working pressure of the blowout preventer;

— The maximum wellbore pressure obtainable, up to the rated working pressure, for a given closing pressure when closing on the specified test mandrel;

— The closing pressure required to seal on the open hole at one-half of rated working pressure.

4.7.3.19 PR2 Test for Sealing Characteristics, Annular BOP

4.7.3.19.1 PR2 Constant Wellbore Pressure Test

4.7.3.19.1.1 Purpose

NOTE This test determines the operator closing pressure required to maintain a wellbore pressure seal on a specified test mandrel as a function of wellbore pressures up to full rated working pressure of the blowout preventer.

4.7.3.19.1.2 Protocol

The test shall be conducted on the designated drill pipe sizes; see Table 26.

The test protocol shall be as follows:

a) Close the preventer using the manufacturer's recommended closing pressure.

b) Apply 3.45 MPa (500 psi) wellbore pressure.

c) Lower the closing pressure in 100 psi step reductions and hold for 3 minutes at each pressure value until a leak develops.

d) Bleed off the wellbore pressure and open the preventer.

e) Repeat Steps a through d, increasing wellbore pressure incrementally until wellbore pressure equals the rated working pressure of the preventer. The wellbore pressure increment shall be determined to result in a minimum of five approximately equally-spaced data points.

4.7.3.19.2 PR2 Constant Closing Pressure Test

4.7.3.19.2.1 Purpose

NOTE This test determines the maximum wellbore pressure obtainable, up to the rated working pressure, for a given operator closing pressure on a test mandrel.

4.7.3.19.2.2 Protocol

The test shall be conducted on the designated drill pipe sizes; see Table 26.

The test protocol shall be as follows:

a) Apply 3.45 MPa (500 psi) closing pressure.

b) Apply increasing wellbore pressure until a leak occurs or wellbore pressure equals the rated working pressure of the preventer.

c) Bleed off the wellbore pressure and open the preventer.

d) Repeat steps a through c, increasing closing pressure 0.69 MPa (100 psi) each time until closing pressure reaches the level recommended by the manufacturer or until the rated working pressure of the preventer is obtained.

4.7.3.19.3 PR2 Full Closure Pressure Test, Open Hole

4.7.3.19.3.1 Purpose

NOTE 1 This test determines the operator closing pressure required to seal on the open hole at one-half of rated working pressure.

The maximum number of flexing cycles required to achieve full closure at room temperature shall be specified in the manufacturer's written procedure.

NOTE 2 This test is only necessary for annular packing elements rated for complete shut-off (CSO) operation.

4.7.3.19.3.2 Protocol

This test shall be conducted without drill pipe in the wellbore.

The test protocol shall be as follows:

a) Close the preventer using the pressure recommended by the manufacturer.

b) Apply wellbore pressure of 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and hold for 3 minutes. If leakage occurs, increase the closing pressure as needed. Do not exceed the manufacturer’s recommended maximum operating pressure.

c) Following a successful low-pressure test, raise wellbore pressure to one-half the rated working pressure of BOP. Hold the pressure for 3 minutes. If leakage occurs, increase closing pressure as needed. Do not exceed the manufacturer’s recommended maximum operating pressure.

4.7.3.19.4 PR2 Sealing Characteristics Documentation, Annular BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, annular packer assembly, test mandrel);

— Record of wellbore pressure vs. operator closing pressure throughout each test;

— The number of flexing cycles required to achieve full closure at room temperature for the “Open Hole Constant Closing” pressure test;

— The closing pressure required to maintain a wellbore pressure seal on the specified test mandrel as a function of wellbore pressures up to full rated working pressure of the blowout preventer;

— The maximum wellbore pressure obtainable, up to the rated working pressure, for a given closing pressure when closing on the specified test mandrel.

— The closing pressure required to seal on the open hole at one-half of rated working pressure.

4.7.3.20 PR2 Extended Range Operational Characteristics, Annular BOP

4.7.3.20.1 Purpose

NOTE 1 This test determines the ability of an annular packing unit to maintain a seal on pipe sizes above and below the rated range, at wellbore pressures less than or equal to rated working pressure. Data collected from this test can be used to report operational characteristics at parameters outside of the full rated working pressure range.

NOTE 2 The rated range is the range of tubulars that can be sealed up to the full rated working pressure of the BOP and meet the minimum fatigue characteristics within that range.

NOTE 3 The extended range is the range outside the rated range in which the manufacturer defines the operational characteristics based on test data. This range may not be extrapolated outside the bounds of the test data.

The pressure rating of an untested tubular size shall be equal to the lowest rating of the successful pressure tests above and below that tubular size.

End user shall consider the mechanical properties of the tubulars (e.g. collapse rating, when using the annular).

4.7.3.20.2 Protocol

The test shall be conducted on tubular sizes (as specified by the manufacturer) that are in the extended range.

The test protocol shall be as follows:

a) Install the test mandrel in annular BOP.

b) Close and open the packing unit seven times using the manufacturer's recommended closing pressure. On every seventh closure, pressure test the packing unit at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and the wellbore pressure as specified by the manufacturer at less than or equal to the rated working pressure of the BOP. Test pressures shall each be stabilized and held for a minimum period of 3 minutes. Do not exceed the manufacturer’s recommended maximum operating pressure.

c) On every 20th pressure-test cycle, measure the ID of the packing element when the operating piston reaches the fully open position. Then, continue to measure the ID of the packer at 5-minute intervals until the packer ID reaches the bore size of the BOP or until 30 minutes has elapsed. Record the ID.

d) Repeat steps a through c until the packing unit fails a pressure test or until 364 openings and closings have been completed (52 pressure tests).

4.7.3.20.3 Extended-range Operational Characteristics, Documentation

Documentation shall include:

— Record of equipment used (e.g. pipe sizes tested, BOP size/pressure rating/model);

— Record of wellbore pressure and operator closing pressure throughout the test on each mandrel size tested. If this test is not performed, the extended-range rating shall be reported as 0 psi;

— Record of wellbore fluid temperature during test;

— A graph of the packing unit inside diameter (ID) after every 20th pressure cycle vs. time up to 30 minutes.

— The number of successful closures and pressure cycles attained.

4.7.3.21 PR1 Fatigue Test, Annular BOP

4.7.3.21.1 Purpose

NOTE 1 This test determines the ability of an annular packing unit to maintain a seal throughout repeated closings and openings.

NOTE 2 This test simulates closing and opening the blowout preventer once per day and wellbore pressure testing at full rated working pressure once per week comparable to one year of service.

4.7.3.21.2 Protocol

The test protocol shall be as follows:

a) Install the test mandrel in annular BOP for packing unit tests. The test shall be conducted on the designated test mandrel pipe sizes in accordance with Table 26.

b) Close and open the packing unit seven times using the manufacturer's recommended closing pressure. On every seventh closure, pressure test the packing unit at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and the full rated working pressure of the BOP. Test pressures shall each be stabilized and held for a minimum period of 3 minutes.

c) On every 20th pressure-test cycle, measure the ID of the packing element when the operating piston reaches the fully open position. Then, continue to measure the ID of the packer at 5-minute intervals until the packer ID reaches the bore size of the BOP or until 30 minutes has elapsed. Record the ID.

d) Repeat Steps b and c until the packing unit fails a pressure test or until 364 openings and closings have been completed (52 pressure tests).

4.7.3.21.3 PR1 Fatigue Test Documentation, Annular BOP

Fatigue test documentation shall include:

— Record of equipment used (e.g. BOP size/pressure rating/model);

— A graph of the packing unit inside diameter (ID) after every 20th pressure cycle vs. time up to 30 minutes;

— The number of successful closures and pressure cycles attained;
— Record of wellbore pressure and operator closing pressure.

4.7.3.22 PR2 Fatigue Test, Annular BOP

4.7.3.22.1 Purpose

NOTE 1 This test determines the ability of an annular packing unit to maintain a seal throughout repeated closings and openings.

NOTE 2 This test simulates closing and opening the blowout preventer once per day and wellbore pressure testing at full rated working pressure once per week up to one year of service.

4.7.3.22.2 Protocol

The test protocol shall be as follows:

a) Install test mandrel in annular BOP for packing unit tests. The test shall be conducted on the designated test mandrel pipe sizes in accordance with Table 26.

b) Close and open the packing unit seven times using the manufacturer's recommended closing pressure. On every seventh closure, pressure test the packing unit at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and the full rated working pressure of the BOP. Test pressures shall each be stabilized and held for a minimum of 3 minutes.

c) On every 20th pressure test cycle, measure the ID of the packing element when the operating piston reaches the fully open position. Then, continue to measure the ID of the packer at 5-minute intervals until the packer ID reaches the bore size of the BOP or until 30 minutes has elapsed. Record the ID.

d) Repeat Steps a through c until the packing unit fails a pressure test or until 364 openings and closings have been completed (52 pressure tests).

NOTE Annular BOP fatigue minimum pressure cycle information is contained on Table 25.

4.7.3.22.3 PR2 Fatigue Test Documentation, Annular BOP

Fatigue test documentation shall include:

— Record of equipment used (e.g. BOP size/pressure rating/model).

— A graph of the packing unit inside diameter (ID) after every 20th pressure cycle vs. time up to 30 minutes.

— The number of successful closures and pressure cycles attained.

— Record of wellbore pressure and operator closing pressure.

— Document any observed wear following the test.

4.7.3.23 PR1 and PR2 Packer Access Test, Annular BOP

4.7.3.23.1 Purpose

NOTE This test determines the ability of the blowout preventer to undergo repeated packer changes without affecting operational characteristics.

4.7.3.23.2 Protocol

The test shall be conducted on the designated drill pipe sizes; see Table 26. A PR2 test may use the PR1 test mandrel size.

This test shall be accomplished by obtaining access to the packing unit and performing a wellbore pressure test to the rated working pressure at every 20th packing unit access.

The test protocol shall be as follows:

a) Perform the manufacturer’s recommended procedures for removing closure as required for packer access.

b) Perform the manufacturer’s recommended procedures, including maintenance and replacement parts, for closing the packer access closure.

c) Repeat Steps a and b to failure or a maximum of 200 times. Every 20th packing unit access, pressure test the BOP to the rated working pressure for a 3-minute holding period.

4.7.3.23.3 PR1 and PR2 Packer Access Test Documentation, Annular BOP

Packer access test documentation shall include:

— Record of equipment used (e.g. BOP size/pressure rating/model);

— The number of successful packer access cycles to failure, or 200 (see Table 25 for performance criteria), whichever is attained first;

— Record of wellbore pressure and operator closing pressure.

4.7.3.24 PR1 Stripping Life Test, Annular BOP

4.7.3.24.1 Purpose

NOTE This test determines the ability of the annular packing unit to maintain control of wellbore pressure while stripping drill pipe and tool joints through the closed packing unit without exceeding an average leak rate of 3.8 l/minute (1 gal/minute).

4.7.3.24.2 Protocol

The test protocol shall be as follows:

For 279 mm (11 in) and larger BOPs, install a 127 mm (5 in) OD test mandrel with a simulated 18° API 6 $^{5}/_{8}$-inch tool-joint profile; for 228 mm (in) and smaller, install an 88.9 mm (3 $^{1}/_{2}$ in) OD test mandrel with a simulated 18° API 5-inch tool-joint profile.

a) Close the BOP with the manufacturer's recommended closing pressure. Apply 6.89 MPa (1,000 psi) wellbore pressure. Reduce the closing pressure until the preventer leak rate is less than 3.8 l/minute (1 gal/minute) (to wet the test mandrel wall).

b) Reciprocate the test mandrel at a minimum of 1,500 mm (5 ft) in each direction and at approximately four cycles per minute. A stripping cycle consists of the tool joint passing through the element twice, once in each direction. Wellbore pressure should vary no more than ±10% during the stripping operation. Increase closing pressure as necessary to maintain a leak rate below 3.8 l/minute (1 gal/minute). Continue testing until a leak rate of 3.8 l/minute (1 gal/minute) develops at the manufacturer’s recommended closing pressure, or 2,500 stripping cycles have been completed.

c) Document any wear on all packer elastomers.

4.7.3.24.3 PR1 Stripping Life Test Documentation, Annular BOP

Documentation shall include:

— Record of equipment used (e.g. BOP size/pressure rating/model);

— Wellbore pressure used during the test;

— Record of reciprocating speed;

— Equivalent length of pipe and number of stripping cycles obtained, or 2,500 stripping cycles, whichever is attained first;

— Closing pressure used during the test;

— Documentation of any wear on elastomers.

4.7.3.25 PR2 Stripping Life Test, Annular BOP

4.7.3.25.1 Purpose

NOTE This test determines the ability of the annular packing unit to maintain control of wellbore pressure while stripping drill pipe and tool joints through the closed packing unit without exceeding an average leak rate of 3.8 l/minute (1 gal/minute).

4.7.3.25.2 Protocol

The test protocol shall be as follows:

For 279 mm (11 in) and larger BOPs, install a test mandrel with an API 5DP 5 19.50 S IEU NC 50 tool-joint profile. For 228 mm (9 in) and smaller BOPs, install a test mandrel with an API 5DP 3 $^{1}/_{2}$ 15.50 G EU NC 38 tool-joint profile.

NOTE Tool-joint profiles may be simulated.

Annular packing units designed for larger drill pipe sizes than specified in Table 26 shall be tested for the largest drill pipe/tool-joint OD size for which the unit was designed.

a) Orient the taper of the tool-joint profile to simulate pin-down installation.

b) Close the BOP with the manufacturer's recommended closing pressure. Apply 6.89 MPa (1,000 psi) wellbore pressure. Reduce the closing pressure until the preventer leak rate is less than 3.8 l/min (1.0 gal/minute) (to wet the test mandrel wall).

c) Reciprocate the test mandrel at a minimum of 1,500 mm (5 ft) in each direction and at approximately four cycles per minute. A stripping cycle consists of the tool joint passing through the element twice, once in each direction. Wellbore pressure should vary no more than ±10% during the stripping operation. Increase closing pressure, as necessary to maintain a leak rate below 3.8 l/minute (1 gal/minute). Continue testing until BOP is unable to maintain a leak rate of less than 3.8 l/minute (1 gal/minute) up to the manufacturer’s maximum closing pressure, or until 2,500 stripping cycles have been completed. The minimum performance criteria shall be achieved prior to exceeding the recommended closing pressure.

4.7.3.25.3 PR2 Stripping Life Test Documentation, Annular BOP

Documentation shall include:

— Record of equipment used (e.g. BOP size/pressure rating/model);

— Wellbore pressure and temperature used during the test;

— Record of reciprocating speed;

— The number of tool joints stripped;

— Closing pressure used during the test;

— Damage to the test mandrel, including when damage was initially observed;

— The number of stripping cycles, or 2,500 stripping cycles, whichever is attained first;

— Documentation of any wear on elastomers.

4.7.3.26 PR1 Low Temperature Design Validation, Annular Type BOP

4.7.3.26.1 Purpose

NOTE This test determines the ability of the nonmetallic seals and molded sealing assemblies used as pressure-controlling and or pressure-containing parts to maintain a wellbore pressure seal after repeated closings and

openings at the minimum rated temperature and rated working pressure of the nonmetallic sealing components and molded sealing assemblies.

4.7.3.26.2 Protocol

The test shall not be started until the wellbore fluid is at or below the test temperature. The wellbore fluid below the annular packing unit shall be maintained at or below the test temperature for the duration of the hold times.

Packing unit tests for both PR1 and PR2 shall use the test mandrel size designated for PR1 in Table 26.

The test protocol shall be as follows:

a) Install test mandrel in annular BOP for packing unit tests.

b) Begin the cooling cycle and continue the cooling until the wellbore fluid temperature is reached and has stabilized.

c) Close and open the BOP seven times using the manufacturer's recommended operating pressure.

d) With wellbore fluid at or below test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 3 minutes after pressure stabilization.

e) Apply the full rated working pressure of the BOP and hold for a minimum of 3 minutes after pressure stabilization.

f) Bleed off wellbore pressure and open annular BOP.

g) Repeat Steps b through f twice more, for a total three pressure test cycles.

4.7.3.26.3 PR1 Low-Temperature Design Validation Documentation, Annular-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, size and type, nonmetallic seals, and molded sealing assemblies).

— Record of wellbore pressure and operator closing pressure throughout the tests.

— Record of wellbore temperature throughout the test.

4.7.3.27 PR2 Low-Temperature Design Validation, Annular Type BOP

4.7.3.27.1 Purpose

NOTE This test determines the ability of the nonmetallic seals and molded sealing assemblies used as pressure controlling and or pressure-containing parts to maintain a wellbore pressure seal after repeated closings and openings at the minimum rated temperature and rated working pressure of the nonmetallic sealing components and molded sealing assemblies.

4.7.3.27.2 Protocol, Annular Packing Unit Tests

The test shall not be started until the BOP assembly and wellbore fluid is at or below the test temperature. The BOP assembly and wellbore fluid shall be maintained at or below the test temperature for the duration of the hold times.

Packing unit tests shall use the test mandrel size designated for PR1 in Table 26.

Other nonmetallic seals used as pressure-containing parts shall be tested in accordance with equipment manufacturer's written procedures.

The test protocol shall be as follows:

a) Install test mandrel in annular BOP for packing unit tests.

b) Begin the cooling cycle and continue the cooling until the BOP assembly and wellbore fluid temperature is reached and has stabilized.

c) Close and open the BOP seven times using the manufacturer's recommended operating pressure.

d) With BOP assembly and wellbore fluid at or below test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 10 minutes after pressure stabilization.

e) Apply the full rated working pressure of the BOP and hold for a minimum of 10 minutes after pressure stabilization.

f) Bleed off wellbore pressure and open annular BOP.

g) Repeat steps b through f, twice more for a total three pressure test cycles.

4.7.3.27.3 PR2 Low-Temperature Design Validation Documentation, Annular-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, size and type, nonmetallic seals, and molded sealing assemblies).

— Record of wellbore pressure and operator closing pressure throughout the tests.

— Record of wellbore temperature throughout the test.

4.7.3.28 PR2 Continuous Operating Temperature Design Validation, Annular-type BOP

4.7.3.28.1 Purpose

NOTE This test determines the ability of the nonmetallic seals and molded sealing assemblies used as pressure controlling and or pressure-containing parts to maintain a wellbore pressure seal after repeated closings and openings at the continuous elevated rated temperature and rated working pressure of the nonmetallic seals and molded sealing assemblies.

4.7.3.28.2 Protocol

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

Packing unit tests for PR2 shall use the test mandrel size designated for PR1 in Table 26.

The test protocol shall be as follows:

a) Install test mandrel in annular BOP for packing unit tests.

b) Begin the heating cycle and continue the heating until the wellbore fluid temperature is reached and has stabilized.

c) Close and open the BOP three times using the manufacturer's recommended operating pressure.

d) With wellbore fluid at or above test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 5 minutes after pressure stabilization.

e) Apply the full rated working pressure of the BOP and hold for a minimum of 10 minutes after pressure stabilization.

f) Bleed off wellbore pressure and open annular BOP.

g) Repeat steps b through f until the minimum acceptance criteria are met. See Table 25 and Table 27.

4.7.3.28.3 PR2 Continuous Operating Temperature Test Documentation, Annular-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, size and type, nonmetallic seals, and molded sealing assemblies).

— Record of wellbore pressure and operator closing pressure throughout the tests.

— Record of wellbore temperature throughout the test.

4.7.3.29 PR1 and PR2 Extreme High-Temperature Design Validation, Annular-type BOP

4.7.3.29.1 Purpose

NOTE This test determines the ability of the of the nonmetallic seals and molded sealing assemblies used as pressure-controlling and or pressure-containing parts to maintain a wellbore pressure seal at the extreme rated temperature and rated working pressure of the nonmetallic seals and molded sealing assemblies.

4.7.3.29.2 Protocol

NOTE The test shall not be started until the wellbore fluid is at or above the test temperature.

The wellbore fluid below the annular packing unit shall be maintained at or above the test temperature for the duration of the hold times.

Packing unit tests for both PR1 and PR2 shall use the test mandrel size designated for PR1 in Table 26.

The test protocol shall be as follows:

a) Install test mandrel in annular BOP for packing unit tests.

b) Begin the heating cycle and continue heating until the test fluid temperature is reached and has stabilized.

c) Apply the full rated working pressure of the BOP and hold for a minimum of 60 minutes after pressure stabilization.

d) Bleed off wellbore pressure.

4.7.3.29.3 PR1 and PR2 Extreme High-Temperature Test Documentation, Annular-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, size and type, nonmetallic seals, and molded sealing assemblies).

— Record of wellbore pressure and operator closing pressure throughout the tests.

— Record of wellbore temperature throughout the test.

4.7.3.30 PR2 Low-temperature Drift Characteristics, Annular Type BOP

4.7.3.30.1 Purpose

NOTE This test determines the drift characteristics of annular packing units after a wellbore pressure test and repeated closings and openings at various temperatures until the minimum rated temperature is reached.

4.7.3.30.2 Protocol

The test shall not be started until the BOP assembly and wellbore fluid is at or below the test temperature. The BOP assembly and wellbore fluid shall be maintained at or below the test temperature for the duration of the hold times.

This test shall be performed at the minimum rated temperature. If the annular packing element will not drift at the minimum rated temperature within 120 minutes, this test shall be repeated at manufacturer's specified temperatures until drift is achieved.

Packing unit tests for PR2 shall use the test mandrel size designated for PR1 in Table 26.

The drift mandrel shall be in accordance with specifications listed in 7.5.7.4.1.

The test protocol shall be as follows:

a) Install test mandrel in annular BOP.

b) Begin the cooling cycle and continue the cooling until the BOP assembly and wellbore fluid temperature is reached and has stabilized.

c) Close and open the BOP seven times using the manufacturer's recommended operating pressure.

d) With wellbore fluid at or below test temperature, close the BOP and apply 1.4 MPa to 2.1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 5 minutes after pressure stabilization.

e) Apply the full rated working pressure of the BOP and hold for a minimum of 10 minutes after pressure stabilization.

f) Bleed off wellbore pressure and remove test mandrel.

g) Pass a drift mandrel through the bore of the assembly after all pressure testing until the drift mandrel passes through the bore without being forced. Record the time required for the drift mandrel to pass through the bore.

h) If the drift mandrel does not pass through the bore of the assembly within 120 minutes after all pressure testing is complete (e.g. after BOP operator is opened), measure the ID of the packing unit.

i) Repeat Steps a through h for each temperature tested.

4.7.3.30.3 PR2 Low-temperature Drift Characteristics Test Documentation, Annular-type BOP

Documentation shall include:

— Record of equipment used (e.g. BOP model, size and type, nonmetallic seals, and molded sealing assemblies).

— Record of wellbore pressure and operator closing pressure.

— Record of wellbore temperature and record the ID of the annular packing unit after step h.

— Record of drift time and temperature if successful.

4.7.3.31 Locking Mechanism Test, Hydraulic Connector

4.7.3.31.1 Purpose

NOTE This test verifies the operation of the locking mechanisms at rated working pressure and establishes the lock/unlock pressure relationship.

The test shall be conducted using an assembled connector with a test stump.

The functional testing, which verifies operation of the locking mechanism to the manufacturer's written design specifications, shall be documented.

4.7.3.31.2 Protocol

The test protocol shall be as follows:

a) Install connector on the appropriate test stump.

b) Lock connector using the manufacturer's maximum lock pressure.

c) Determine the pressure required to unlock the connector with the primary unlock system. Record required pressure.

d) Repeat Steps b and c with 67 % of manufacturer's lock pressure.

e) Repeat Steps b and c with 33 % of manufacturer's lock pressure.

f) Repeat Steps b through e twice more.

g) If connector is equipped with a secondary unlock system, repeat Steps b through f using only the secondary unlock system.

h) Inspect and document any wear of locking mechanism.

4.7.3.31.3 Documentation

Documentation shall include:

— Record of equipment used (e.g. hydraulic connector model, size and type, and gasket type)

— Record of locking pressure and corresponding unlocking pressures

4.7.3.32 Sealing Mechanism Test, Hydraulic Connector

4.7.3.32.1 Purpose

This test shall verify the operation of the wellbore sealing mechanics at 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and rated working pressure and shall demonstrate the pressure integrity of the wellbore seal.

This test shall be conducted using an assembled connector with a blind upper connection and a test stump, mandrel, or riser/LMRP mandrel.

4.7.3.32.2 Protocol

The test protocol shall be as follows:

a) Install the connector on the appropriate test stump.

b) Lock the connector to the stump using the manufacturer's recommended locking pressure, perform a 1.4 MPa to 2.1 MPa (200 psi to 300 psi) and a full rated working pressure test for a minimum of 3 minutes, reduce the wellbore pressure to zero, and unlock the connector. Repeat this for five cycles.

c) After the fifth cycle, lift the connector off of the test stump after unlocking it, then return it to the stump.

d) On every sixth cycle, lock the connector and perform the wellbore pressure tests with the locking pressure removed.

e) Repeat Steps b through d until the connector fails to seal or a total of 24 pressure cycles have been completed.

f) Document the load (over pull and connector weight) required to remove the connector from the stump.

g) If the gasket profile contains a secondary sealing surface, repeat the sealing mechanism test using the secondary sealing surface of the gasket.

4.7.3.33 Combined Loading, Hydraulic Connector

Qualification testing of the connector shall be performed at a minimum starting at zero psi and continuing in 5,000 psi increments to the rated pressure taken from the capacity chart (Figure 8). The same conditions/assumptions (preload, bending, tension/compression, pressure end-load, etc.) as used during the capacity chart generation shall be used in the test.

It is recommended that the test be performed for:

— Rated Capacity Chart (0.67 x yield or design factor = 1.5)

— Extreme Capacity Chart (0.8 x yield or design factor = 1.25)

— Survival Capacity Chart (1 x yield or design factor = 1)

At a minimum, the test shall be performed at survival conditions.

Pre-test dimensional inspection of all critical areas shall be done.

After each test series (rated, extreme, survival), the connector shall be disassembled and a post-test dimensional inspection shall be performed. Photographs shall be taken and documented in the test report.

Strain gages and linear variable displacement transformer (LVDT) can be used to determine stresses and hub separation in critical areas.

Hub separation observed during static load testing with pressure and associated pressure end-load should be measured and reported. The location point of the hub face separation pattern around the circumference should be reported. Hub face separation may be measured using the LVDT.

Acceptance criteria shall be zero leakage and within acceptable stress levels for each load case.

NOTE Elastic, elastic-plastic, or other verification analysis methods may be used. The verification analysis method is left up to the manufacturer as long as it is validated with testing.

4.7.3.34 Gasket Test, Hydraulic Connector

The connector gasket test shall be performed per API 6A, Annex F, but the acceptance criterion shall be in accordance with 4.7.1.

NOTE Gasket qualification may be performed in a test fixture that simulates the connector performance.

4.8 PR1 Operating Manual Requirements

The manufacturer shall prepare and have available an operating manual for each model ram or annular-type blowout preventer or hydraulic connector manufactured in accordance with this standard. The operating manual shall contain the following information at a minimum:

a) operation and installation instructions;

b) physical data, including weight, center of gravity, and overall dimensions;

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 that includes flange makeup procedure, requirements for lubricant, torque, tightening pattern, percentage increments for torque, etc.;

f) parts information, including a recommended spares list;

g) storage information;

h) operational characteristics summary, as applicable:

1) sealing characteristics test;

2) fatigue test;

3) stripping life test;

4) hang-off test (include tool-joint description);

5) shear ram test;

6) ram locking device test;

7) ram/packer access test;

8) locking mechanism test;

9) BOP temperature rating;

10) ram assembly temperature rating;

11) external pressure differential capacity (psid) of all proprietary wellbore wetted seals utilized in the equipment. This applies to BOPs and hydraulic connectors utilized in subsea applications;

12) connector load capacity chart.

4.9 PR2 Operating Manual Requirements

The manufacturer shall prepare and have available an operating manual for each model ram or annular-type blowout preventer or hydraulic connector manufactured in accordance with this standard. The operating manual shall contain the following information at a minimum:

a) operation and installation instructions;

b) physical data, including weight, center of gravity, and overall dimensions;

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, including flange makeup procedure that includes requirements for lubricant, torque, tightening pattern, percentage increments for torque, etc.;

f) parts information, including a recommended spares list;

g) storage information;

h) operational characteristics summary, as applicable:

1) sealing characteristics test:

i) operating pressure versus wellbore pressure for specific pipe size (annular BOP only);

ii) MOPFLPS (ram BOP only);

iii) operating range (annular BOP only);

iv) extended-range wellbore and operating pressure maximums (annular BOP).

2) fatigue test;

3) stripping life test:

i) feet of pipe/tool-joint count;

ii) mandrel size tested;

iii) tool-joint description (annular BOP only).

4) hang-off test:

i) tool-joint description;

ii) hang-off load.

5) shear ram test:

i) diametrical shear rating—shear sample specifications;

ii) shear side load rating—shear sample specifications.

6) ram locking device test;

7) ram/packer access test;

8) locking mechanism test;

9) BOP temperature rating;

10) ram assembly temperature rating;

11) external pressure differential capacity (psid) of all proprietary wellbore wetted seals utilized in the equipment;

NOTE This applies to BOPs and connectors utilized in subsea applications.

12) Connector Capacity Chart.

i) recommended inspection of certain components—including NDE, visual inspection, dimensional inspection, and other inspections—as deemed appropriate by the manufacturer. The components shall include shear blades, bonnet bolts (or other bonnet/door-locking devices), ram cavities, and ram blocks, along with other components as deemed appropriate by the manufacturer.

4.10 Technical Data Sheet

The manufacturer shall prepare and provide a technical data sheet for each model ram or annular-type blowout preventer or hydraulic connector, blowout preventer ram, or annular packing element manufactured in accordance with this standard. The technical data sheet shall contain the following applicable information at a minimum:

a) part number;

b) performance requirement level;

c) rated working pressure(s);

d) operating ranges (pressures and diameters);

e) closing pressure to effect a wellbore seal at rated working pressure of BOP for available operators;

f) MOPFLPS pressure (for ram assemblies and annular packing elements);

g) temperature ranges;

h) elastomer type (for ram assemblies and annular packing elements);

i) qualification test results (e.g., hang-off rating, fatigue performance (including total number of cycles and cycles at initial operating pressure), side load capacity, diametrical offset shearing test results, etc. (if applicable for ram assemblies and annular packing elements);

j) size and weight;

k) any additional pertinent information.

5 Material Requirements

5.1 General

NOTE This section describes the material performance, processing, and compositional requirements for pressure-containing or pressure-controlling parts.

Other parts shall be made of materials that satisfy the design requirements in Section 4 when assembled into equipment named in this specification. Metallic materials shall meet the requirements of NACE MR0175/ISO 15156.

5.2 Written Specifications

5.2.1 Metallic Parts

A written material specification shall be required for all metallic pressure-containing and pressure-controlling parts. The manufacturer's written specified requirements for metallic materials shall define the following:

a) material composition with tolerance;

b) material qualification;

c) allowable melting practice(s);

d) forming practice(s);

e) heat treatment procedure, including cycle time and temperature with tolerances, heat treating equipment and cooling media, heating and cooling requirements;

f) NDE requirements;

g) mechanical property requirements;

h) weld repair requirements;

i) material traceability;

j) furnace calibrations and certification.

5.2.2 Nonmetallic Parts

Each manufacturer shall have written specifications for all elastomeric materials used in the production of drill-through equipment. These specifications shall include the following physical tests and limits for acceptance and control:

a) hardness in accordance with ASTM D2240 or ASTM D1415;

b) tensile and elongation properties in accordance with ASTM D412 or ASTM D1414;

c) compression set in accordance with ASTM D395 or ASTM D1414;

d) immersion (fluid compatibility) testing in accordance with ASTM D471 or ASTM D1414.

1) test liquid, temperature, and the duration of the test shall be defined;

2) test shall be performed at or above the extreme temperature rating of the nonmetallic sealing components in which the elastomeric material is used, per Table 4.

5.3 Pressure-containing parts

5.3.1 Property requirements

Pressure-containing parts shall be manufactured from materials as specified by the manufacturer that meet the requirements of Table 29 and Table 30.

Charpy V-notch impact testing shall conform to 5.3.4.2.

Table 29—Material Property Requirements for Metallic Pressure-Containing Parts

Material Designation	Yield Strength 0.2 % Offset min.		Tensile Strength min.		Elongation in 50 mm min.	Reduction of Area min.
	MPa	(psi)	MPa	(psi)	%	%
36K	248	(36,000)	483	(70,000)	21	none specified
45K	310	(45,000)	483	(70,000)	19	32
60K	414	(60,000)	586	(85,000)	18	35
75K	517	(75,000)	655	(95,000)	18	35
Non-standard Materials	As specified	As specified	As specified	As specified	15	20
NOTE Information on strength of materials at elevated temperatures is found in API 6A and API TR 6MET.						

Table 30—Material Applications for Metallic Pressure-Containing Parts

Part	Rated Working Pressure							
	6.9 MPa (1,000 psi)	13.8 MPa (2,000 psi)	20.7 MPa (3,000 psi)	34.5 MPa (5,000 psi)	69.0 MPa (10,000 psi)	103.5 MPa (15,000 psi)	138.0 MPa (20,000, psi)	172.4 MPa (25,000, psi)
Body	36K, 45K, 60K, 75K					45K, 60K, 75K	60K, 75K	60K, 75K
End Connections	60K					75K		
Blind Flanges	60K					75K		
Blind Hubs	60K					75K		
NOTE Non-standard materials may be used that have a yield strength that is not less than that of the lowest-strength standard material permitted for the applications above.								

5.3.2 Processing

5.3.2.1 Melting, Casting, and Hot Working

5.3.2.1.1 Melting Practices

The manufacturer shall select and specify the melting practices for all materials for pressure-containing parts.

5.3.2.1.2 Casting Practices

The materials manufacturer shall document foundry practices that establish limits for sand control, core-making, rigging, and melting.

5.3.2.1.3 Hot-working Practices

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

5.3.2.2 Heat Treating

All heat-treatment operations shall be performed using equipment qualified in accordance with the requirements specified by the manufacturer and the requirements as specified in Annex B.

Temperature and times for heat treatment shall be determined in accordance with the manufacturer's approved written specification. The number and location of both part and environmental thermocouples (with controlling and monitoring designations) shall be clearly identified. Thermocouples attached to the parts shall be used as controlling thermocouples. A minimum of two part thermocouples are required per heat treat batch. The soak time shall begin once all controlling thermocouples are within +/- 14°C (+/- 25 °F) of the qualified temperature set point. Temperature ramp rates and temperature tolerances shall be defined for the heat treat cycle.

Furnace loading shall be performed to ensure that the presence of one part does not adversely affect the heat-treating response of any other part. The use of supporting or separating equipment may be required to ensure uniform and adequate heating in the qualified heating zone of the furnace, or to support the running of part thermocouples.

Quenching shall be performed in accordance with the manufacturer's written specifications.

a) Water quenching

The temperature of the water or water-based quenching medium shall not exceed 38 °C (100 °F) at the start of the quench, nor exceed 49 °C (120 °F) at the completion of the quench.

b) Oil quenching/polymer

The temperature of any oil/polymer-quenching medium shall be greater than 38 °C (100 °F) at the start of the quench.

The heat-treat facility shall have a procedure to control and maintain the quality of the quenching media. The procedure shall identify controls of chemistry and purity. Process conditions for the use of the quenching media shall be defined.

5.3.3 Chemical Composition

5.3.3.1 General

The manufacturer shall specify the range of chemical composition of the material used to manufacture pressure-containing parts.

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.

5.3.3.2 Composition Limits

The chemical composition limits of pressure-containing parts manufactured from carbon and low-alloy steels or martensitic stainless steels shall conform to Table 31.

NOTE Limits for non-martensitic alloy systems are not required to conform to tables 31 and 32.

Table 31—Steel Composition Limits (% Mass Fraction) for Pressure-containing Parts

Alloying Element	Carbon and Low-alloy Steels Limit	Martensitic Stainless Steels Limit
	% Mass Fraction (Maximum)	% Mass Fraction (Maximum)
Carbon	0.45	0.15
Manganese	1.80	1.00
Silicon	1.00	1.50
Phosphorus	0.025	0.025
Sulphur	0.025	0.025
Nickel	1.00	4.50
Chromium	2.75	11.0 to 14.0
Molybdenum	1.50	1.00
Vanadium	0.30	N/A

5.3.3.3 Tolerance on Composition Limits

The permitted tolerances on alloy element content shall conform to Table 32.

5.3.4 Material Qualification

5.3.4.1 Tensile Testing

Tensile test specimens shall be removed from a qualification test coupon (QTC) as described in 5.3.5. This QTC shall be used to qualify a heat and the products produced from that heat.

Tensile tests shall be performed at room temperature in accordance with the procedures specified in ASTM A 370 or ISO 6892.

Table 32—Alloying Element Range—Maximum Tolerance Requirements

Alloying Element	Carbon and Low-alloy Steels Limit	Martensitic Stainless Steels Limit
	% Mass Fraction	% Mass Fraction
Carbon	0.08	0.08
Manganese	0.40	0.40
Silicon	0.30	0.35
Nickel	0.50	1.00
Chromium	0.50	—
Molybdenum	0.20	0.20
Vanadium	0.10	0.10
NOTE These values are the maximum allowable for any specific element, and not exceed the maximum specified in Table 31.		

A minimum of one tensile test shall be performed. The results of the tensile test(s) shall satisfy the applicable requirements of Table 29. If the results of the first tensile tests do not satisfy the applicable requirements, two additional tensile tests may be performed in an effort to qualify the material. The results of each of these additional tests shall satisfy the requirements of Table 29.

5.3.4.2 Impact Testing

Impact testing shall be performed on each heat of material in accordance with ASTM A370 using the Charpy V-notch technique.

Impact test specimens shall be removed from a QTC in accordance with 5.3.5. This QTC shall be used to qualify a heat and the products produced from that heat.

Standard-size specimens of cross-section 10 mm × 10 mm shall be used, except where there is insufficient material, in which case the next smaller standard sub-size specimen obtainable per ASTM A370 shall be used. When it is necessary to prepare sub-size specimens, the reduced dimension shall be in the direction parallel to the base of the V-notch.

In order to qualify material for a temperature rating, the impact tests shall be performed at or below the test temperature shown in Table 33.

Table 33—Acceptance Criteria for Charpy V-notch Impact Tests

Temperature Rating	Test Temperature		Minimum Impact Value Required for Average of Each Set of Three Specimens		Minimum Impact Value Permitted for One Specimen Only Per Set	
	°C	(°F)	J	(ft-lb)	J	(ft-lb)
T-75/250	– 59	– 75	20	15	14	10
T-75/350	– 59	– 75	20	15	14	10
T-20/250	– 29	– 20	20	15	14	10
T-20/350	– 29	– 20	20	15	14	10
T-0/250	– 18	0	20	15	14	10
T-0/350	– 18	0	20	15	14	10

A minimum of three impact specimens shall be tested to qualify a heat of material. The average of the impact property value shall be at least the minimum value shown in Table 33. In no case shall an individual impact value fall below two-thirds of the required minimum average. No more than one of the three test results shall be below the required minimum average. If a test fails, one retest of three additional specimens (removed from the same location within the same QTC, with no additional heat

treatment) may be made. The retest shall exhibit an impact value for each specimen equal to or exceeding the required minimum average.

The values listed in Table 33 are the minimum acceptable values for forgings and wrought products tested in the transverse direction and for castings and weld qualifications. Forgings and wrought products may be tested in the longitudinal direction instead of the transverse direction, in which case they shall exhibit 27 J (20 ft-lb) minimum average value.

If sub-size specimens are used, the Charpy V-notch impact requirements shall be equal to that of the 10 mm × 10 mm specimens multiplied by the adjustment factor listed in Table 34.

Table 34—Adjustment Factors for Sub-size Impact Specimens

Specimen Dimension	Adjustment Factor	Minimum Average Impact Value, Wrought Materials	
		Transverse Direction and Castings J (ft-lb)	Longitudinal Direction J (ft-lb)
10 mm × 10 mm	1 (none)	20 (15); ref.	27 (20); ref.
10 mm × 7.5 mm	0.833	17 (13)	23 (17)
10 mm × 6.7 mm	0.780	16 (12)	21 (16)
10 mm × 5.0 mm	0.667	13 (10)	18 (13)
10 mm × 3.3 mm	0.440	9 (7)	12 (9)
10 mm × 2.5 mm	0.333	7 (5)	9 (7)

5.3.5 Qualification Test Coupon (QTC)

5.3.5.1 General

The properties exhibited by the QTC shall represent the properties of the material comprising the equipment it qualifies. A single QTC may be used to represent the impact and/or tensile properties of components produced from the same heat, provided it satisfies the requirements of this specification.

When the QTC is a trepanned core or a prolongation removed from a production part, the QTC shall only qualify parts having the same or smaller equivalent round (ER).

NOTE A QTC may only qualify material and parts produced from the same heat. (Remelt heat may be qualified on a master heat basis.)

5.3.5.2 Equivalent Round (ER)

5.3.5.2.1 General

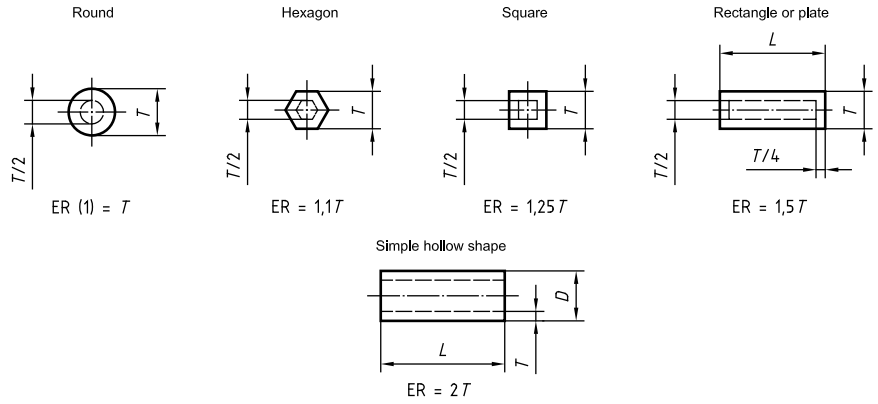
The dimensions of a QTC for a part shall be determined using the following ER method.

5.3.5.2.2 ER Methods

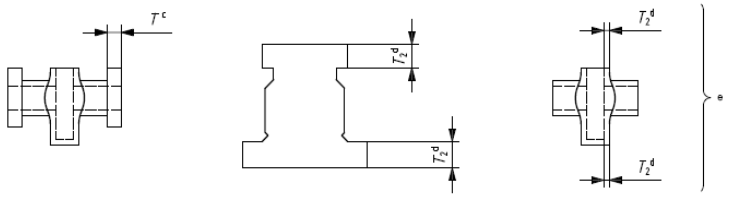
Figure 9 illustrates the basic models for determining the ER of simple solid and hollowed parts and more complicated equipment. The ER of a part shall be determined using the actual dimensions of the part in the "as-heat-treated" condition.

5.3.5.2.3 Required Dimensions

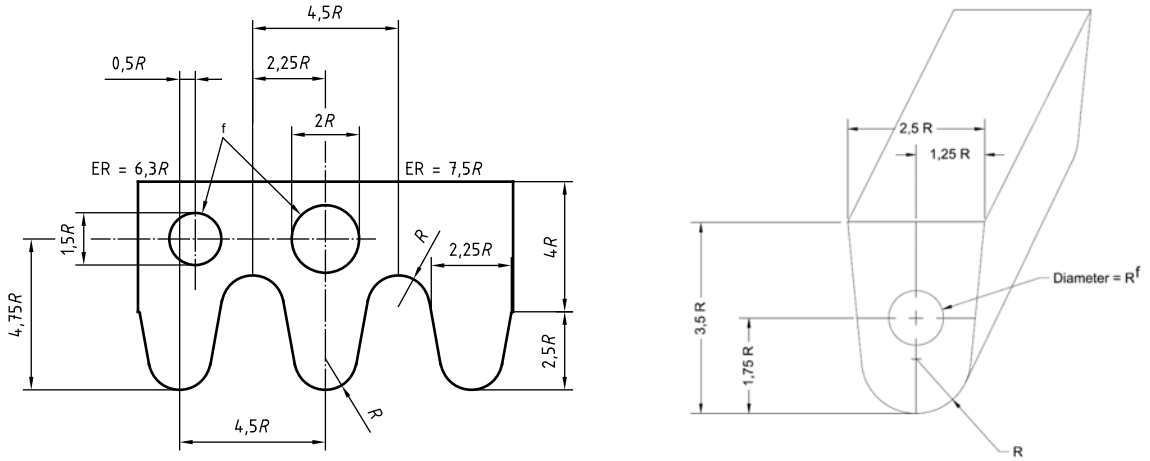
The ER of the QTC shall be equal to or greater than the dimensions of the part it qualifies



a) Simple Geometric Equivalent Rounds (ER) Sections/Shapes Having Length *L*



b) Complex-shaped Components



c) Keel Block Configuration, ER = 2.3 *R*

NOTES

a. 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.

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

c. On multi-flanged components, *T* shall be the thickness of the thickest flange

d. Where *T* is the thickness when the component is heat-treated as in t2, use the larger of the two indicated dimensions.

e. Bodies with screwed and open ends.

f. Envelope for test specimen removal

When all internal and external surfaces during heat treatment are within 13 mm ($^1/_2$ in) of the final surfaces, then ER = 1 – $^1/_4$ *T*. When all internal and external surfaces during heat treatment are not within 13 mm ($^1/_2$ in) of the final surfaces, then ER = 2 *T*.

Figure 9—Equivalent Round Models

5.3.5.3 Processing

5.3.5.3.1 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 may not qualify material from the same primary melt which 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 which has been processed in like manner and is from the same primary melt. No additional alloying shall be performed on these individual remelt ingots.

5.3.5.3.2 Casting Practices

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

5.3.5.3.3 Hot-working Practices

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

5.3.5.3.4 Welding

Welding on the QTC is prohibited, except for attachment-type welds.

5.3.5.3.5 Heat Treating

All heat-treatment operations shall be performed using equipment that is used to process parts, and qualified in accordance with Annex B.

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

When the QTC is not heat-treated as part of the same heat treatment load as the parts it qualifies, the austenitizing (or solution heat-treat) temperatures for the QTC shall be within 14 °C (25 °F) of those for the parts. The tempering temperature for the part shall be no lower than 14 °C (25 °F) below that of the QTC. The upper limit shall be no higher than permitted by the heat-treatment procedure for that material. The cycle time of the QTC at each temperature shall not exceed that for the parts.

5.3.5.4 Hardness Testing

A hardness test shall be performed on the QTC after the final heat-treatment cycle.

Hardness testing shall be performed in accordance with procedures specified in ASTM E10, ASTM E18, ASTM A370, ISO 6506-1 or ISO 6508-1 as appropriate.

5.4 Pressure-controlling Parts

5.4.1 Property Requirements

Pressure-controlling parts shall be manufactured from materials as specified by the manufacturer.

5.4.2 Processing

5.4.2.1 Melting, Casting, and Hot Working

The melting, casting, and hot-working practices of pressure-controlling parts shall meet 5.3.2.1.

5.4.2.2 Heat Treating

All heat-treatment operations for pressure-controlling parts shall conform to 5.3.2.2.

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 pressure-controlling parts manufactured from carbon and low-alloy steels or martensitic stainless steels shall conform to the manufacturer’s specifications.

5.4.3.3 Tolerance on Composition Limits

The permitted tolerances on alloy element content shall conform to Table 32.

5.4.4 Material Qualification

5.4.4.1 Tensile Testing

Tensile testing for pressure-controlling parts shall meet the requirements of 5.3.4.1.

5.4.4.2 Impact Testing for Wellbore Wetted Pressure-Controlling Parts

Impact testing shall be performed as specified in 5.3.4.2 on all wellbore wetted pressure-controlling parts, except for shear blades. Acceptance criterion for shear blades shall be per the manufacturer’s written specification.

6 Welding Requirements

6.1 General

All welding of components exposed to wellbore fluid shall conform to the welding requirements of NACE MR0175/ISO 15156. Verification of conformance shall be established through implementation of the manufacturer's written welding procedure specification (WPS) and the supporting procedure qualification record (PQR).

When material specifications for pressure-containing and pressure-retaining components require impact testing, verification of conformance shall be established through implementation of 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 for each weld, at a minimum:

— part sketch denoting new weld/repair area;

— part number;

— serial number;

— welder’s name;

— welder’s stamp number;

— PT/MT report number of verification of defect removal;

— WPS used;

— filler material heat/batch/lot;

— weld flux heat/batch/lot, if used;

— number PWHT hours used;

— number PWHT hours remaining.

6.2 Weldment Design and Configuration

6.2.1 Pressure-containing Fabrication Weldments

Pressure-containing fabrication weldments are wetted by wellbore fluid.

Only full penetration welds fabricated in accordance with the manufacturer's written specification shall be used.

NOTE Figures 10 and 11 are provided for reference.

Welding and completed welds shall meet 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 meet the quality control requirements of Section 7.

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

Surface NDE shall be performed after the load test and meet the requirements of 4.5.

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

6.2.3 Repair Welds

All repair welding shall be carried out in accordance with the manufacturer's written specification. Figures 12 and 13 are provided for reference.

Welding and completed welds shall meet the requirements of 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

Standard dimensions for the preparation of type SR ring grooves for overlays are specified in 4.3. 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

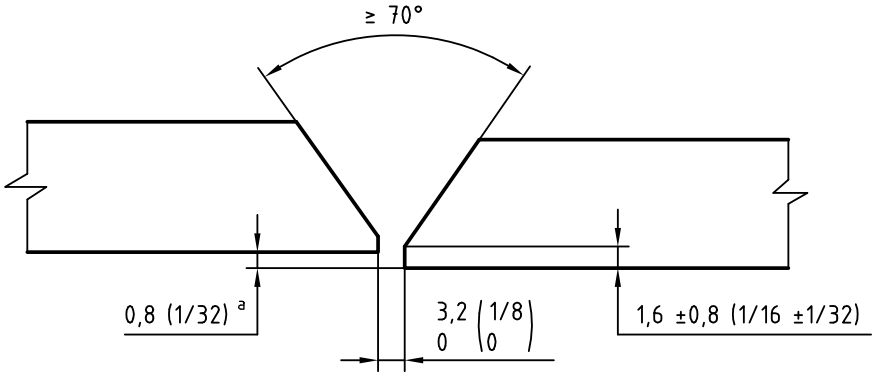
The manufacturer shall use a written procedure that provides controls for consistently meeting the manufacturer-specified material surface properties in the final machined condition. As a minimum, this shall include inspection methods and acceptance criteria.

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.

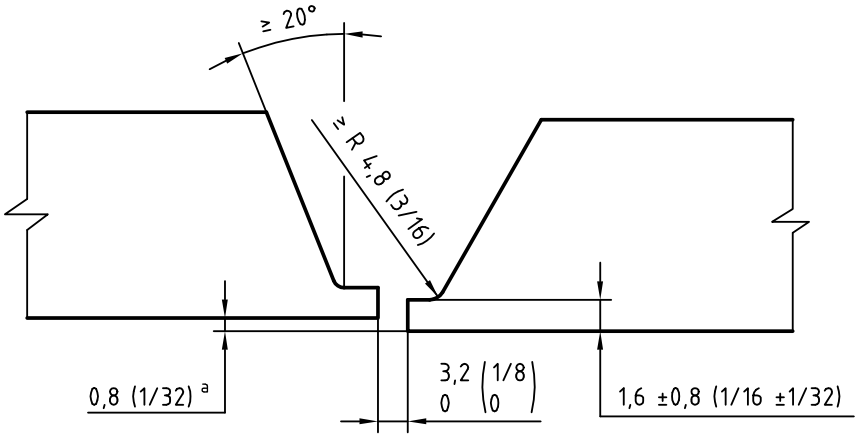
6.2.4.3 Mechanical Properties

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.

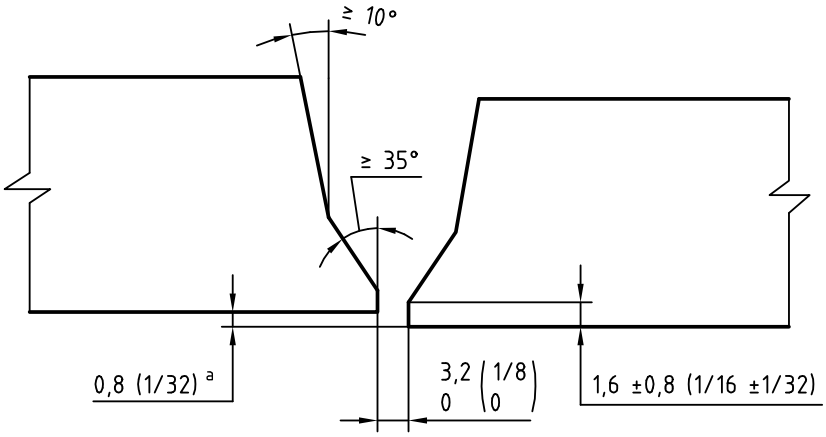
Dimensions in millimeters (inches)



a) V-groove



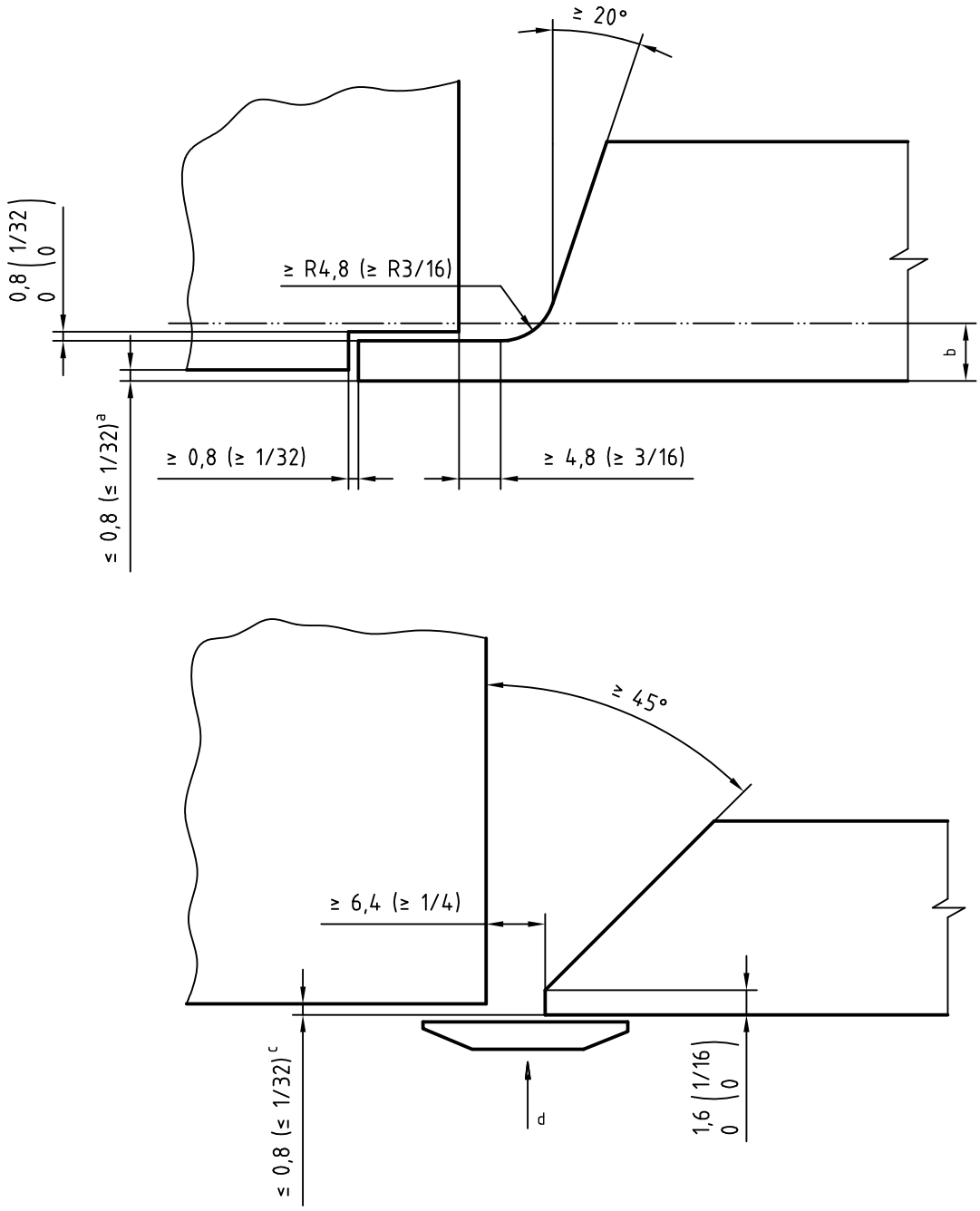
b) U-groove



c) Heavy wall V-groove

a Maximum misalignment

Figure 10—Typical Weld Grooves for Pipe Butt Joints



Dimensions in millimeters (inches)

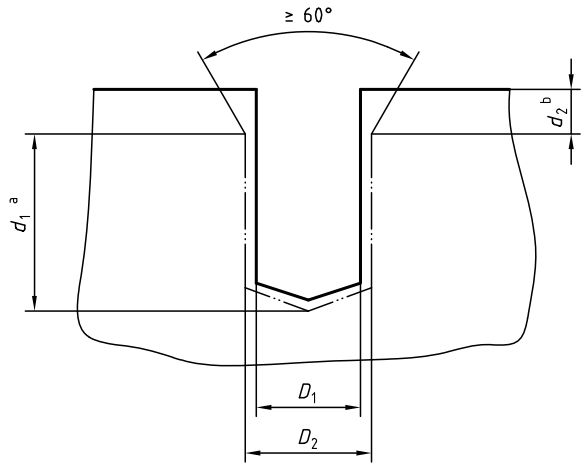
a Mismatch (unless removed by machining)

b Remove to sound metal by machining

c Maximum mismatch

d Backing to be removed. Material to be compatible with base material.

Figure 11—Typical Attachment Welds



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 12—Typical Repair Welds

Dimensions in millimeters (inches)

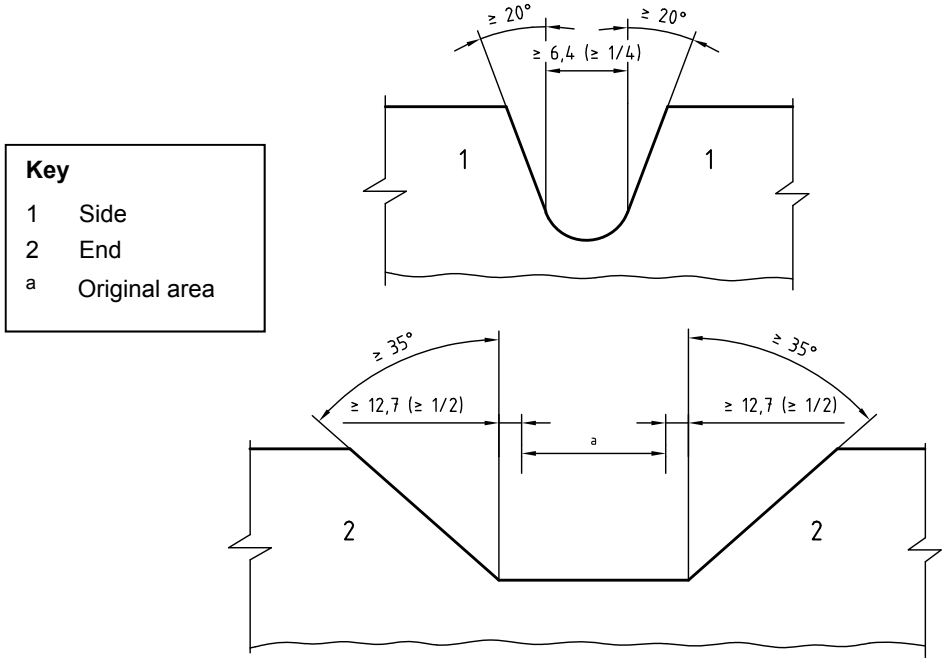


Figure 13—Typical Excavation for Repair Welds

6.3 Welding Controls

6.3.1 Procedures

The manufacturer shall have procedures for the qualification of tack welders, welders, and welding operators that define the following: training, qualification, monitoring qualification, retraining 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, retraining, 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, nonessential, 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.

Dimensions of groove and fillet welds with tolerances shall be documented in the manufacturer's specification. Figures 10 and 11 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 weld materials of differing strength are joined, the weld metal properties shall be greater than or equal to that of the lesser-strength 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 procedures 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 control methodology for 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 traveler 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 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 (ISRs) 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 14 °C (25 °F) below the minimum specified tempering temperature.

Furnace post-weld heat treatment shall be performed in equipment meeting the requirements of Annex B.

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 232 °C (450 °F) and 399 °C (750 °F) 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 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 $\leq$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:

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

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 Criteria

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

Welding consumables shall be clearly identified by trade name, as applicable, and their 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 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/ISO 15156 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)

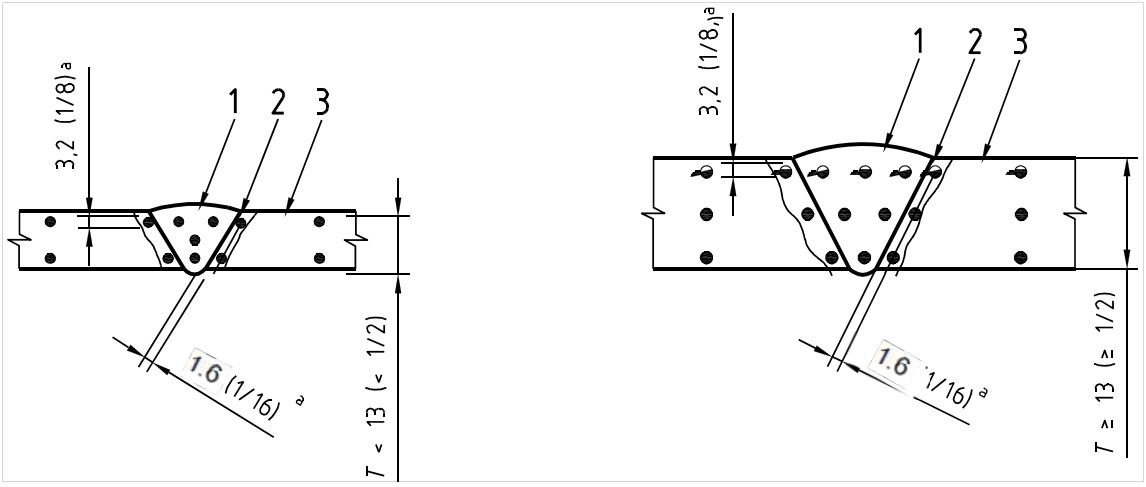
If the Rockwell method is selected by the manufacturer, the following procedure shall be used:

a) For a weld cross-section thickness less than 13 mm ($^1/_2$ in), 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 13 mm ($^1/_2$ in), 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 1.6 mm (0.06 in) of the weld interface and at least one each within 3.2 mm (0.125 in) from top and bottom of the weld. See Figure 14 for test locations.

Dimensions in millimeters (inches)



Key

1 Weld
2 HAZ
3 Base
[a] Typical

Figure 14—Rockwell Hardness 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 13 mm (½ in), 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 13 mm (½ in), six hardness tests each shall be made in the base material(s) and the weld;

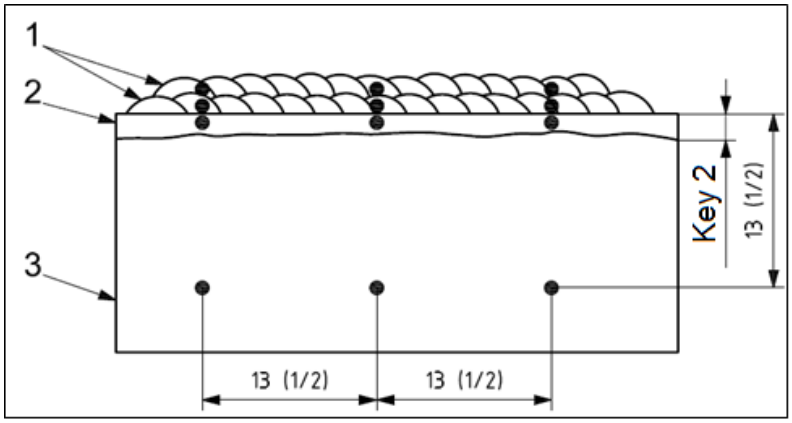
c) Multiple HAZ hardness tests equally spaced 3.2 mm (0.125 in) apart shall be performed in each of the base materials within 0.25 mm (0.01 in) of the weld interface and at least one within 1.6 mm (0.06 in) from the top and the bottom of the weld. See Figure 16 for test locations.

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 heat-affected zone, and in each layer of the overlay up to a maximum of two layers in conformance with the test locations specified in Figure 15.



Key Dimensions in millimeters (inches)

1 Weld

2 HAZ Rockwell B&C impressions shall be within 1.6 mm (0.062 in) 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 15—Hardness Test Locations for Weld Overlay

Using the Vickers or Rockwell 15N measurement methods per Section 6.5, hardness impressions shall be entirely within the heat-affected zone and located as close as possible to, but no more than 1 mm (0.039 in) from, the fusion boundary between the weld overlay and 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, testing shall be performed per the instructions and diagrams as outlined in Annex F or, alternatively, the following paragraphs shall be followed.

NOTE The preferred method is outlined in Annex F.

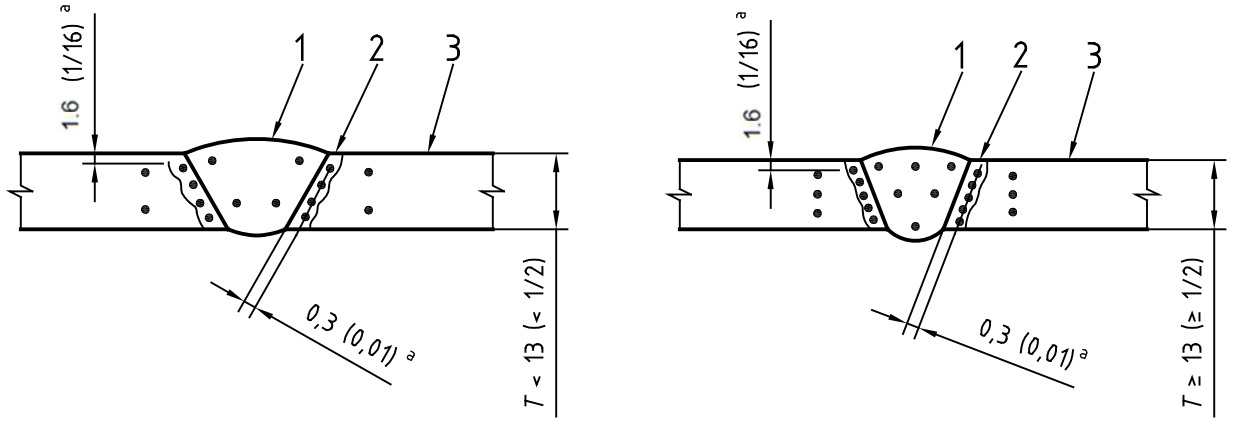
When impact testing is required by the base material specification, the testing shall be performed in accordance with ASTM A370 using the Charpy V-notch technique. Results of testing in the weld and base material HAZ shall meet the minimum requirements of the base material. Records of results shall become 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) When weld thickness of the product is equal to or greater than 50 mm (2 in), impact testing shall be performed on weld metal and HAZ material removed within 1/4 thickness.

Dimensions in millimeters (inches)



Key

1 Weld
2 HAZ
3 Base
a Typical

Figure 16—Vickers Hardness Test Locations

6.5.2 ASME BPVC Section IX, Article II—Welding Procedure Qualifications

6.5.2.1 General

Article II of ASME BPVC 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 ±14 °C (±25 °F). 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 3.2 mm (0.125 in) 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 a class given in Table 35:

Table 35—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 sulfide service shall conform to the requirements of NACE MR0175/ ISO 15156.

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 12). The repair welding qualification test hole shall be qualified by radiography according to Section 7, or shall be cross-sectioned through the centerline of the hole. 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, counterbore, 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 31).

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 national standard.

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

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 ±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.

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 maximum increments of three months can be established.

7.3 Quality Control Personnel Qualifications

7.3.1 Nondestructive Examination (NDE) Personnel

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

7.3.2 Visual Examination Personnel

Personnel performing visual examinations shall have an annual eye examination in accordance with ASNT SNT TC-1A or ISO 9712.

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 AWS QC1 is used, the allowable certifications are:

— AWS Senior Certified Welding Inspector (SCWI);

— AWS Certified Welding Inspector (CWI);

— AWS Certified Associate Welding Inspector (CAWI).

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).

The manufacturer shall have written procedures:

— defining the roles, responsibilities, authority, and accountability of a welding inspector;

— defining essential welding variables and equipment monitoring;

— 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 manufacturer's written procedure for validation of supplier processes.

— defining the In-house welding inspector certification program, if used, including training syllabus, instructor qualification requirements, length of certification, and renewal requirements.

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 equipment exposed to wellbore fluid shall conform to the requirements of NACE MR0175/ISO 15156, in addition to the specific requirements of this specification.

7.4.2 Materials

Subsection 7.5.1 includes detailed qualification requirements for parts and qualification test coupons.

7.4.3 Quality Control Instructions

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

7.4.4 Nondestructive 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 Pressure-containing and Pressure-controlling Parts

7.5.1.1 General

Pressure-containing and pressure-controlling parts include those exposed to wellbore fluid (except for studs and nuts, closure bolting, ring gaskets, nonmetallic sealing materials, molded sealing assemblies, and metallic inserts in molded assemblies; see 7.5.2 through 7.5.4).

7.5.1.2 Tensile Testing

7.5.1.2.1 Pressure-containing Parts

Methods and acceptance criteria shall be in accordance with 5.3.4.

7.5.1.2.2 Pressure-controlling Parts Exposed to Wellbore Fluid

Tensile testing shall be performed in accordance with 5.4.4 and acceptance criteria shall be in accordance with the manufacturer's written specifications.

7.5.1.3 Impact Testing

7.5.1.3.1 Pressure-containing Parts

Methods and acceptance criteria shall be in accordance with 5.3.4.

7.5.1.3.2 Pressure-controlling Parts Exposed to Wellbore Fluid

Impact testing shall be performed in accordance with 5.4.4.2 and acceptance criteria shall be in accordance with the manufacturer's written specifications.

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, as appropriate.

At least one hardness test 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. It is permissible for hardness marking to be covered by other components after assembly.

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

Hardness measurements on parts manufactured from carbon low-alloy and martensitic stainless-type steels shall exhibit maximum values in accordance with NACE MR0175/ISO 15156 and minimum values equal to or greater than those specified in Table 36.

Table 36—Minimum Hardness Requirements

API Material Designation	Hardness (Brinell)
36K	140 HBW
45K	140 HBW
60K	174 HBW
75K	197 HBW

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-test results, shall be used with the hardness measurements in order 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:

$$HBW_C = \left[\frac{UTS}{UTS_{QTC}}\right] \times HBW_{QTC} \quad (6)$$

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. 483 MPa (70,000 psi), 586 MPa (85,000 psi) or 655 MPa (95,000 psi);

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

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

In the event that 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.

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 5.3.3.

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 the manufacturer's written specifications.

Non-well fluid-wetted 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 this section.

7.5.1.9.2 Surface NDE of Ferromagnetic Materials

All accessible well fluid-wetted surfaces and all accessible sealing surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by either magnetic particle (MP) or liquid penetrant (LP) methods.

7.5.1.9.3 Surface NDE of Non-ferromagnetic Materials

All accessible well fluid-wetted surfaces 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 well fluid-wetted surfaces 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 are not permitted on well fluid-wetted surfaces 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, nonmetallic 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

Acceptance criteria are:

- No relevant indication with a major dimension equal to or greater than 5 mm ($^{3}/_{16}$ in);
- No more than 10 relevant indications in any continuous 40 cm^2 (6 in^2) area;
- Four or more relevant indications in a line separated by less than 1.6 mm ($^{1}/_{16}$ in) (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 13 mm ($^1/_2$ in) 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

One hundred percent of all surfaces prepared for welding shall be visually examined prior to initiating welding.

Examinations shall include a minimum of 13 mm ($^1/_2$ in) 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 the 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 are not permitted on or within 3 mm ($^1/_8$ in) of sealing surfaces.

7.5.1.13 Weld NDE—Surface Examination (Other Than Visual)

7.5.1.13.1 General

One hundred percent of all pressure-containing welds, repair and weld metal overlay welds, and repaired fabrication welds shall be examined by either MP or LP methods after all welding, post-weld heat treatment, and machining operations are completed. Weld metal overlays that will remain in the as-welded condition need only be inspected after the initial PWHT. Repair welds to fabrication welds and to weld metal overlays will need to be LP inspected both before and after the weld repair operation, and after any subsequent PWHT or machining operation.

The examination shall include 13 mm ($^1/_2$ in) 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 7.5.1.9.4, except:

a) magnetic particle examination shall reveal:

— no relevant linear indications;

— no rounded indications greater than 3 mm ($^1/_8$ in) for welds whose depth is 16 mm ($^5/_8$ in) or less or 5 mm ($^3/_{16}$ in) for welds whose depth is greater than 16 mm (0.63 in).

b) liquid penetrant examination shall reveal:

— no rounded indications greater than 3 mm ($^1/_8$ in) for welds whose depth is 16 mm ($^5/_8$ in) or less or 5 mm ($^3/_{16}$ in) for welds whose depth is greater than 16 mm (0.63 in).

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 13 mm ($^1/_2$ in) of adjacent base metal on all sides of the weld.

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).

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 25 mm (1 inch) (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 13 mm ($^1/_2$ in) 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 E 94, 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 %. Wire-type image quality indicators are acceptable for use in accordance with ASTM E 747.

7.5.1.15.2.2 Acceptance Criteria

The following shall not be accepted:

a) any type of crack, zone of incomplete fusion, or penetration;

b) any elongated slag inclusion that has a length equal to or greater than specified in Table 37;

Table 37—Weld Inclusion Criteria

Weld Thickness t		Inclusion Length	
mm	(in)	mm	(in)
< 19	< 0.76	6.4	0.25
$19 \le t \le 57$	$0.76 \le t \le 2.25$	0.33 t	0.33 t
> 57	> 2.25	19.0	0.75

c) any 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) any rounded indications in excess of that specified in ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Appendix 4.

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 BPVC, Section V, Article 4.

7.5.1.15.3.2 Acceptance Criteria

The following shall not be accepted:

a) any indication whose signal amplitude exceeds the reference level;

b) any linear indication interpreted as a crack, incomplete joint penetration, or incomplete fusion;

c) any slag indication with amplitude exceeding the reference level whose length exceeds that specified in Table 37.

NOTE If a weld joins two parts 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 7.5.1.15.4.2a 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 Section 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 to pressure-containing parts:

a) Sampling

— As far as practical, the entire 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 A388 (immersion method may be used) and ASTM E 428.

— Calibration: Distance amplitude curve (DAC) shall be based on 1.6 mm ($^1/_{16}$ in) flat-bottom hole for metal thicknesses through 38 mm ($1^1/_2$ in), on 3.2 mm ($^1/_8$ in) flat-bottom hole for metal thicknesses from 38 mm ($1^1/_2$ in) through 150 mm (6 in), and on 6.4 mm ($^1/_4$ in) flat-bottom hole for metal thicknesses exceeding 150 mm (6 in).

2) 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 13 mm ($^1/_2$ in) 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 38;

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

Table 38—Weld Inclusion Criteria

Material Thickness in (mm)	Inclusion Length in (mm)
< 0.75 (19.0)	0.25 (6.4)
0.75 to 2.25 (19 to 57)	0.33T (0.33T)
>2.25 (>57.0)	0.75 (19.0)
Thickness, T; inclusion length in (mm)	

7.5.2 Bolting

Bolting shall conform to the requirements of 4.3.3, and thread form and dimensions of bolts shall conform to the manufacturer's written specification.

7.5.3 Ring Gaskets

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

7.5.4 Pressure-containing and Pressure-controlling Nonmetallic Sealing Materials and Molded Sealing Assemblies

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;

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 the manufacturer's written specifications.

7.5.4.2 Metallic Inserts in Molded Assemblies

7.5.4.2.1 Dimensional Verification

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

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

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

7.5.4.2.2 Hardness Testing

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

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

Acceptance shall be in accordance with the manufacturer's written requirements and NACE MR0175/ISO15156.

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

7.5.5 Annular Packers When Shipped Separately From a BOP

When shipped separately (not part of an assembled BOP), annular packers shall be pressure-tested in accordance with 7.5.7.7.2.

When shipped separately (not part of an assembled BOP), annular packers shall be drift-tested following the pressure test. Drift tests shall conform to 7.5.7.4.

7.5.6 All Other Drill-through Equipment Not Covered in 7.5.1 Through 7.5.6

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

7.5.7 Assembled Equipment Factory Acceptance Test (FAT)

7.5.7.1 General

Assembled equipment includes bonnet or door assemblies when shipped separately from a BOP.

The quality control requirements for assembled equipment shall include drift tests, pressure tests, and hydraulic operating system tests.

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

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

7.5.7.2 Serialization

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

7.5.7.3 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).

7.5.7.4 Drift Test

7.5.7.4.1 Method

A drift test is required on ram BOP, annular BOP, hydraulic connectors, drilling 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.

Drift mandrel gauge length shall be at least 51 mm (2 in) longer than any cavity that intersects the bore, but not less than 305 mm (12 in).

7.5.7.4.2 Acceptance

For annular BOPs, the drift mandrel shall pass through the bore within 30 minutes after the pressure has been removed from a rated working pressure test with no external force being applied to the drift.

For ram BOPs, hydraulic connectors, drilling spools, and adapters, the drift mandrel shall pass through the bore with no external force being applied to the drift.

7.5.7.5 Pressure Test Equipment

A data acquisition 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.

7.5.7.6 Hydrostatic Proof Testing

7.5.7.6.1 General

All drill-through equipment shall be subjected to a hydrostatic proof test prior to shipment from the manufacturer's facility. Water, water with additives, or dielectric fluid shall be used as the testing fluid. Any additives shall be documented in the test records.

7.5.7.6.2 In-plant Hydrostatic Proof Test

Drill-through 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 39. For equipment with end or outlet connections having different working pressures, the lowest-rated working pressure shall be used to determine the hydrostatic proof test pressure.

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

Table 39—Hydrostatic Test Pressures

Rated Working Pressure		Hydrostatic Test Pressure	
MPa	(psi)	MPa	(psi)
6.9	(1,000)	10.34	(1,500)
13.79	(2,000)	20.68	(3,000)
20.68	(3,000)	31.02	(4,500)
34.45	(5,000)	51.72	(7,500)
68.95	(10,000)	103.4	(15,000)
103.4	(15,000)	155.1	(22,500)
137.9	(20,000)	206.8	(30,000)
172.4	(25,000)	258.8	(37,500)

7.5.7.6.3 Hydraulic Operating-chamber Test

The hydraulic operating system test shall be administered on each assembled blowout preventer and hydraulic connector. This includes any hydraulic locking chamber(s).

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

7.5.7.6.4 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 no visible leakage.

7.5.7.7 Closed-preventer Test

7.5.7.7.1 General

7.5.7.7.1.1 Test Conditions

Each ram and annular blowout preventer shall be subjected to a closed-preventer 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-preventer tests shall meet the requirements of 7.5.7.6.1.

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

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

7.5.7.7.1.2 Low-pressure Test

A pressure of 1.4 MPa to 2.1 MPa (200 psi to 300 psi) shall be applied and held below the closed ram or annular packing unit for not less than 10 minutes after stabilization.

7.5.7.7.1.3 High-pressure Test

A pressure at least equal to the rated working pressure of the preventer shall be applied and held below the closed ram or annular packing unit for not less than 10 minutes after stabilization (see exception for annular packing units in 7.5.7.7.2).

7.5.7.7.1.4 Acceptance Criterion

There shall be no visible leakage.

7.5.7.7.2 Annular Packing Unit Tests

Annular packing units shall be tested in two stages.

The stage-one test shall require pressure testing on the appropriate size drill pipe in accordance with Table 40.

Table 40—Pipe Size Requirements

Bore Size		Pipe Diameter	
mm	(in)	mm	(in)
179 and 228	(7 1/16 and 9)	88.9	(3 1/2)
279 and larger	(11 and larger)	127.0	(5)

The stage-two test shall require pressure testing without a drill pipe in the preventer (i.e. on the open hole). The high-pressure test for this stage shall be as specified in 7.5.7.7.1.3, except at a minimum it

shall be performed at 50 % of the rated working pressure of the preventer. This requirement only applies to annular packers rated for CSO.

7.5.7.7.3 BOP Assembly Equipped with Pipe, Blind, and Variable-bore Rams

These tests shall be performed with the appropriate size drill pipe for the rams being tested. VBRs shall be tested on the minimum and maximum sizes for their range.

7.5.7.7.4 BOP Assembly Equipped with Blind Shear Rams

Each preventer equipped with blind shear rams shall be subjected to a shearing test. The size, weight, and grade shear pipe used shall conform to Table 23.

These tests shall be performed without tension in the pipe and with zero wellbore pressure.

Shearing and sealing shall be achieved in a single operation. After the pipe has been sheared and before the shear ram is retracted, the wellbore shall be pressure tested to rated working pressure.

Documentation shall include the manufacturer's shear ram and blowout preventer configurations, and the actual closing pressure to shear the pipe. Documentation shall also include pipe description (size, weight, and grade), actual pipe tensile properties, and impact properties as specified in API 5DP.

7.5.7.7.5 Ram-locking System

The closed-preventer test for each blowout preventer equipped with a 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 preventer shall be tested in accordance with 7.5.7.7.1.2 and 7.5.7.7.1.3 after the rams are closed, the locks are engaged, and all operating pressure(s) are released.

7.5.7.8 Hydraulic Connector Tests

7.5.7.8.1 General

Since there is no closure unit (such as a ram or packer), a rated working pressure test is not required. The hydrostatic proof test shall take the place of any rated working pressure tests.

Each hydraulic connector shall be subjected to a low-pressure test and a hydrostatic proof test. The hydraulic operating chamber pressure used shall be equal to or less than the manufacturer's specified operating pressure. The test fluids used shall meet the requirements of 7.5.7.6.1.

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

The tests shall conform to 7.5.7.8.2 and 7.5.7.8.3, with the low-pressure test always preceding the high-pressure test.

7.5.7.8.2 Low-pressure Test

A pressure of 1.4 MPa to 2.1 MPa (200 psi to 300 psi) shall be applied and held on the connector for not less than 10 minutes after stabilization.

7.5.7.8.3 High-pressure Test

A pressure at least equal to the hydrostatic proof test pressure shall be applied and held on the connector for a time period of not less than 10 minutes after stabilization.

7.5.7.8.4 Acceptance Criterion

There shall be no visible leakage.

7.5.7.8.5 Procedure

The connector pressure test shall be in two stages.

During stage one, the connector with a blind flange or blind hub on top shall be locked on the appropriate test stump using the manufacturer's recommended operating pressure. Then, the operating/locking pressure shall be removed prior to the pressure test.

During stage two, the connector shall be locked on the appropriate test stump, mandrel, or LMRP mandrel using the manufacturer's recommended operating pressure, blocked in place, and pressure tested.

Lock and unlock the hydraulic connector at least six times to the full stroke length using the manufacturer’s recommended operation pressure. If the connector has a secondary unlock system, repeat six locking and unlocking cycles using the secondary unlock system (using the manufacturer’s recommended operating pressure). This test is to determine if any hydraulic seals were damaged during installation.

7.5.7.8.6 Pressure-containing Components When Shipped Separately From a BOP or Hydraulic Connector

Pressure-containing BOP or hydraulic connector bodies, bonnets/doors, and annular tops (heads or covers), when shipped separately (not part of an assembled BOP or hydraulic connector), shall include hydrostatic pressure test.

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 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/ISO 15156 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 10 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 and annular BOP packers and seals.

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

7.6.4 Records to be Maintained by the Manufacturer

7.6.4.1 Records

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

7.6.4.2 Parts or Components Covered in 7.5.1

The following records shall be retained:

a) weld procedure qualification record;

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) weld map;

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 20E and API 20F for closure bolting, pressure-retaining bolting, and pressure-controlling bolting.

7.6.4.4 Nonmetallic Sealing Materials and Molded Sealing Assemblies

The manufacturer shall retain a certification of conformance for nonmetallic sealing materials and molded sealing assemblies to the manufacturer's written requirements.

7.6.4.5 Annular Packers Shipped Separately

The following records shall be retained:

a) pressure test records (7.5.7.7.2);

b) drift test record (7.5.7.4).

7.6.4.6 Assembled Drill-through Equipment

The following records shall be retained:

a) pressure test records (7.5.7.6, 7.5.7.7);

b) drift test record (7.5.7.4).

7.6.5 Records Furnished to Original Purchaser Upon Product Delivery

A manufacturer’s certificate of conformance, containing information as stated in Annex E, shall be furnished to the purchaser.

A data book containing information as stated in Annex C shall be furnished unless otherwise specified by the purchaser.

7.7 Failure Reporting

Failure reporting shall be performed according to Annex D.

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 41.

Equipment shall be stamped on the product with the product description code (PDC) or alphanumeric code, followed by “API 16A.”

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 Nonmetallic Components

8.2.2.1 Wellbore Nonmetallic Components

For identification of wellbore nonmetallic components, such as ram and annular-type BOP 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 Nonmetallic Components

Identification of non-wellbore nonmetallic components, such as elastomeric seals used in ram and annular-type BOP 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

Closure bolting, pressure-retaining bolting, and pressure-controlling bolting shall be marked in accordance with API 20E or API 20F.

Table 41—Marking Requirements and Location

Marking	Ram Blowout Preventer	Annular Blowout Preventer	Hydraulic Connector	Drilling Spools, Spacer Spools, Mandrels, & Adapters	Loose Connector	OECs (Integral & Loose)[d]	Clamps	Ram Blocks	Annular & Ram Packers & Top Seals
API 16A	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Connection OD [a, b, c]	Mfr's specification	Nameplate and/or body	Mfr's specification	Mfr's specification
Mfr's name or mark	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Connection OD [a, b, c]	Mfr's specification	Nameplate and/or body	Mfr's specification	Mfr's specification
Model or type designation (if applicable) (8.4.2.1)	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body				Nameplate and/or body		
Serial number (if applicable)	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body			Nameplate and/or body	Mfr's specification	f
Size designation (Table 46)	Nameplate and/or body & connection OD [a]	Nameplate and/or body & connection OD [a]	Nameplate and/or body & connection OD [a]	Nameplate and/or body & connection OD [a]	Connection OD [a, b, c]	Mfr's specification	e		
Rated working pressure (Table 47)	Nameplate and/or body & connection OD [a]	Nameplate and/or body & connection OD [a]	Nameplate and/or body & connection OD [a]	Nameplate and/or body & connection OD [a]	Connection OD [a, b, c]	Mfr's specification	e		
Temperature rating (Table 48)	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Connection OD [a, b, c]	Mfr's specification	Nameplate and/or body		
Mfr's part number	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Connection OD [a, b, c]	Mfr's specification	Nameplate and/or body	Mfr's specification	Mfr's specification
Date of manufacture	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Connection OD [a, b, c]	Mfr's specification	Nameplate and/or body	Mfr's specification	Mfr's specification
Product description code (8.4)	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body	Connection OD [a, b, c]	Mfr's specification	Nameplate and/or body[e]		
Hydr OS rated working pressure	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body						
Hydr OS recommended operating pressure	Nameplate and/or body	Nameplate and/or body	Nameplate and/or body						
Hydraulic open & close ports	Mfr's specification	Mfr's specification	Mfr's specification						
Equipment orientation	Upper portion								

Marking	Ram Blowout Preventer	Annular Blowout Preventer	Hydraulic Connector	Drilling Spools, Spacer Spools, Mandrels, & Adapters	Loose Connector	OECs (Integral & Loose)[d]	Clamps	Ram Blocks	Annular & Ram Packers & Top Seals
Ring groove designation	Connection OD [a, b, c]	Connection OD [a, b, c]	Connection OD [a, b, c]	Connection OD [a, b, c]	Connection OD [a, b, c]	Mfr's specification[c]			
Nonmetallic codification system (8.3.3)									Mfr's specification

[a] All type 16B and 16BX hub connections shall be marked on the neck of the connection, 12 mm ($^1/_2$ in) max. from the required length of the neck.

[b] All flanges shall be marked in accordance with API 6A.

[c] If the ring groove is overlaid with corrosion-resistant material, it shall be marked "CRA."

[d] All API 6A OECs shall be marked in an easily accessible and readable area selected by the manufacturer.

[e] The size designation in the PDC may be replaced by the two-digit clamp number in accordance with Table 16. If the clamp number is used, the rated working pressure code shall be replaced by the letters "CC."

[f] Serialization shall be required for annular packers. The location of the serial number shall be per manufacturer's specification.

8.3.3 Nonmetallic Codification

Wellbore nonmetallic components, as described in 8.2.2.1, shall be marked with an alphanumeric code system in the sequence denoted below. The meaning of the digits that make up this alphanumeric number is described in Table 42. In addition, the manufacturer's part number shall be marked on the component.

Example of product code: AA BBBB CCCC DDDD EEE FFFF

Table 42—Code System for Nonmetallic Sealing Materials

Code	Description
AA	Compound hardness (durometer)
BBBB	Elastomer Compound Marking Code (see Table 43 and ASTM D 1418)
CCCC	Date of manufacture (see 8.4.2.5)
DDDD	Lot/serial number (in accordance with manufacturer's specifications)
EEE	Temperature class (see Table 4)
FFFF	Date of expiration

The date-of-expiration code shall consist of the month (in numerical form) and the last two digits of the year (e.g. May 2016 is coded as 0516 for Code FFFF) denotes shelf-life expiration date. For PR1, use "G" for continuous elevated temperature.

Table 43—Elastomer Compound Marking Code

Common Name/ Trade Name	Chemical Name	ASTM D1418 Code	Nonmetallic Sealing Code
Butyl	Isobutylene, isoprene	IIR	IIRX
CO	Polychloromethyl oxirane (epichlorohydrin polymer)	CO	COXX
ECO	Ethylene oxide (oxirane) and chloromethyl oxirane (epichlorohydrincopolymer)	ECO	ECOX
Kel-F[a]	Chlorofluoro elastomer	CFM	CFMX
Hypalon[a]	Chlorosulfonated polyethylene	CSM	CSMX
EPR	Ethylene-propylene copolymer	EPM	EPMX
EPT	Ethylene-propylene diene monomer	EPDM	EPDM
Viton[a]	Fluoroelastomer	FKM	FKMX
Natural rubber	Polyisoprene	NR	NRXX
Isoprene (natural or synthetic)	Polyisoprene	IR	IRXX
XNBR	Carboxylic acrylonitrile butadiene	XNBR	XNBR
HNBR	Hydrogenated acrylonitrile butadiene	HNBR	HNBR
Nitrile rubber	Acrylonitrile butadiene	NBR	NBRX
Acrylic	Polyacrylic	ACM	ACMX
Diene rubber	Polybutadiene	BR	BRXX
Neoprene	Polychloroprene	CR	CRXX
Vistanex[a]	Polyisobutylene	IM	IMXX
Thiokol[a]	Polysulfide	—	THIO
Silicone	Polysiloxanes	Si	SIXX
SBR (GR-S)	Styrene-butadiene	SBR	SBRX
Urethane	Diisocyanates + polyols	—	URET

[a] This is the trade name or trademark 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 Product Description Code (PDC)

8.4.1 General

The product description code (PDC) is used as an aid in describing equipment manufactured to this standard. The PDC is a 15-digit number that can be used to fully describe the equipment to which it is applied. The location and meaning of the digits that make up the PDC are described below and in Table 44.

Example of product description codes (PDC): AA BB CC DD EEEE FFF

Table 44—Product Description Code

Code	Description
AA	Equipment type (see 8.4.2.1)
BB	Size designation (see 8.4.2.2)
CC	Rated working pressure (see 8.4.2.3)
DD	Temperature rating (see 8.4.2.4)
EEEE	Date of manufacture (see 8.4.2.5)
FFF	Performance requirement (see 8.4.2.6)

8.4.2 Code Designations

8.4.2.1 Equipment Type (AA)

The equipment type code provides a basic description of the equipment. See Table 45 for codification.

Table 45—Equipment Type

Generic description of equipment	Code AA
Single ram BOP	01
Double ram BOP	02
Single annular BOP	03
Double annular BOP	04
Drilling spool	05
Adapter	06
Triple ram BOP	07
Hydraulic connector	08
Clamp	09
Quad ram BOP	10
Spacer spool	11
Mandrel	12
Other	99

8.4.2.2 Size Designation (BB)

The size designation provides the bore size of the equipment. See Table 46 for codification.

Table 46—API Equipment Size Designation

API size designation		Code BB
mm	(in)	
179	(7 1/16)	07
228	(9)	09
279	(11)	11
346	(13 5/8)	13
425	(16 3/4)	16
476	(18 3/4)	18
527	(20 3/4)	20
540	(21 1/4)	21
680	(26 3/4)	26
762	(30)	30

8.4.2.3 Rated Working Pressure (CC)

The rated working pressure is the maximum pressure at which the equipment is designed to operate. See Table 47 for codification.

Table 47—Rated Working Pressure

Rated working pressure		Code CC
MPa	(psi)	
6.89	(1,000)	01
13.8	(2,000)	02
20.7	(3,000)	03
34.5	(5,000)	05
69.0	(10,000)	10
103.5	(15,000)	15
138.0	(20,000)	20
172.4	(25,000)	25
206.8	(30,000)	30

8.4.2.4 Temperature Rating for Metallic Materials (DD)

See Table 48 for codification of the temperature rating, applicable to metallic materials only.

Table 48—Temperature Ratings (Metallic Materials)

Operating temperature range		Code DD
°C	(°F)	
– 59 to 121	– 75 to 250	72
– 59 to 177	– 75 to 350	73
– 29 to 121	– 20 to 250	22
– 29 to 177	– 20 to 350	23
– 18 to 121	0 to 250	02
– 18 to 177	0 to 350	03

8.4.2.5 Date of Manufacture (EEEE)

The date of manufacture shall consist of the month (in numerical form) and the last two digits of the year (e.g. May 2003 is coded as 0503 for Code EEEE).

8.4.2.6 Performance requirement (FFF)

The performance requirement code shall be either PR1 or PR2

9 Storing and Shipping

9.1 Storing for Periods Greater than 30 Days

9.1.1 Rust Prevention

Prior to storage, parts and equipment shall have exposed metallic surfaces protected with a rust preventative that will not become fluid at temperatures below 50 °C (125 °F).

For BOPs, the rams or sealing elements shall be removed and the internal body/cavities be thoroughly washed, inspected, and coated with corrosion inhibitor, in accordance with the manufacturer's recommendations.

9.1.2 Connection-surface Protection

All connection faces and ring gasket grooves shall be protected with durable covers.

9.1.3 Hydraulic Operating System

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.

It is recommended to paint the following words in stencil on the outside of the assembly near the operating control ports: “Shipped with fluid xxxxx.”

CAUTION Mixing OEM control fluids may create highly caustic compounds. These compounds can cause extreme damage to lip seal elastomers.

NOTE Equipment may be stored with customer-specified control fluid to avoid contamination with corrosion-inhibiting fluid.

9.1.4 Elastomeric Seals

Elastomeric seals shall be stored in accordance with the manufacturer's written procedures.

9.1.5 Ring Gaskets

Ring gaskets shall be wrapped or boxed for storage and shipping.

9.2 Shipping

All equipment shall be shipped in accordance with the manufacturer's written procedures.

Annex A
(informative)

API Monogram Program
Use of the API Monogram by Licensees

A.1 Scope

A.1.1 Applicability

This annex is normative (mandatory) for products supplied bearing the API Monogram and manufactured at a facility licensed by API; for all other instances it is not applicable.

A.1.2 General

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

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

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

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

A.2 Normative References

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

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

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

A.3 API Monogram Program: Licensee Responsibilities

A.3.1 Monogram Program Requirements

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

a) quality management system requirements of API Q1;

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

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

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

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

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

a) products that do not conform to API specified requirements shall not bear the API Monogram;

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

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

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

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

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

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

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

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

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

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

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

A.3.3 Design and Design Documentation

Each licensee and/or applicant for licensing shall maintain current design documentation as identified in API Q1 for all of the applicable products that fall under the scope of each Monogram license. The design document information shall provide objective evidence that the product design meets the requirements of the applicable and most current API product specification(s) and/or standard(s). The design documentation shall be made available during API audits of the facility.

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

A.3.4 Manufacturing Capability

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

A.3.5 Use of the API Monogram in Advertising

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

A.4 Product Marking Requirements

A.4.1 General

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

A.4.2 Product Specification Identification

Manufacturers shall mark products as specified by the applicable API specifications or standards. Marking shall include reference to the applicable API specification and/or standard. Unless otherwise specified, reference to the API specifications and/or standards shall be, as a minimum, "API [Document Number]" (e.g. API 6A or API 600). Unless otherwise specified, when space allows, the marking may include use of "Spec" or "Std", as applicable (e.g. API Spec 6A or API Std 600).

A.4.3 Units

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

A.4.4 Nameplates

Nameplates, when applicable, shall be made of a corrosion-resistant material unless otherwise specified by the API specification and/or standard. Nameplate shall be located as specified by the API specification and/or standard. If the location is not specified, then the licensee shall develop and maintain a procedure detailing the location to which the nameplate shall be applied. Nameplates may be attached at any time during the manufacturing process.

The API Monogram and license number shall be marked on the nameplate, in addition to the other product marking requirements specified by the applicable product specification and/or standard.

A.4.5 License Number

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

A.5 API Monogram Program: Nonconformance Reporting

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

Annex B
(normative)

Qualification of Heat-treating Equipment

B.1 General

All heat treatment of parts and QTCs shall be performed with equipment meeting the requirements of this annex.

B.2 Temperature Tolerance

The temperature at any point in the working zone shall not vary by more than ± 13 °C (± 25 °F) from the furnace set-point temperature after the furnace working zone has been brought up to temperature. Furnaces that are used for tempering, aging, and/or stress-relieving shall not vary by more than ± 8 °C (± 15 °F) from the furnace set-point temperature after the furnace working zone has been brought up to temperature.

B.3 Furnace Calibration

B.3.1 General

Heat treatment of production parts shall be performed with heat-treating equipment that has been calibrated and surveyed.

B.3.2 Records

Records of furnace calibration and surveys shall be maintained for a period of not less than two years.

B.3.3 Temperature Survey Method for Calibration of Batch-type Furnaces

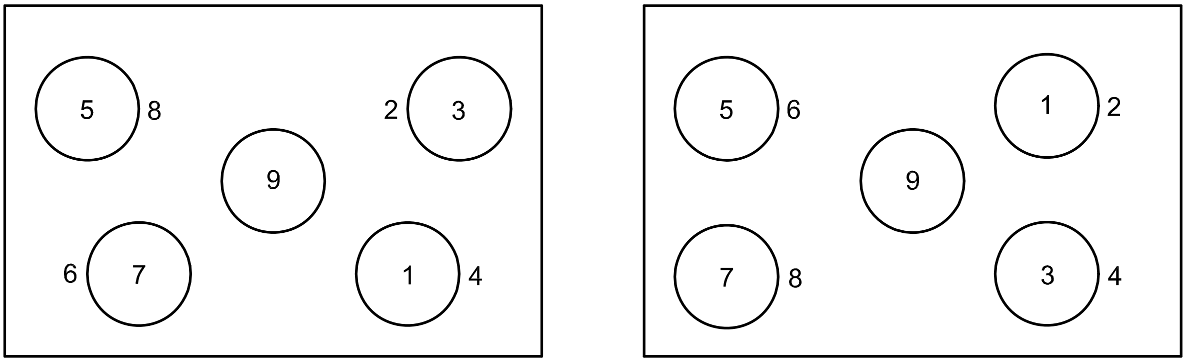
A temperature survey within the furnace working zone(s) shall be performed on each furnace at the maximum and minimum temperatures for which each furnace is to be used.

A minimum of nine thermocouple test locations shall be used for all furnaces having a working zone greater than 0.3 m^3 (10 ft^3).

For each 3.5 m^3 (125 ft^3) of furnace working zone surveyed, at least one thermocouple test location shall be used, up to a maximum of 40 thermocouples. See Figures B.1 and B.2 for examples of thermocouple locations.

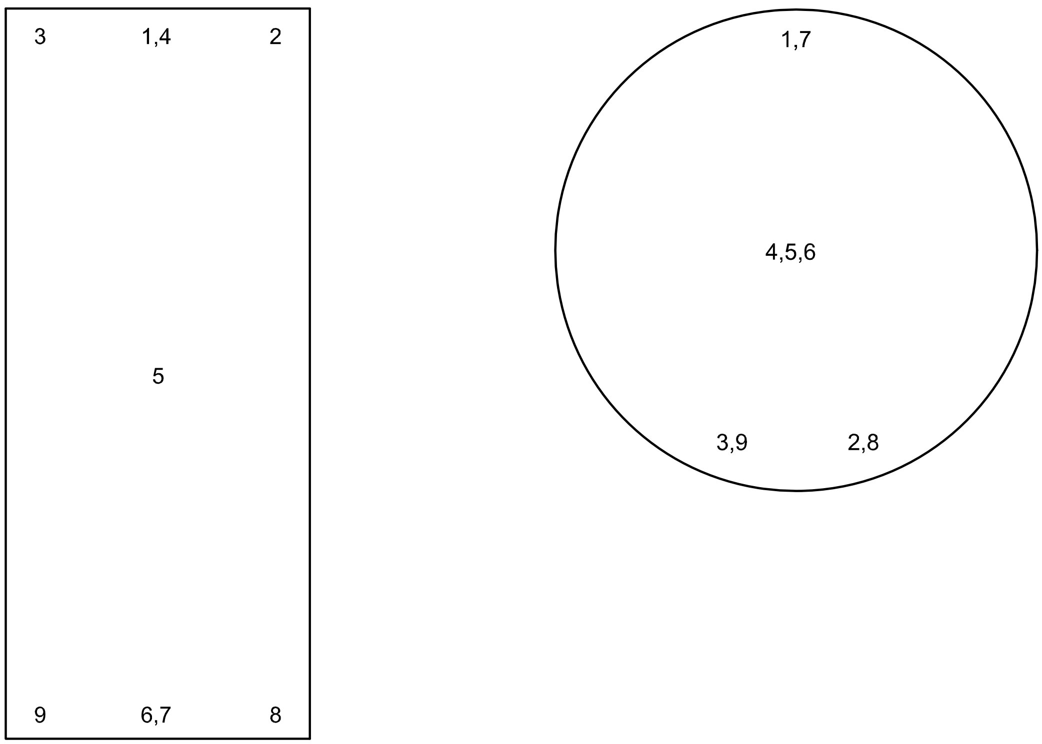
For furnaces having a working zone less than 0.3 m^3 (10 ft^3), the temperature survey may be made with a minimum of three thermocouples located either at the front, center, and rear, or at the top, center, and bottom of the furnace working zone.

After insertion of the temperature-sensing devices, readings shall be taken at least once every 3 minutes to determine when the temperature of the furnace working zone approaches the bottom of the temperature range being surveyed.



a) Top view **b) Side view**

Figure B.1—Thermocouple Locations—Rectangular Furnace (Working Zone)



a) Side view **b) Top view**

Figure B.2—Thermocouple Locations—Cylindrical Furnace (Working Zone)

Once the furnace temperature has reached the set-point temperature, the temperature of all test locations shall be recorded at 2-minute intervals, maximum, for at least 10 minutes. Then, readings shall be taken at 5-minute intervals, maximum, for sufficient time (at least 30 minutes) to determine the recurrent temperature pattern of the furnace working zone.

Before the furnace set-point temperature is reached, none of the temperature readings shall exceed the set-point temperature by more than 13 °C (25 °F).

After the furnace control set-point temperature is reached, no temperature reading shall vary beyond the limits specified. The temperatures within each furnace shall be surveyed within one year prior to use of the furnace for heat treatment.

When a furnace is repaired or rebuilt, a new temperature survey shall be carried out before the furnace is used for heat treatment, subject to the following. Repairs that return the furnace to the condition it was in at the time of the last furnace survey, and calibration or repairs that do not affect the temperature tolerance of the furnace, shall not require a new temperature survey and calibration. The SAE AMS2750E sections on furnace modifications and furnace repairs shall be used to determine whether a new furnace survey is required. All furnace repairs and modifications shall be documented, and the responsible quality assurance organization shall determine whether an additional furnace survey and calibration is required based on the repairs or modifications in accordance with AMS2750E.

B.3.4 Continuous-type Furnaces Method

Furnaces used for continuous heat treatment shall be calibrated in accordance with procedures specified in AMS2750E.

B.4 Instruments

B.4.1 General

Automatic controlling and recording instruments shall be used.

Thermocouples shall be located in the furnace working zone(s) and protected from furnace atmospheres by means of suitable protective devices.

B.4.2 Accuracy

The controlling and recording instruments used for the heat-treatment processes shall be accurate to ± 1 % of their full-scale range.

B.4.3 Calibration

Temperature-controlling and -recording instruments shall be calibrated at least once every three months.

Equipment used to calibrate the production equipment shall be accurate to ± 0.25 % of full-scale range.

Annex C
(informative)

Purchasing Guidelines

C.1 General

This annex provides recommended guidelines for enquiry and purchase of equipment covered by the scope of API 16A.

C.2 Blowout Preventers and Drilling Spools

C.2.1 Size Designation

The size designation consists of the vertical through-bore dimension. A list of standard sizes is included in Table 1.

C.2.2 Service Conditions

C.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 16A are given in 4.2.1.

C.2.2.2 Temperature Ratings

C.2.2.2.1 Metallic Materials

Metallic parts will be designed to operate in one of six temperature ratings, which should be designated by the purchaser. These ratings can be found in Table 3.

C.2.2.2.2 Wellbore Elastomeric Materials

The purchaser should provide the operating temperature range for wellbore elastomeric materials in accordance with Table 4.

C.2.2.2.3 All Other Elastomeric Seals

The purchaser should provide the operating temperature range for all other elastomeric materials.

C.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 BOP or drilling spool is determined by the lowest pressure rating of all end or outlet connections.

C.2.4 Equipment Details, Manufacturing Data Book

A data book should contain the following information:

— assembly drawings, actual overall package dimensions, pressure rating, end connection/outlet description, mass, center of gravity, list of materials for components defined in 7.5.1, and the location of their use;

— Table C.1 outlines contents for the construction of the Manufacturing Data Book (MDB) in order to provide the minimum traceability requirements for maintenance and remanufacturing of pressure-control equipment manufactured under API 16A.

NOTE The MDB is required to generate the complete product history file for repair and remanufacturing.

Table C.1—Manufacturing Data Book (MDB)

Document Contents	Delivered to Equipment Owner	Maintained by Manufacturer
Date of Manufacturing	✓	✓
Purchase Order/Sales Order Number	✓	✓
Date of FAT	✓	✓
Part and Serial Numbers of Equipment and Location (including elastomers)	✓	✓
Assembly Drawings	✓	✓
Certificate of Conformance—include listing of the specification(s) to which equipment is certified	✓	✓
Design Verification Documentation		✓
Third-party Review Certificate	When in purchase order	
Third-party Type Approval Certificate	When in purchase order	✓
Material Test Records (including the following):		
a) Chemical Analysis	✓	✓
b) Tensile Tests	✓	✓
c) Impact Tests	✓	✓
d) Hardness Tests	✓	✓
e) NDE Reports	✓	✓
f) Heat Treatment	✓	✓
Material Specification Number	✓	✓
WPS/PQR Third-party or Customer Review Records	As per 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 Type, Heat, and/or Batch Number	✓	✓
c) Flux Type and Lot Number		✓
d) WPS Number	✓	✓
e) PWHT Charts	✓	✓
f) Total Remaining PWHT Time Per Weld	✓	✓
g) Weld Maps	✓	✓
h) Weld Inspection Records	✓	✓
i) Sketch of Local PWHT Heater Size Location and Thermocouple Location	✓	✓
Welder Qualification Records	As per purchase order	✓
Test Report(s), Pressure Testing, and FAT		
a) Pressure Test Records	✓	✓
b) Factory Acceptance Test	✓	✓
Dimensions (as defined by OEM)	✓	✓
Bolting Traceability Records	✓	✓

Annex D
(normative)

Failure Reporting

D.1 Manufacturer's Requirements

D.1.1 Manufacturer's Internal Requirements

All significant problems experienced with drill-through equipment noted during its manufacture or testing shall be formally communicated to the individual or group within the manufacturer's organization responsible for the design and specification documents.

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 drill-through equipment.

D.2.2 Manufacturer's External Requirements

All failures experienced with drill-through equipment that prevent the equipment from meeting the functional requirements shall be reported in writing to every known equipment owner of the drill-through equipment within three weeks after notification of the occurrence.

The manufacturer shall communicate any design changes resulting from a malfunction, or failure history, to every owner of the affected equipment. That notice shall be within 30 days after the design change.

Annex E
(normative)

Minimum Requirements for Certificate of Conformance (COC)

E.1 General

This annex provides the minimum requirements for the Certificate of Conformance for equipment covered by the scope of API 16A. Format changes are allowed.

E.2 Certificate Requirements

E.2.1 Company Information

The Certificate of Conformance shall contain the name and contact details of the manufacturing company from whom it is issued.

E.2.2 Certificate Issue Date

The Certificate of Conformance shall contain the date when it is issued.

E.2.3 Customer Information

The Certificate of Conformance shall contain the name of the customer and the relevant purchase order number.

E.2.4 Additional Tracking Information

Additional tracking information may be included for company internal purposes, such as work order or certificate number.

E.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.

E.2.6 Additional Endorsements

The certificate may indicate applicable additional endorsements, such as conformance with NACE or other industry specifications. If an API monogram is included, the API standard number and facility license number shall be provided.

E.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 shall be provided;

— Traceability: a number traceable to 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.

E.2.8 Ratings

The certificate shall include a list of applicable ratings, including a minimum of:

— rated working pressure;

— rated temperature of metallic components;

— design temperature of nonmetallic components;

— environmental limits, according to NACE MR0 175/ISO 15156, based on the rated working pressure and maximum temperature rating of metallic components.

E.2.9 Record Retention

The certificate shall state the manufacturer's record-retention policy.

E.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.

E.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.

E.3 Example Certificate of Conformance

Figure E.1 contains an example certificate of conformance:

Company Logo

Company Name:

Company Address:

Company telephone number:

CERTIFICATE OF CONFORMANCE

Certificate Issue Date:	
Customer:	
Customer Purchase Order:	
Work Order No.:	
Certificate Number:	

This certificate confirms that the equipment requested per the above purchase order and listed below has been manufactured in conformance with:
• API Specification 16A, "Specification for Drill-through Equipment," 4th Edition.
•
•
•

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 based 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.) • Chloride concentration, mg/l (max.)

• pH (min.) • Elemental sulphur resistant (yes or no)
Other limitation:

C. List of Certified Equipment:

Item	Assembly or Part No.	PR	Qty.	Description	Serial Number(s)
1					
2					
3					

Certificate of Conformance Approval

Signature Signature

Name: Name:

Title: Title:

Date: Date:

Controlled Document No. Revision Date/Level

Revision Date/Level

Figure E.1—Example Certificate of Conformance

Annex F
(normative)

Charpy V-notch Impact Test Location for Weld Qualification

When impact testing is required, the testing shall be performed in accordance with ASTM A370 using the Charpy V-notch technique. Results of testing in the weld and HAZ shall meet the minimum requirements of the base material, for both average and minimum toughness requirements.

If any one of the three specimens falls below the minimum allowed toughness requirement, two additional Charpy test specimens will be required from that area, and both shall be at or above the minimum toughness requirement. Records of results shall become part of the PQR.

The number and location of the Charpy V-notch impact test specimen shall be in accordance with Figure F.1, following the sampling requirements in relation with the material thickness, weld type, and weld thickness used for the qualification:

— Less or equal to 19 mm (0.75 inch): Charpy specimens shall be taken from the external surface (within 1.5 mm from the surface), and shall be subject to the requirements for multi-process and double-sided welds.

— Greater than 19 mm (0.75 inch) to less than 38 mm (1.5 inch): Charpy specimens shall be taken from the external and internal surface (within 2 mm from both surfaces), and shall be subject to the requirements for multi-process and double-sided welds.

— Greater or equal to 38 mm (1.5 inch): Charpy specimens shall be taken from the external and internal surfaces within 2 mm (0.1 inch) from both surfaces and from the mid-wall position, and shall be subject to the requirements for multi-process and double-sided welds.

When impact testing is required, sets of three test specimens shall be removed from the weld and heat-affected zone.

If multiple welding processes are used to produce the weldment, the weld metal and appropriate HAZ test specimens shall be removed for each welding process.

On double-sided welds, weld metal from the root region containing consumed tack welds made with different weld metal should be Charpy tested.

NOTE The manufacturer can decide to take an impact specimen as near as practical at the midway thickness of the weld for qualification of a single V groove.

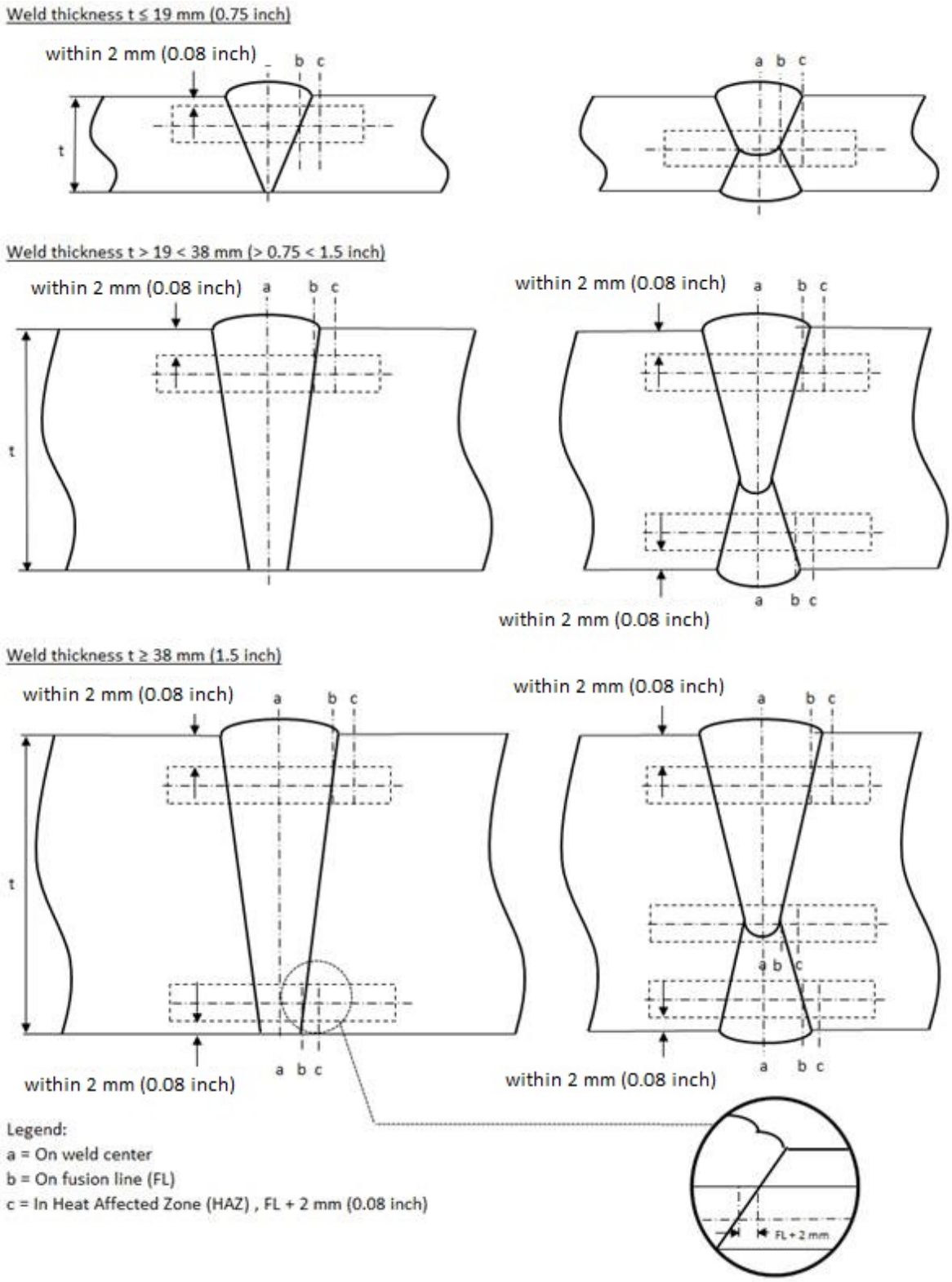


Figure F.1—Location of Charpy V-notch Impact Test

Annex G
(informative)

Conversion of U.S. Customary Units to the SI System (Metric)

G.1 General

The purpose of this annex is to document the rules for conversion of U.S. 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 16A. 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. This procedure is graphically illustrated in Figure G.1. 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 For more information, see ISO 8000 (all parts).

G.2 Conversion Rules

USC dimensions are converted from the dimensional tables of API 16A in the following manner:

a) 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 $7\ ^{1}/_{16}$ in, or 7.0625 in.

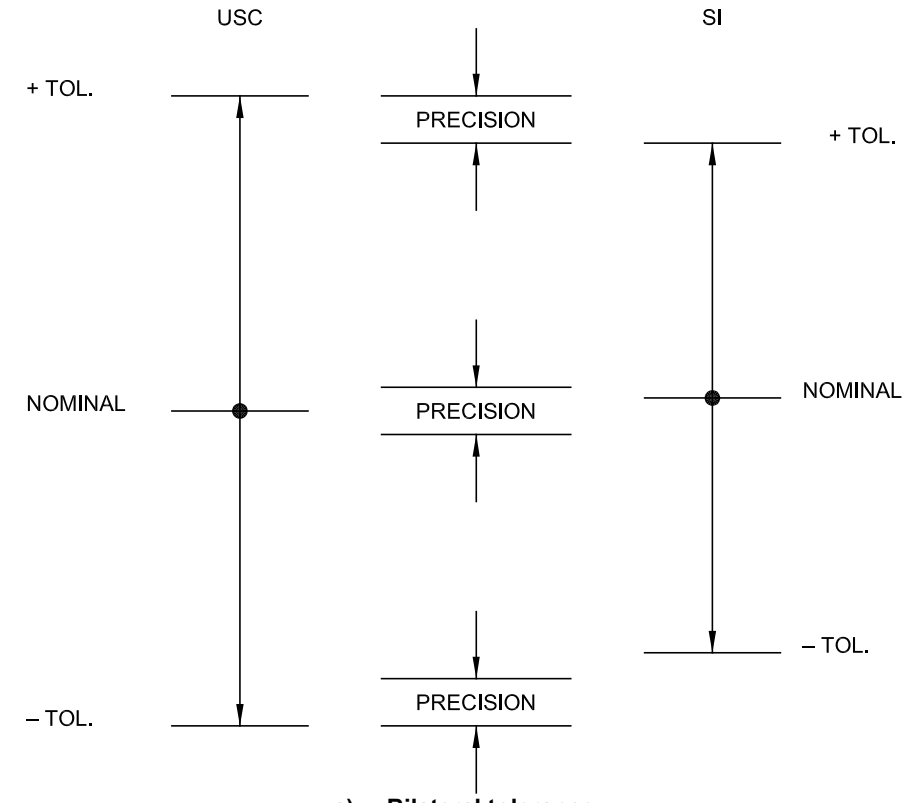
b) Multiply the resulting exact decimal equivalent of the fractional-inch dimension by 25.4 mm to obtain the exact millimeter dimension. Example: $7\ ^{1}/_{16}$ in $=$ 7.0625 in $=$ 179.3875 mm.

c) Round for the particular dimension. Rounding rules differ for different dimensions, depending on the function of the dimension, and involve several steps.

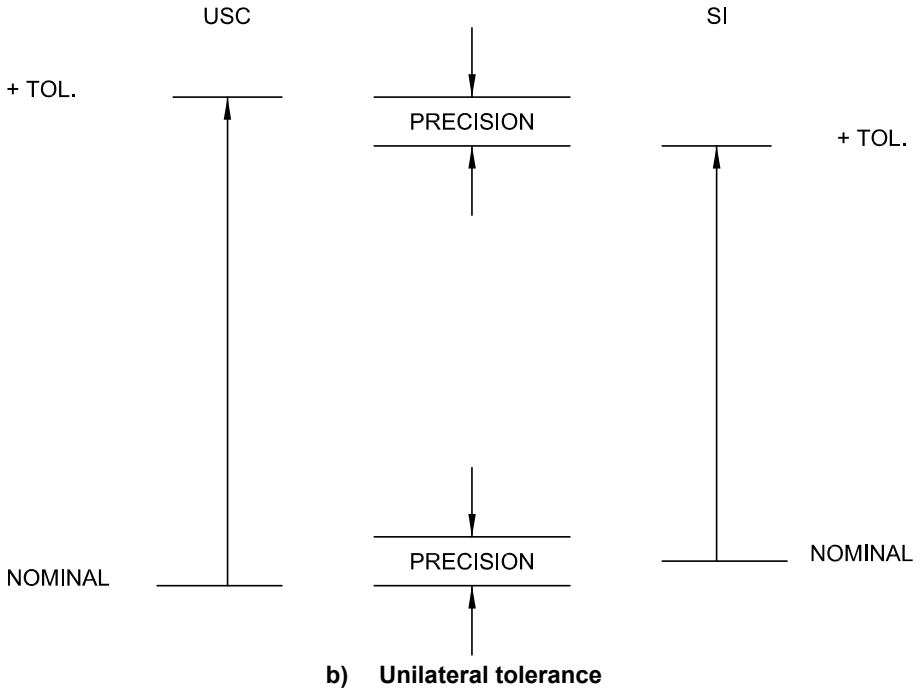
   1) Determine the precision required of the USC dimension. The precision should normally be smaller than one-tenth of the tolerance range. For example, a dimension with a $\pm$ 0.015 in tolerance would require a converted dimension precision of $1/10 \times 0.030$ in $\times$ 25.4 mm/in $=$ 0.0762 mm. 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 0.0762 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.



a) **Bilateral tolerance**



b) **Unilateral tolerance**

Figure G.1—Metric Conversions

Example: $7\ ^{1}/_{16}$ in + 0.031 / 0 in bore

The precision of the converted dimension should be
$^{1}/_{10} \times\ ^{1}/_{32}$ in × 25.4 mm/in = 0.079375 mm ≈ 0.05 mm.

For the minimum extreme: $7\ ^{1}/_{16}$ in = 7.0625 in = 179.3875 mm ≈ 179.40 mm.

For the maximum extreme: $7\ ^{1}/_{16} + \ ^{1}/_{32}$ in = 7.09375 in = 180.18125 mm ≈ 180.15 mm.

G.3 Pressure Ratings

Pressure ratings in the SI system are expressed in megapascals (MPa).

The pressures in API Specification 16A are required to be measured within an accuracy of ± 0.5 % of full scale. For a 5,000 psi rating, this would be ± 25 psi (± 0.172 MPa). Since one-tenth of the tolerance is 5 psi (0.034474 MPa), the converted dimension should be rounded to the nearest ± 0.02 MPa. Thus, 5,000 psi is rounded to 34.48 MPa. API pressure ratings are converted as shown in Table G.1.

Table G.1—Pressure Ratings

USC Values		Converted (SI) Values		Precision	Rounded SI Values	
Nominal	Max.	Nominal	Max.		Nominal	Max.
psi	psi	MPa	MPa	MPa	MPa	MPa
2,000	2,010	13.789514	13.858462	0.01	13.79	13.85
3,000	3,015	20.684271	20.787692	0.01	20.68	20.77
5,000	5,025	34.473785	34.646154	0.02	34.48	34.64
10,000	10,050	68.947570	69.292308	0.02	68.94	69.26
15,000	15,075	103.421355	103.938462	0.05	103.40	103.85
20,000	20,100	137.895140	138.584616	0.05	137.90	138.55
25,000	25,000	172.36875			172.37	
30,000	30,000	206.8425			206.84	

G.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 16A equipment are in accordance with Table G.2.

Table G.2—Nominal Sizes

USC Values			Converted (SI) Values		Precision	Rounded SI Values	
Size	Min.	Max.	Min.	Max.		Min.	Max.
in	in	in	Mm	mm	mm	mm	mm
1 13/16	1.8125	1.8435	46.0375	46.8249	0.05	46.05	46.80
2 1/16	2.0625	2.0935	52.3875	53.1749	0.05	52.40	53.15
2 9/16	2.5625	2.5935	65.0875	65.8749	0.05	65.10	65.85
3 1/16	3.0625	3.0935	77.7875	78.5749	0.05	77.80	78.55
3 1/8	3.1250	3.1560	79.3750	80.1624	0.05	79.40	80.15
4 1/16	4.0625	4.0935	103.1875	103.9749	0.05	103.20	103.95
7 1/16	7.0625	7.0935	179.3875	180.1749	0.05	179.40	180.15
9	9.000	9.031	228.6000	229.3874	0.05	228.60	229.35
11	11.000	11.031	279.4000	280.1874	0.05	279.40	280.15
13 5/8	13.625	13.656	346.0750	346.8624	0.05	346.10	346.85
16 3/4	16.750	16.781	425.4500	426.2374	0.05	425.45	426.20
18 3/4	18.750	18.781	476.2500	477.0374	0.05	476.25	477.00
20 3/4	20.750	20.781	527.05	527.8374	0.05	527.05	527.80
21 1/4	21.250	21.281	539.7500	540.5374	0.05	539.75	540.50
26 3/4	26.750	26.781	679.450	680.2374	0.05	579.45	680.20
30	30.000	30.031	752.000	762.7874	0.05	752.00	762.80

G.5 Conversion Factors

G.5.1 Length

1 inch (in) = 25.4 millimeters (mm), exactly.

G.5.2 Pressure/stress

1 pound per square inch (psi) = 0.006894757 megapascals (MPa).

G.5.3 Impact Energy

1 foot-pound (ft-lb) = 1.355818 joules (J).

G.5.4 Torque

1 foot-pound (ft-lb) = 1.355818 newton meters (N·m).

G.5.5 Force

1 pound-force (lbf) = 4.448222 newtons (N).

Bibliography

[1] API Specification 7-2, *Specification for Threading and Gauging of Rotary Shouldered Thread Connections*

[2] API 16AR, *Standard for Repair and Remanufacturing of Drill-through Equipment*

[3] ASTM E92, *Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials*

[4] ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

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

[6] ASTM E709, *Standard Guide for Magnetic Particle Testing*

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

[8] ASTM A453/A453M, *Standard Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels*

[9] IEEE/ASTM SI10, *American National Standard for Metric Practice*

[10] ISO 80000-1, *Quantities and Units -- Part 1: General*

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