INTERNATIONAL STANDARD

ISO 13533

First edition
2001-12-01

Petroleum and natural gas industries — Drilling and production equipment — Drill-through equipment

Industries du pétrole et du gas naturel — Équipements de forage et de production — Équipements à travers lesquels s'effectue le forage

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13533 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

Annexes A and B form a normative part of this International Standard. Annexes C, D, E, F, G and H are for information only.

Introduction

This International Standard is based on API Specification 16A, second edition, 1 June 1998.

This International Standard is intended to provide for the availability of safe and functionally interchangeable drill-through equipment utilized in the petroleum and natural gas industry.

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

For the convenience of users of this International Standard, annex H provides a list of those normative International Standards cited in clause 2 with national or regional standards which have been found mutually applicable in the context of the requirements in the text. The user may optionally apply the national or regional standard in the context of the requirement for which the International Standard is cited.

Petroleum and natural gas industries — Drilling and production equipment — Drill-through equipment

1 Scope

This International Standard specifies 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 will be designed.

This International Standard 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 connectors;

f) drilling spools;

g) adapters;

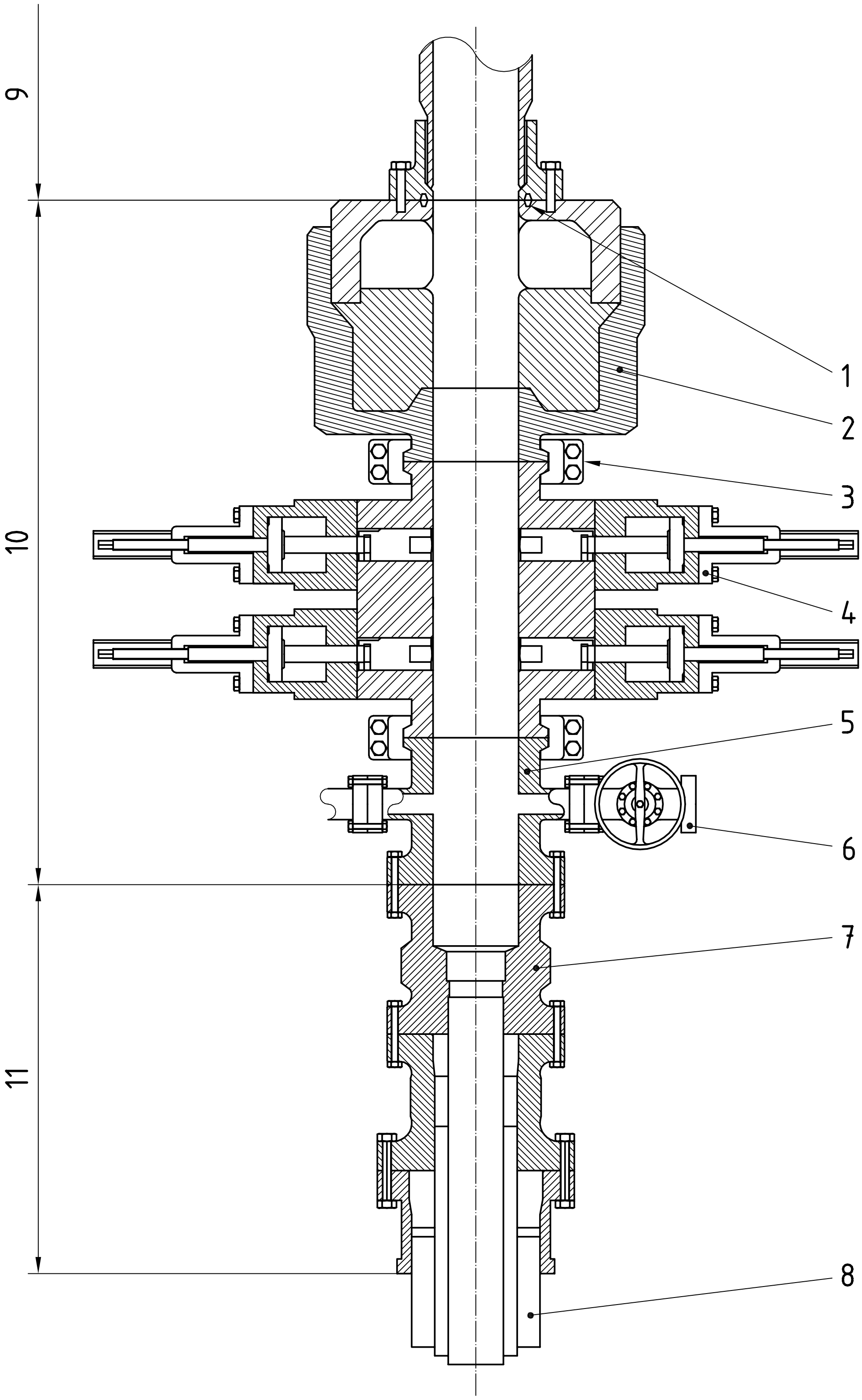
h) loose connections;

i) clamps.

Dimensional interchangeability is limited to end and outlet connections.

Typical equipment defined by this International Standard is shown in Figures 1 and 2; recommendations for failure reporting are outlined in annex F.

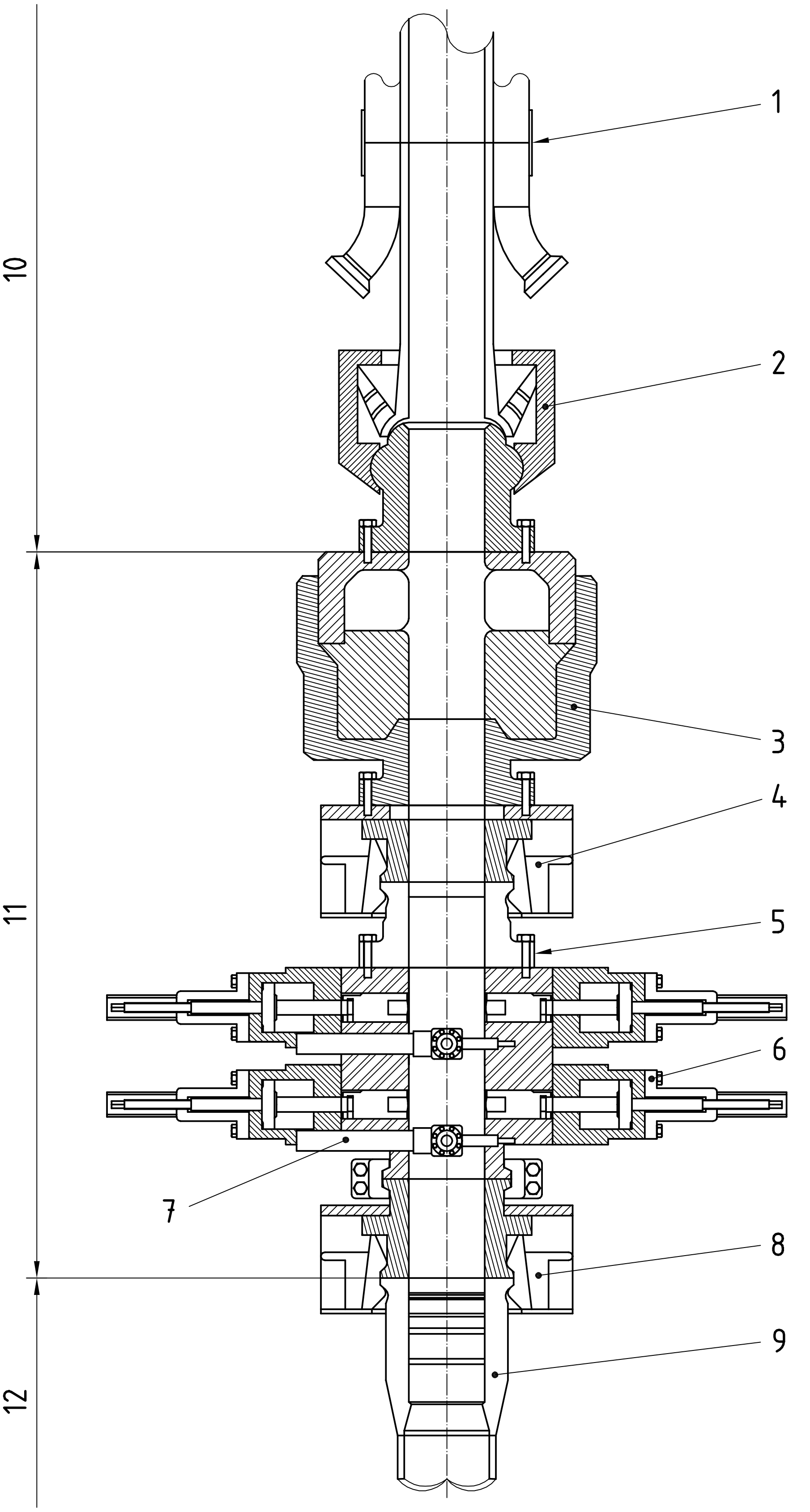
This International Standard does not apply to field use or field testing of drill-through equipment.



Key

1 Ring gaskets ISO 10423
2 Annular BOP
3 Clamp
4 Ram BOP
5 Drilling spool
6 Valve ISO 10423
7 Wellhead
8 Casing
9 End and outlet connections
10 Drill-through equipment ISO 13533
11 Wellhead equipment ISO 10423

Figure 1 — Typical surface drill-through equipment



Key

1 Riser connector
2 Flex/ball joint
3 Annular BOP
4 Hydraulic connector
5 Adapter
6 Ram BOP
7 Valve ISO 10423
8 Hydraulic connector
9 Wellhead
10 Riser equipment
11 Drill-through equipment ISO 13533
12 Wellhead equipment ISO 10423

Figure 2 — Typical subsea drill-through equipment

2 Normative references

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2859-1:1989, *Sampling procedures for inspection by attributes — Part 1: Sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection*

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

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

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

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

ISO 10423:2001, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and christmas tree equipment*

ISO 11961:1996, *Petroleum and natural gas industries — Steel pipes for use as drill pipe — Specification*

ISO 13665, *Seamless and welded steel tubes for pressure purposes — Magnetic particle inspection of the tube body for the detection of surface imperfections*

API Bulletin 6AF, *Capabilities of API flanges under combinations of load*

ASME Boiler and Pressure Vessel Code Section V, Article 5, *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, Pressure Vessel — Alternate Rules, Appendix 4, *Design Based on Stress Analysis*

ASME Boiler and Pressure Vessel Code Section VIII, Division 2, Pressure Vessel — Alternate Rules, Appendix 6, *Experimental Stress Analysis*

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

ASTM A 193:1999, *Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service*

ASTM A 320:1999, *Specification for Alloy Steel Bolting Materials for Low Temperature Service*

ASTM A 370:1997, *Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A 453:1999, *Specification for Bolting Materials, High Temperature, 50 to 120 ksi Yield Strength, with Expansion Coefficients Comparable to Austenitic Steels*

ASTM D 395:1998, *Standard Test Methods for Rubber Property — Compression Set*

ASTM D 412:1998, *Test Methods for Vulcanized Rubber, Thermoplastic Rubbers and Thermoplastic Elastomers*

ASTM D 471:1998, *Standard Test Method for Rubber Property — Effect of Liquids*

ASTM D 1414:1994, *Standard Test Methods for Rubber O-Rings*

ASTM D 1415:1994, *Standard Test Method for Rubber Property — International Hardness*

ASTM D 1418:1999, *Standard Practice for Rubber and Rubber Lattices — Nomenclature*

ASTM D 2240:1997, *Test Method for Rubber Property — Durometer Hardness*

ASTM E 94:1993, *Standard Guide for Radiographic Testing*

ASTM E 140:1999, *Hardness Conversion Tables for Metals*

ASTM E 165:1995, *Standard Test Method for Liquid Penetrant Examination*

ASTM E 569:1997, *Standard Practice for Acoustic Emission Monitoring of Structures During Controlled Simulation*

ASTM E 747:1997, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality Indicators (IQI) used for Radiography*

ASNT-SNT-TC-1A:1992, *Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing*

NACE MR0175–2000, *Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*

SAE AMS-H-6875A:1998, *Heat Treatment of Steel Raw Materials*

3 Terms and definitions

For the purpose of this International Standard, the following terms and definitions apply.

3.1
acceptance criteria
defined limits placed on characteristics of materials, products or service

3.2
adapter
pressure-containing piece of equipment having end connections of different nominal size designation and/or pressure rating

3.3
annular blowout preventer
blowout preventer that uses a shaped elastomeric sealing element to seal the space between the tubular and the wellbore or an open hole

3.4
blind connection
end or outlet connection with no centre bore, used to completely close off a connection

3.5
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

3.6
blind ram
closing and sealing component in a ram blowout preventer that seals the open wellbore

3.7
blowout preventer
BOP
equipment (or valve) installed at the wellhead to contain wellbore pressure either in the annular space between the casing and the tubulars or in an open hole during drilling, completion, testing or workover operations

3.8
body
any portion of equipment between end connections, with or without internal parts, which contains wellbore pressure

3.9
bolting
threaded fasteners used to join end or outlet connections

3.10
calibration
comparison and adjustment to a standard of known accuracy

3.11
cast, verb
pour molten metal into a mould to produce an object of desired shape

3.12
casting, noun
object at or near finished shape obtained by solidification of a substance in a mould

3.13
chemical analysis
determination of the chemical composition of material

3.14
clamp, noun
device with internal angled shoulders used to fasten mating hubs

3.15
clamping load
axial load applied to clamp hubs by the clamp due to bolt tightening

3.16
closure bolting
threaded fasteners used to assemble pressure-containing parts other than end and outlet connections

3.17
conformance
compliance with specified requirements in every detail

3.18
corrosion-resistant ring groove
ring groove lined with metal resistant to metal-loss corrosion

3.19
critical component
part having requirements specified in this International Standard

3.20
data acquisition system
system for storing and/or providing permanent copies of test information

EXAMPLES Strip chart recorders, circular chart recorders or computer systems.

3.21
date of manufacture
date of the manufacturer's final acceptance of finished equipment

3.22
drilling spool
pressure-containing piece of equipment having end connections, used below or between drill-through equipment

NOTE When outlet connections are provided, they shall be manufactured in accordance with this International Standard.

3.23
end connection
flange (studded or open-face), hub connection or **other end connection** (3.47) used to join together equipment and integral to that equipment

3.24
equipment
any single completed unit that can be used for its intended purpose without further processing or assembly

3.25
fabrication weld
weld joining two or more parts

3.26
flange
protruding rim, with holes to accept bolts and having a sealing mechanism, used to join pressure-containing equipment together by bolting to another flange

3.27
forge, verb
plastically deform metal, usually hot, into desired shapes with compressive force, with open or closed dies

3.28
forging, noun
shaped metal part formed by the forging method

3.29
full-penetration weld
weld that extends throughout the complete wall section of the parts joined

3.30
gasket-seating load
that portion of the clamping load required to seat the gasket and bring the hub faces into contact

3.31
gasket-retaining load
that portion of the clamping load required to offset the separating force the gasket exerts on the hubs when pressurized

3.32
heat-affected zone
HAZ
that portion of the base metal which has not been melted, but whose mechanical properties or microstructure has been altered by the heat of welding or cutting

3.33
heat
cast lot
material originating from a final melt

NOTE For remelted alloys, a heat is defined as the raw material originating from a single remelted ingot.

3.34
heat treatment
heat treating
alternate steps of controlled heating and cooling of materials for the purpose of changing physical or mechanical properties

3.35
heat treatment load
that material moved as a batch through one heat treatment cycle

3.36
hot-work, verb
deform metal plastically at a temperature above the recrystallization temperature

3.37
hub
protruding rim with an external angled shoulder and a sealing mechanism used to join pressure-containing equipment

3.38
hydraulic connector
hydraulically actuated drill-through equipment that locks and seals on end connections

3.39
indication
visual sign of cracks, pits or other abnormalities found during liquid penetrant and magnetic particle examinations

3.40
integral, adj
⟨parts⟩ joined by the forging, casting or welding process

3.41
job-lot traceability
ability for parts to be traced as originating from a job lot which identifies the included heat(s)

3.42
leakage
visible passage of pressurized fluid from the inside to the outside of the pressure-containment area of the equipment being tested

3.43
linear indication
⟨liquid penetrant or magnetic particle examination⟩ indication whose length is equal to or greater than three times its width

3.44
loose connection
flange (studded or open-face), hub connection or **other end connection** (3.47) used to join together equipment, but not integral to the equipment

3.45
major repair weld
weld whose depth is greater than 25 % of the original wall thickness or 25 mm, whichever is less

3.46
non-pressure-containing weld
weld whose failure will not reduce the pressure-containing integrity of the component

3.47
other end connection
OEC
connection which is not specified in an ISO standard

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

3.48
part
individual piece used in the assembly of a single unit of equipment

3.49
pipe ram
closing and sealing component in a ram blowout preventer that seals around tubulars in the wellbore

3.50
post-weld heat treatment
PWHT
any heat treatment subsequent to welding, including stress relief

3.51
pressure-containing part
pressure-containing member
part exposed to wellbore fluids whose failure to function as intended would result in a release of wellbore fluid to the environment

EXAMPLES Bodies, bonnets and connecting rods.

3.52
pressure-containing weld
weld whose failure will reduce the pressure-containing integrity of the component

3.53
pressure-controlling part
pressure-controlling member
part intended to control or regulate the movement of wellbore fluids

EXAMPLES Packing elements, rams, replaceable seats within a pressure-containing member or part.

3.54
pressure end load
axial load resulting from internal pressure applied to the area defined by the maximum seal diameter

3.55
pressure-retaining part
pressure-retaining member
part not exposed to wellbore fluids whose failure to function as intended will result in a release of wellbore fluid to the environment

EXAMPLES Closure bolts and clamps.

3.56
product family
model or type of specific equipment listed in clause 1 of this International Standard

3.57
qualified personnel
individual with characteristics or abilities gained through training, experience or both, as measured against the manufacturer's established requirements

3.58
ram blowout preventer
blowout preventer that uses metal blocks with integral elastomer seals to seal off pressure on a wellbore with or without tubulars in the bore

3.59
rated working pressure
maximum internal pressure that the equipment is designed to contain and/or control

3.60
record, noun
retrievable information

3.61
relevant indication
⟨liquid penetrant or magnetic particle examination⟩ any indication with a major dimension over 1,6 mm (0,062 in)

3.62
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

3.63
repair
process disassembly, reassembly and testing of drill-through equipment, with or without the replacement of parts

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

3.64
rounded indication
⟨liquid penetrant or magnetic particle examination⟩ any indication that is approximately circular or elliptical and whose length is less than three times its width

3.65
serialization
assignment of a unique code to individual parts and/or pieces of equipment to maintain records

3.66
special process
operation which converts or affects material properties

3.67
stabilized
⟨pressure testing⟩ in a 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.

3.68
stabilized
⟨temperature testing⟩ in a state in which the initial temperature fluctuations have decreased to within the manufacturer's specified range

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

3.69
standard connection
flange, hub or studded connection manufactured in accordance with an ISO standard, including dimensional requirements

3.70
stress relief
controlled heating of material to a predetermined temperature for the purpose of reducing any residual stresses

3.71
studded connection
connection in which thread-anchored studs are screwed into tapped holes

3.72
surface finish
Ra
measurement of the average roughness of a surface

NOTE 1 It is expressed in micrometres (µm).

NOTE 2 All of the surface finishes given in this International Standard are to be considered maxima.

3.73
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

3.74
variable-bore ram
VBR
closing and sealing component in a ram blowout preventer that is capable of sealing on a range of tubular sizes

3.75
visual examination
examination of parts and equipment for visible defects in material and workmanship

3.76
volumetric non-destructive examination
examination for internal material defects by radiography, acoustic emission or ultrasonic testing

3.77
weld groove
area between two metals to be joined that has been prepared to receive weld filler metal

3.78
weld, verb
act of fusing materials, with or without the addition of filler materials

3.79
weld joint
fitting together of components in order to facilitate their joining by welding

3.80
wrought structure
structure that contains no cast dendritic structure

3.81
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 It is expressed in newtons per square millimetre (pounds per square inch) of loaded area.

NOTE 2 All yield strengths specified in this International Standard are considered as being the 0,2 % yield offset strength in accordance with ISO 6892.

4 Abbreviated terms

ANSI	American National Standards Institute
API	American Petroleum Institute
AQL	acceptance quality level
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BOP	blowout preventer
HAZ	heat-affected zone
ID	inside diameter
LP	liquid penetrant
MP	magnetic particle
NACE	National Association of Corrosion Engineers
NDE	non-destructive examination
OD	outside diameter
OEC	other end connection
OEM	original equipment manufacturer
OS	operating system
PQR	procedure qualification record
VBR	variable-bore ram
WPS	welding procedure specification

5 Design requirements

5.1 Size designation

Equipment to which this International Standard is applicable shall have a vertical through-bore dimension (drift diameter) corresponding with the size designation as shown in Table 1.

Table 1 — Equipment size

Nominal size designation		Drift 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

5.2 Service conditions

5.2.1 Rated working pressure

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

Table 2 — Equipment rated working pressures

MPa	(psi)
13,8	2 000
20,7	3 000
34,5	5 000
69,0	10 000
103,5	15 000
138,0	20 000

5.2.2 Temperature ratings

Minimum temperature is the lowest ambient temperature to which the equipment may be subjected. Maximum temperature is the highest temperature of the fluid that may flow through the equipment.

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

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

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

Table 3 — Temperature ratings for metallic materials

Classification	Operating range °C	Operating range °F
T-75	− 59 to 121	− 75 to 250
T-20	− 29 to 121	− 20 to 250
T-0	− 18 to 121	0 to 250

Table 4 — Temperature ratings for non-metallic sealing materials

Lower limit (first digit)			Upper limit (second digit)		
Code	Temperature °C	Temperature (°F)	Code	Temperature °C	Temperature (°F)
A	− 26	− 15	A	82	180
B	− 18	0	B	93	200
C	− 12	10	C	104	220
D	− 7	20	D	121	250
E	− 1	30	E	149	300
F	4	40	F	177	350
G	Other	Other	G	Other	Other
X	See note	See note	X	See note	See note

NOTE These components may carry a temperature class of 4 °C to 82 °C (40 °F to 180 °F) without performing temperature verification testing provided they are marked as temperature class “XX”.

EXAMPLE Material “EB” has a temperature rating of − 1 °C to 93 °C (30 °F to 200 °F).

5.2.3 Retained fluid ratings

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

5.3 Equipment-specific design requirements

5.3.1 Flanged end and outlet connections

5.3.1.1 General

Flanged end and outlet connections shall conform to the dimensional requirements of ISO 10423.

Type 6B and API 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.

Table 5 — Pressure rating and size ranges of ISO 10423 flange connectors

Pressure rating		Type 6B	Type 6BX
MPa	(psi)		
13,8	2 000	2 1/6 to 21 1/4	26 3/4 to 30
20,7	3 000	2 1/16 to 20 3/4	26 3/4 to 30
34,5	5 000	2 1/16 to 11	13 5/8 to 21 1/4
69,0	10 000		1 13/16 to 21 1/4
103,5	15 000		1 13/16 to 18 3/4
138,0	20 000		1 13/16 to 13 5/8

5.3.1.2 API type 6B flange connections

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

Dimensions for type 6B integral flanges shall conform to ISO 10423.

Dimensions for all ring grooves shall conform to ISO 10423.

5.3.1.3 API type 6BX flange connections

Type 6BX flanges are of the ring joint type and are designed with a raised face. Depending on tolerances, the connection make-up bolting 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. Therefore, one of the flanges in a 6BX connection shall have a raised face. The type 6BX flange shall be of the through-bolted or studded design.

Dimensions for type 6BX integral flanges shall conform to ISO 10423.

Dimensions for all ring grooves shall conform to ISO 10423.

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

5.3.2 Studded end and outlet connections

5.3.2.1 General

The two types of studded end and outlet connections (6B and 6BX) referred to in this International Standard shall conform to ISO 10423.

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

The design for studded end and outlet connections shall be the same as specified in 5.3.1.1, except as required in 5.3.2.2 and 5.3.2.3.

5.3.2.2 Type 6B studded connections

Dimensions for type 6B studded connections shall conform to ISO 10423 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 ISO 10423.

Stud bolt holes shall be sized and located to conform to ISO 10423. The thread form of the tapped hole shall conform to the requirements of 5.3.3. 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.

5.3.2.3 Type 6BX studded connections

Dimensions for Type 6BX studded connections shall conform to ISO 10423 concerning bore size, diameter of the bolt circle and flange OD.

The studded connection shall be fully machined in accordance with ISO 10423.

Stud bolt holes shall be sized and located in accordance with ISO 10423. The thread form of the tapped hole shall conform to the requirements of 5.3.3. 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.

5.3.3 Studs, nuts and tapped stud holes (bolting)

Bolting for end and outlet connections, both studded and flanged, shall meet the requirements of ISO 10423.

5.3.4 Hubbed end and outlet connections

5.3.4.1 General

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

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

16B and 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 6.

Table 6 — Pressure ratings and size ranges of type 16B and 16BX hubs

Pressure rating		Type 16B	Type 16BX
MPa	(psi)		
13,8	2 000	7 1/6, 16 3/4, 21 1/4	
20,7	3 000	11, 13 5/8, 16 3/4	
34,5	5 000		2 1/16 to 21 1/4
69,0	10 000		1 13/16 to 21 1/4
103,5	15 000		1 13/16 to 18 3/4
138,0	20 000		1 13/16 to 11

5.3.4.2 Type 16B hubs

Type 16B hubs are of the ring joint type and are designed for face-to-face make-up. The type RX ring gasket is used for these connections. In order to accomplish a face-to-face make-up, the special type SR ring grooves shall be used as listed in Table 7 and Table 8.

Dimensions for type 16B integral hubs shall conform to Table 7 or Table 8 and to Figure 3.

Dimensions for type 16B blind hubs shall conform to Table 7 or Table 8 and to Figure 4.

Dimensions for ring grooves shall conform to Table 9 and Figure 5. All 23° surfaces of ring grooves shall have a surface finish no rougher than *Ra* = 1,6 µm [63 µin (micro-inch) RMS].

Type 16B hubs shall use type RX gaskets in accordance with 5.3.7.

Type 16B hub connections may be manufactured with corrosion-resistant overlays in the ring grooves. Prior to overlay, the ring groove shall be prepared as specified in Table 10 and Figure 6.

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

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

Dimensions in millimetres (inches)

Surface roughness in micrometres

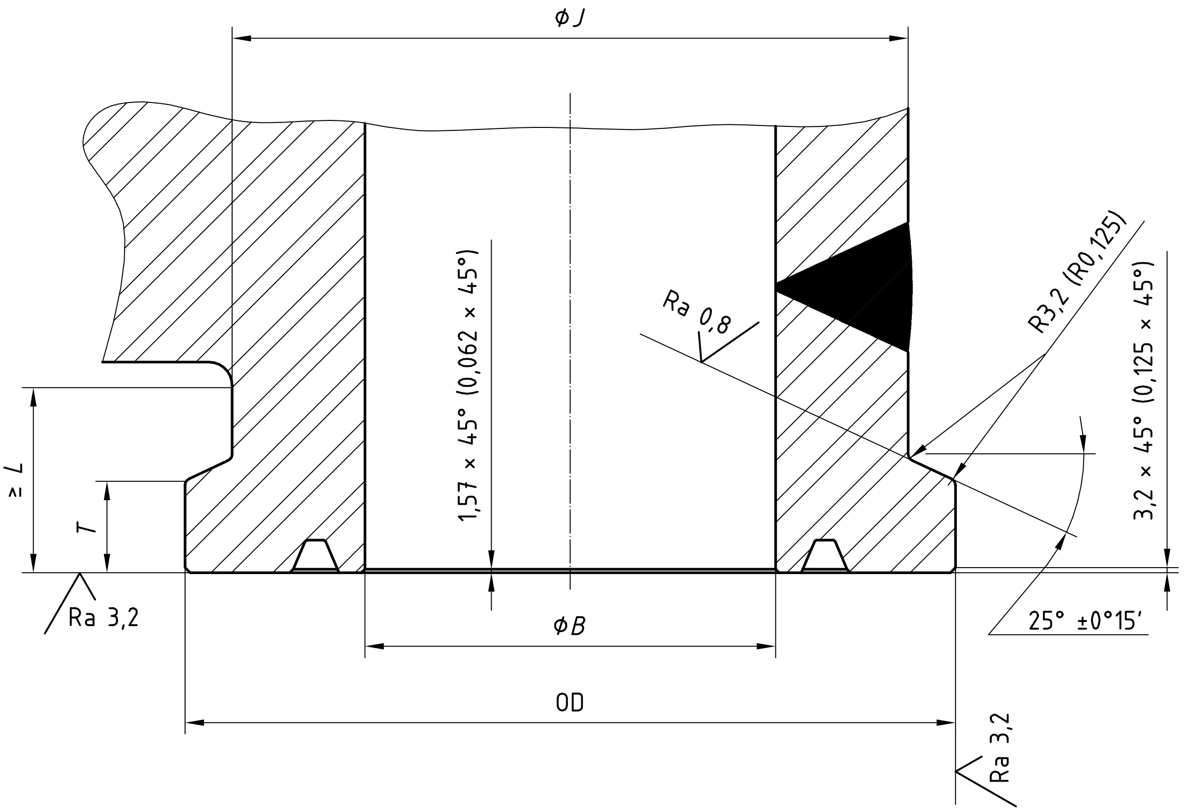
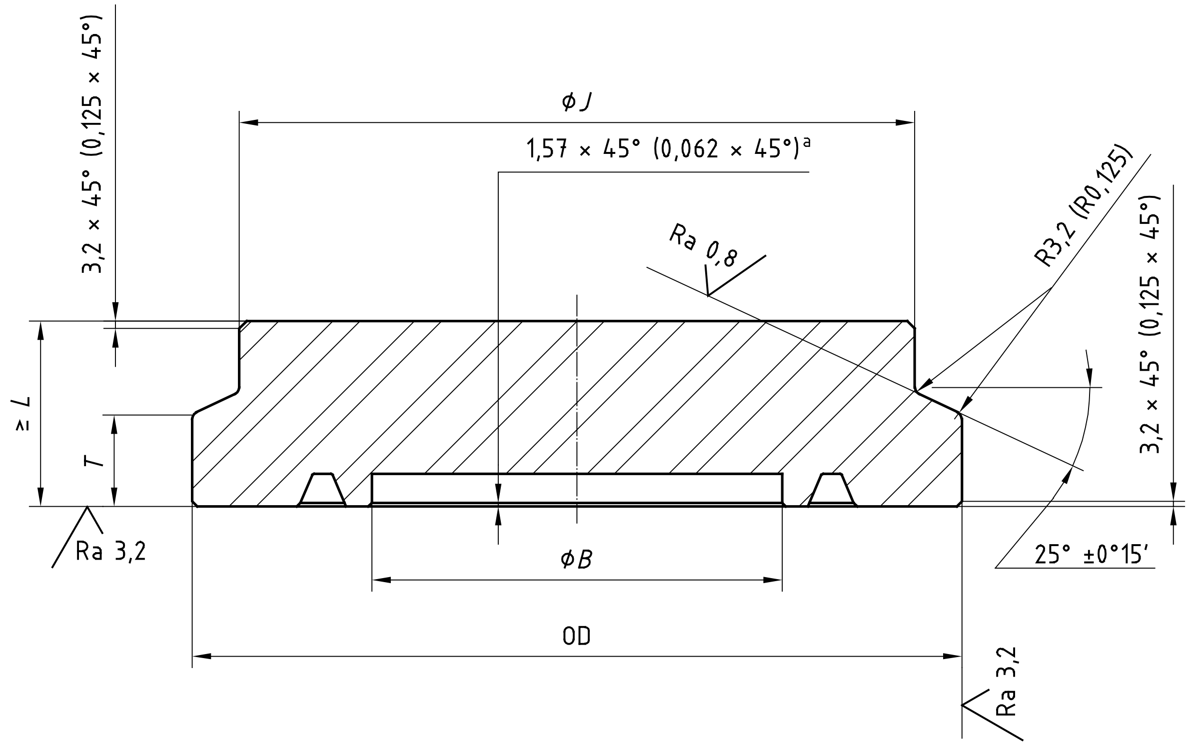


Figure 3 — Type 16B and 16BX integral hub connections

Dimensions in millimetres (inches)
Surface roughness in micrometres



NOTE 1 For 13,8 MPa (2 000 psi) and 20,7 MPa (3 000 psi) type 16B blind hubs, refer to Table 7 and Table 8 for hub dimensions, ring groove dimensions and tolerances. If corrosion-resistant inlay is used in ring grooves, refer to Table 9 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 (200 000 psi) type 16BX blind hubs, refer to Table 11, Table 12, Table 13 or Table 14 for hub dimensions, ring groove dimensions and tolerances. If corrosion-resistant inlay is used in ring grooves, refer to ISO 10423 for rough machining details.

[a] The counterbore of a type 16B or 16BX 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 on the appropriate ring groove dimension table.

Figure 4 — Type 16B and 16BX blind hubs

Table 7 — Type 16B integral hub connections for 13,8 MPa (2 000 psi) rated working pressure

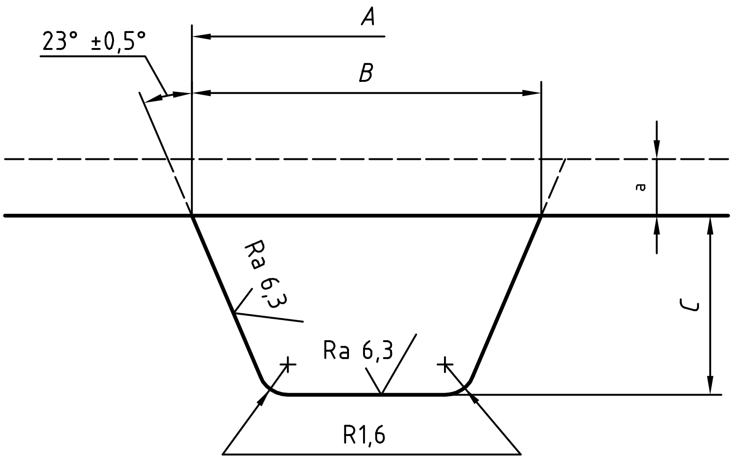
Nominal size	Bore	Outside diameter	Total thickness	Large diameter of neck	Minimum neck length	Ring groove number	Clamp number
	B	OD	*T*	*J*	*L*		
mm (in)	mm (in)	mm (in)	mm (in)	mm (in)	mm (in)		
179 (7 1/16)	179,40 (7,062)	263,52 (10,375)	36,64 (1,443)	225,40 (8,875)	63,5 (2,50)	SR-45	25
425 (16 3/4)	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 mm	0,75 / 0	0,10 / −0,10	0 / −0,22	0 / −0,70	−1,4		
(in)	(0,031 / 0)	(0,005 / −0,005)	(0 / −0,010)	(0 / −0,031)	(−0,06)		

Table 8 — 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)	84,0 (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 (in)	$^{0,75}_{0}$ $\left(^{0,031}_{0}\right)$	$^{0,10}_{-0,10}$ $\left(^{0,005}_{-0,005}\right)$	$^{0}_{-0,22}$ $\left(^{0}_{-0,010}\right)$	$^{0}_{-0,72}$ $\left(^{0}_{-0,031}\right)$	−1,4 (−0,06)		

Dimensions in millimetres (inches)

Surface roughness in micrometres



a The counterbore of a type 16B or 16BX 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 on the appropriate ring groove dimension table.

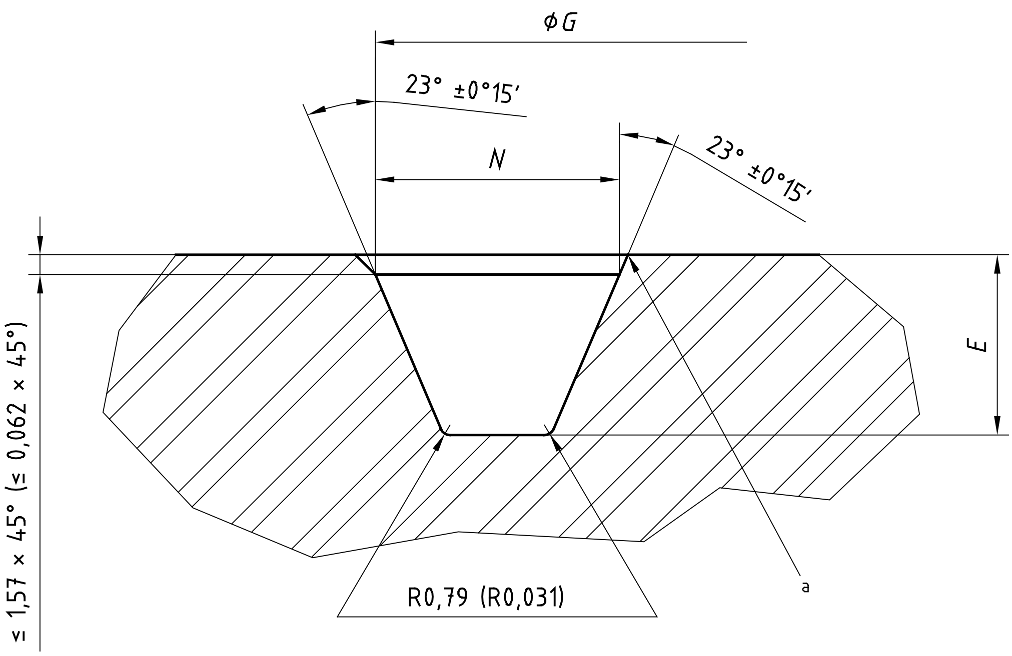
Figure 5 — Rough machining of type SR ring grooves

Table 9 — 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	236,62	9,316	23,98	0,944	17,75	0,699
SR-53	349,08	13,743	23,98	0,944	17,75	0,699
SR-57	405,48	15,964	23,98	0,944	17,75	0,699
SR-65	494,38	19,464	23,98	0,944	17,75	0,699
SR-73	611,68	24,082	26,92	1,060	20,96	0,825
Tolerance	$^{+7}_{0}$	$^{+0,3}_{0}$	$^{+7}_{0}$	$^{+0,3}_{0}$	$^{+7}_{0}$	$^{+0,3}_{0}$

NOTE Allow 3,2 mm (1/8 in) or greater for final machining of overlay.

Dimensions in millimetres (inches)



a Break sharp corner

Figure 6 — Finish machining of type SR ring grooves

Table 10 — Finish machining of type SR ring grooves

Ring groove number	Outside diameter of groove G mm	Outside diameter of groove G (in)	Width of groove N mm	Width of groove N (in)	Depth of groove E mm	Depth of groove E (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	$^{+0,09}_{0}$	$^{+0,004}_{0}$	$^{+0,09}_{0}$	$^{+0,004}_{0}$	$^{+0,38}_{0}$	$^{+0,016}_{0}$
NOTE Allow 3,2 mm (1/8 in) or greater for final machining of overlay.						

5.3.4.3 Type 16BX hubs

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

Dimensions for type 16BX integral hubs shall conform to Table 11, Table 12, Table 13 or Table 14 and Figure 3.

Dimensions for type 16BX blind hubs shall conform to Table 11, Table 12, Table 13 or Table 14 and Figure 4.

Dimensions for all ring grooves shall conform to ISO 10423.

Type 16BX hubs shall use type BX gaskets in accordance with 5.3.7.

Type 16BX hubs may be manufactured with corrosion-resistant overlays in the ring grooves. Prior to overlay, the ring grooves shall conform to ISO 10423.

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

The counterbore in a type 16BX hub is optional. 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.

5.3.5 Clamps

5.3.5.1 General

This subclause 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 5.3.4.

5.3.5.2 Design

Clamps shall be designed for use in the combination of designated size ranges and pressure ratings shown in Table 15. Clamps shall be designated by the clamp number shown in Table 15.

Clamp connectors shall be designed according to 5.4.2. Each clamp shall be designed for the highest loading that may be induced by any hub it is intended to fit.

Stresses shall be calculated at make-up, operating and test conditions.

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

a) the bolt load required to seat the gasket and bring the hub faces into contact, or

b) the bolt load required to retain the sum of the rated working pressure end load and the gasket-retaining load.

Make-up of the clamp shall be sufficient such that the hub faces meet and there is no 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 radius of the gasket as the sealing radius.

All clamps shall have grooves in their bores with angles of 25°± 0,25° to fit type 16B and type 16BX hubs.

All 25° surfaces in clamp grooves shall have a surface finish *Ra* of 0,8 µm (32 µin RMS) or less.

Table 11 — 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
78 (3 1/8)	79,40 (3,125)	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
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 (in)	$^{0,75}_{0}$ $\left(^{0,031}_{0}\right)$	$^{0,10}_{-0,10}$ $\left(^{0,005}_{-0,005}\right)$	$^{0}_{-0,22}$ $\left(^{0}_{-0,010}\right)$	$^{0}_{-0,70}$ $\left(^{0}_{-0,031}\right)$	$_{-1,4}$ $\left(_{-0,06}\right)$		

Table 12 — 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 1/8)	79,40 (3,125)	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
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 (in)	$^{0,75}_{0}$ $\left(^{0,031}_{0}\right)$	$^{0,10}_{-0,10}$ $\left(^{0,005}_{-0,005}\right)$	$^{0}_{-0,22}$ $\left(^{0}_{-0,010}\right)$	$^{0}_{-0,70}$ $\left(^{0}_{-0,031}\right)$	$-1,4$ $(-0,06)$		

Table 13 — 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
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 (in)	$^{+0,75}_{0}$ $\left(^{0,031}_{0}\right)$	$^{+0,10}_{-0,10}$ $\left(^{0,005}_{-0,005}\right)$	$^{0}_{-0,22}$ $\left(^{0}_{-0,010}\right)$	$^{0}_{-0,70}$ $\left(^{0}_{-0,031}\right)$	$-1,4$ $\left(-0,06\right)$		

Table 14 — Type 16BX integral hub connections for 138,0 MPa (20 000 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 3/16)	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 (in)	$^{+0,75}_{0}$ $\left(^{0,031}_{0}\right)$	$^{+0,10}_{-0,10}$ $\left(^{0,005}_{-0,005}\right)$	$^{0}_{-0,22}$ $\left(^{0}_{-0,010}\right)$	$^{0}_{-0,70}$ $\left(^{0}_{-0,031}\right)$	$-1,4$ $\left(-0,06\right)$		

The coefficient of friction shall be considered and shall be + 0,1 at make-up and − 0,1 while operating. Friction, therefore, inhibits make-up and assists in holding the connection at operating and test conditions.

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

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 5.4.3. Torque values for clamp bolting shall be determined by the manufacturer to suit his design.

5.3.5.3 Material

Clamps shall be manufactured from material conforming to this International Standard. Material requirements of NACE MR0175 are not necessary.

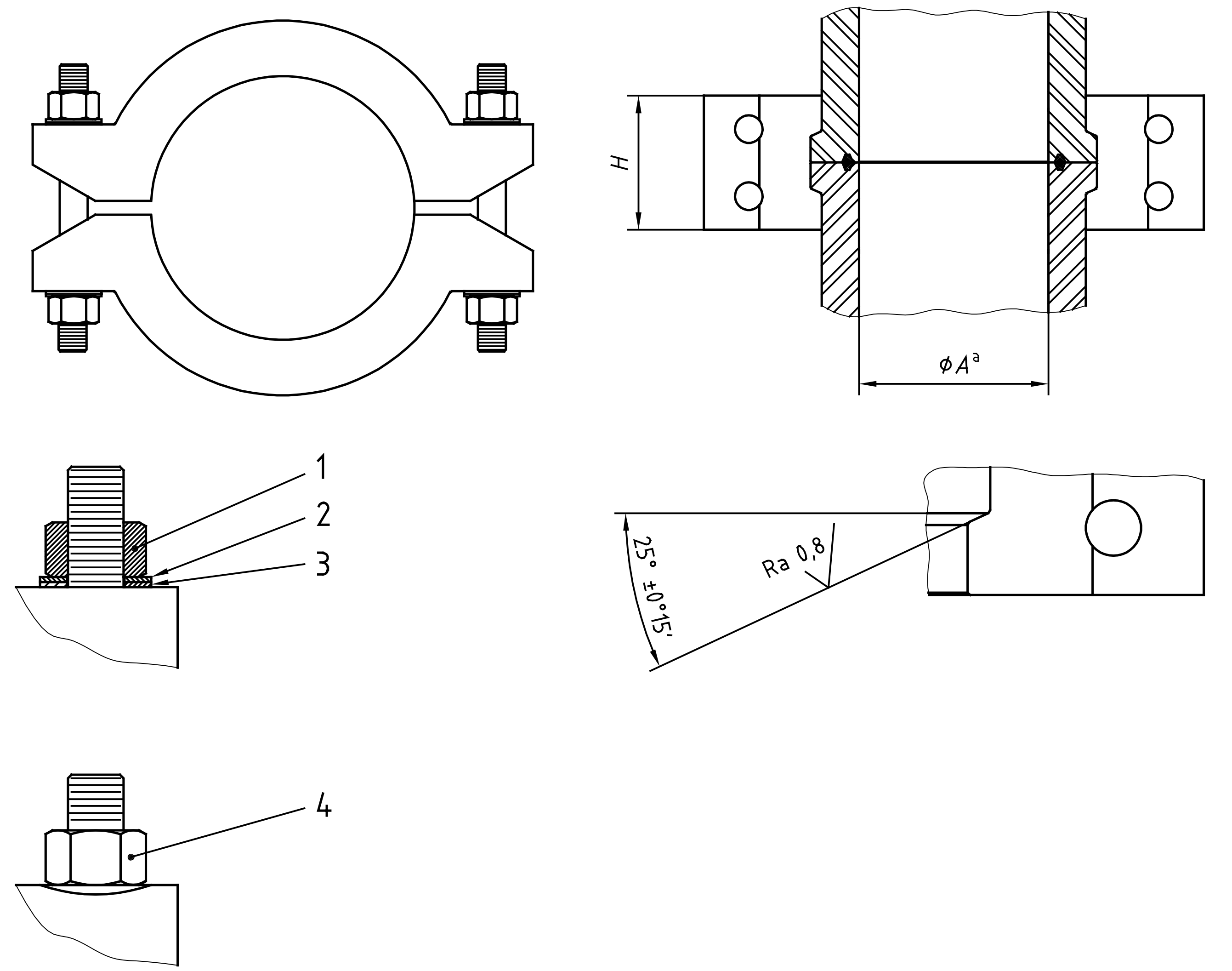
Bolting shall comply with 5.3.3.

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

Table 15 — Clamps for type 16B and 16BX hub connections

Clamp number	Hub			Clamp number	Hub		
	Designated size	Working pressure			Designated size	Working pressure	
	A	MPa	(psi)		*A*	MPa	(psi)
1	1 13/16	68,95	10 000	10	7 1/16	68,95	10 000
	2 1/16	34,45	5 000		9	68,95	10 000
2	1 13/16	103,4	15 000		11	34,45	5 000
	2 1/16	68,95	10 000	11	13 5/8	20,68	3 000
	2 9/16	34,45	5 000	12	16 3/4	13,79	2 000
3	1 13/16	137,9	20 000	13	13 5/8	34,45	5 000
	2 1/16	103,4	15 000	14	16 3/4	20,68	3 000
	2 1/16	137,9	20 000	15	7 1/16	137,9	20 000
	2 9/16	103,4	15 000		11	103,4	15 000
4	2 9/16	68,95	10 000		13 5/8	68,95	10 000
	3 1/8	34,45	5 000	18	21 1/4	13,79	2 000
5	3 1/16	68,95	10 000	19	16 3/4	34,45	5 000
	4 1/16	34,45	5 000	22	7 1/16	103,4	15 000
6	2 9/16	137,9	20 000		11	68,95	10 000
	3 1/16	103,4	15 000	25	7 1/16	13,79	2 000
	4 1/16	68,95	10 000	26	18 3/4	103,4	15 000
8	3 1/16	137,9	20 000		21 1/4	68,95	10 000
	4 1/16	103,4	15 000	27	18 3/4	68,95	10 000
	7 1/16	34,45	5 000		21 1/4	34,45	5 000
	9	34,45	5 000	28	11	137,9	20 000
9	11	20,68	3 000		13 5/8	103,4	15 000
10	4 1/16	137,9	20 000		16 3/4	68,95	10 000

Surface roughness in micrometres



Key

1 Nut
2 Outer washer
3 Inner washer
4 Spherical nut
a Size designation as specified in Table 15

Figure 7 — Clamps for type 16B and 16BX hub connections

Table 16 — Ring gasket numbers for ISO 13533 equipment

Ring number	Designated size	Rated working pressure		Ring number	Designated size	Rated working pressure	
		MPa	(psi)			MPa	(psi)
Type 6B integral flange connections				BX 158	11	103,4	15 000
R or RX 45	7 1/16	13,79	2 000	BX 159	13 5/8		
R or RX 49	9			BX 164	18 3/4		
R or RX 53	11			BX 156	7 1/16	137,9	20 000
R or RX 57	13 5/8			BX 157	9		
R or RX 65	16 3/4			BX 158	11		
R or RX 73	21 1/4			BX 159	13 5/8		
R or RX 45	7 1/16	20,68	3 000	Type 16B integral hub connections			
R or RX 49	9			RX 45	7 1/16	13,79	2 000
R or RX 53	11			RX 65	16 3/4		
R or RX 57	13 5/8			RX 73	21 1/4		
R or RX 66	16 3/4			RX 53	11	20,68	3 000
R or RX 74	20 3/4			RX 57	13 5/8		
R or RX 46	7 1/16	34,45	5 000	RX 73	16 3/4		
R or RX 50	9			Type 16BX integral hub connections			
R or RX 54	11			BX 156	7 1/16	34,45	5 000
Type 6BX integral flange connections				BX 157	9		
BX 167	26 3/4	13,79	2 000	BX 158	11		
BX 303	30			BX 160	13 5/8		
BX 168	26 3/4	20,68	3 000	BX 162	16 3/4		
BX 303	30			BX 165	21 1/4		
BX 160	13 5/8	34,45	5 000	BX 156	7 1/16	68,95	10 000
BX 162	16 3/4			BX 157	9		
BX 163	18 3/4			BX 158	11		
BX 165	21 1/4			BX 159	13 5/8		
BX 156	7 1/16	68,95	10 000	BX 162	16 3/4		
BX 157	9			BX 164	18 3/4		
BX 158	11			BX 166	21 1/4		
BX 159	13 5/8			BX 156	7 1/16	103,4	15 000
BX 162	16 3/4			BX 158	11		
BX 164	18 3/4			BX 159	13 5/8		
BX 166	21 1/4			BX 164	18 3/4		
BX 156	7 1/16	103,4	15 000	BX 156	7 1/16	137,9	20 000
BX 157	9			BX 158	11		

5.3.6 Blowout preventers and drilling spools

5.3.6.1 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 and drilling 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 and drilling spools shall have a cylindrical passage (bore) through the body, including end connections. The body bore diameter shall conform to the minimum bore dimension of the end connections as shown in Table 1.

5.3.6.2 Design

Design methods shall conform to 5.4.

End connections on all equipment within the scope of this International Standard shall conform to the requirements of 5.3.1, 5.3.2, 5.3.4 or 5.3.9.

Outlet connections shall conform to the requirements of 5.3.1, 5.3.2 or 5.3.4. The number of outlets is optional.

5.3.6.3 Material

Material used for pressure-containing parts or members shall comply with clause 6.

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

5.3.7 Ring gaskets

Gaskets used for equipment manufactured to this International Standard shall meet all the requirements of ISO 10423.

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 16 for a summary of groove and gasket usage.

5.3.8 Weld neck hubs

This International Standard is not applicable to weld neck hubs.

5.3.9 Other end connections (OECs)

5.3.9.1 General

This subclause provides requirements for other end connections which may be used for joining drill-through equipment and which are not specified in an International Standard. OECs include flanges and hubs in accordance with this International Standard, but with proprietary gasket preparations. OECs may also be in accordance with the manufacturer's specifications.

5.3.9.2 Design

OECs shall be designed in accordance with 5.4.

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.

5.3.9.3 Materials

OEC materials shall meet the requirements of clause 6.

5.3.9.4 Testing

Equipment utilizing OECs shall successfully complete the tests required in clause 8.

5.3.10 Blind connections

5.3.10.1 Flanges

Type 6B and 6BX blind flanges shall conform to the dimensional requirements of ISO 10423.

5.3.10.2 Hubs

Dimensions of 16B and 16BX blind hubs shall conform to Figure 4 and Table 7, Table 8, Table 11, Table 12, Table 13, or Table 14 in accordance with applicable size and pressure rating.

5.3.10.3 Other end connections (OECs)

The design and configuration of blind OECs shall conform to 5.3.9.2, 5.3.9.3, and 5.3.9.4.

5.3.11 Adapters

Length of adapters is not addressed in this International Standard. End connections shall meet the requirements of 5.3.1, 5.3.2, 5.3.4, or 5.3.9.

5.3.12 Hydraulic connectors

5.3.12.1 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.

5.3.12.2 Design

Design methods shall conform to 5.4.

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

5.3.12.3 Connections

The top connection shall conform to the requirements of 5.3.1, 5.3.2, 5.3.4 or 5.3.9.

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

5.3.12.4 Gasket retention mechanism

A gasket retention mechanism shall be provided. This mechanism may be hydraulic or mechanical.

5.3.12.5 Position indicator

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

5.3.12.6 Material

Material shall conform to the requirements of 5.3.6.3.

5.3.13 Test, vent, injection and gauge connections

Sealing and porting of flanges, hubs and OECs shall conform to the requirements of ISO 10423.

5.4 Design methods

5.4.1 End and outlet connections

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

5.4.2 Members containing wellbore pressure

5.4.2.1 General

Pressure-containing parts or members shall be designed in accordance with one or more of the methods given in 5.4.2.2 to 5.4.2.4.

NOTE This International Standard 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.

5.4.2.2 ASME method

This design methodology is described in the ASME Boiler and Pressure Vessel Code Section VIII, Division 2, Appendix 4. Design-allowable stresses are limited by the following criteria:

$$S_t \leqslant 0{,}9\ S_y$$

and

$$S_m \leqslant (2/3)\ S_y$$

where

S_m is the design stress intensity at rated working pressure;

S_t is the maximum allowable general primary membrane stress intensity at hydrostatic test pressure;

S_y is the material's specified minimum yield strength.

5.4.2.3 Distortion energy theory

This design methodology for the basic pressure vessel wall thickness uses a combination of the triaxial stresses based on the hydrostatic test pressure and is limited by the following criterion:

$$S_e = S_y$$

where

S_e is the maximum allowable equivalent stress computed by the distortion energy theory method;

S_y is the material's specified minimum yield strength.

5.4.2.4 Experimental stress analysis

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

5.4.3 Closure bolting

Stresses shall be determined considering all loading on the closure, including pressure acting over the seal area, gasket loads and any additive mechanical loads. The maximum tensile stress shall be determined considering initial make-up loads, working conditions and hydrostatic test conditions. The stresses, based on the minimum cross-sectional area, shall not exceed the following limits:

$$S_a \leqslant 0{,}83\ S_y$$

where

S_a is the maximum allowable tensile stress;

S_y is the material's specified minimum yield strength.

5.4.4 Other parts

Pressure-retaining parts and pressure-controlling parts shall be designed to satisfy the manufacturer's written specifications and the service conditions defined in 5.2.

5.4.5 Miscellaneous design information

5.4.5.1 General

End and outlet connections to the wellbore shall be integral.

5.4.5.2 Hydraulic connectors

The manufacturer shall document the load/capacity for the hydraulic connector using the format for API flanges in API Bulletin 6AF. This format relates pressure to allowable bending moment for various tensions. The manufacturer shall state whether the limitation is stress level or facial separation. Analytical design methods shall conform to 5.4.

5.4.5.3 Clamps

The manufacturer shall document the load/capacity for the clamp connection using the format for API flanges in API Bulletin 6AF. This format relates pressure to 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 5.4.

5.4.5.4 OECs

The manufacturer shall document the load/capacity for the OEC using the format used for API flanges in API Bulletin 6AF. This format relates pressure to 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 5.4.

5.5 Design verification testing

5.5.1 General

Design verification testing shall be performed on equipment specified in clause 1 and shall be described in the manufacturer's written specification(s). Design verification testing shall not be required on adapters, drilling spools, clamps, or flanges, hubs and ring gaskets in accordance with this International Standard.

Experimental confirmation of the design shall be documented and verified as required in 5.6.

5.5.2 Blowout preventers

Tests of the operating characteristics for blowout preventers shall conform to 5.7.

5.5.3 Hydraulic connectors

Tests of the operating characteristics for hydraulic connectors shall conform to 5.7.

5.5.4 Annular packer units

Tests on annular packing units shall conform to 5.7.

Design temperature verification testing on annular packing units shall conform to 5.8.3.

5.5.5 Ram blocks, packers and top seals

Tests on ram blocks, packers and top seals shall conform to 5.7.

Design temperature verification testing on ram packers and top seals shall conform to 5.8.2.

5.5.6 OECs

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

5.6 Documentation

5.6.1 Design documentation

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

5.6.2 Design review

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

5.6.3 Design verification

Design verification procedures and results shall be documented.

5.6.4 Documentation retention

Documents required in accordance with clause 5 shall be retained for ten years after the last unit of that model, size and rated working pressure is manufactured.

5.7 Tests for BOP and hydraulic connector operational characteristics

5.7.1 General

5.7.1.1 Requirements

All testing shall be in accordance with Table 17.

5.7.1.2 Procedure

All tests for operational characteristic shall be conducted using water at ambient temperature as the wellbore fluid. Unless otherwise noted, the level of piston closing pressure shall be the pressure recommended by the manufacturer and shall not exceed the designed hydraulic operating system working pressure. The manufacturer shall document his procedure and results. Procedures in annex C may be used.

5.7.1.3 Acceptance criteria

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

5.7.1.4 Scaling

If scaling of size and working pressure is utilized, scaling shall conform to Table 17. The manufacturer shall document his technical justifications.

5.7.2 Ram-type blowout preventer

5.7.2.1 Test of sealing characteristics

This test determines the actual opening or closing pressure required to either maintain or break a wellbore pressure seal. The test shall also define the ability of the ram packer to effect a seal when closing against elevated wellbore pressures. For fixed-bore pipe rams, a 127 mm (5 in) test mandrel shall be used for 279 mm (11 in) and larger blowout preventers, and a 88,9 mm (3 1/2 in) test mandrel shall be used for blowout preventers smaller than 279 mm (11 in). Sealing characteristics tests on a variable-bore ram (VBR) shall include pipe sizes at the minimum and maximum of the ram's range.

Documentation shall include:

a) a record of closing pressure vs. wellbore pressure to effect a seal against elevated wellbore pressures;

b) a record of operator (closing or opening) pressure vs. wellbore pressure to break a wellbore pressure seal.

5.7.2.2 Fatigue test

This test determines the ability of the ram packers and seals to maintain a wellbore pressure seal after repeated closings and openings. This test simulates closing and opening the blowout preventer once per day and testing wellbore pressure at 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and full rated working pressure once per week for 1,5 years of service. For fixed-bore pipe rams, a 127 mm (5 in) test mandrel shall be used for 279 mm (11 in) and larger blowout preventers. An 88,9 mm (3 1/2 in) test mandrel shall be used for blowout preventers smaller than 279 mm (11 in). Tests on VBRs shall be performed at the minimum and maximum sizes for their range.

Documentation shall include:

a) magnetic particle (MP) inspection of ram blocks in accordance with manufacturer's written procedure;

b) total number of cycles to failure to maintain a seal or 546 close/open cycles and 78 pressure cycles, whichever is attained first.

Table 17 — Required tests for operational characteristics

<table>
<tr><th rowspan="2">Test</th><th colspan="4">Ram BOP</th><th rowspan="2">Annular BOP</th><th rowspan="2">Hydraulic connectors</th></tr>
<tr><th>Fixed bore [a]</th><th>Variable bore</th><th>Blind [a]</th><th>Shear</th></tr>
<tr><td>Sealing characteristics</td><td>P1, S2</td><td>P3, S3</td><td>P1, S2</td><td>P1, S2</td><td>P1, S2</td><td rowspan="7">N/A</td></tr>
<tr><td>Fatigue</td><td>P1, S2</td><td>P3, S3</td><td>P1, S2</td><td>P1, S2</td><td>P1, S2</td></tr>
<tr><td>Stripping</td><td>P2, S2</td><td>P2, S2</td><td>N/A</td><td>N/A</td><td>P1, S2</td></tr>
<tr><td>Shear</td><td>N/A</td><td>N/A</td><td>N/A</td><td>P1, S2</td><td>N/A</td></tr>
<tr><td>Hang-off</td><td>P1, S2</td><td>P3, S3</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Packer access</td><td colspan="4">P2, S2[b]</td><td>P2, S2[c]</td></tr>
<tr><td>Ram locking device</td><td colspan="4">P2, S2[d]</td><td>N/A</td></tr>
<tr><td>Locking mechanism</td><td colspan="5" rowspan="2">N/A</td><td>P2, S2</td></tr>
<tr><td>Sealing mechanism</td><td>P1, S3</td></tr>
<tr><td>Temperature verification</td><td colspan="5">P3, S3</td><td>N/A</td></tr>
<tr><td colspan="7">P1 = Qualifies all rated working pressures equal to and below that of the product tested.
P2 = Qualifies all rated working pressures of the product tested.
P3 = Qualifies only the rated working pressure of the product tested. Exception is when packers of identical dimensions and materials have multiple pressure ratings; they need only be tested at their maximum pressure rating.
S2 = Qualifies all size designations of the product tested.
S3 = Qualifies only the size designation of the product tested.</td></tr>
<tr><td colspan="7">[a] One fixed bore test qualifies other fixed bore pipe sizes and blind rams for the same test.
[b] Only one ram access test is required for a product family.
[c] Only closure mechanisms of functionally similar designs may be scaled.
[d] Only one ram locking device test (performed with any ram) is required for a product family.</td></tr>
</table>

5.7.2.3 Test for stripping life

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 4 litre/min (1 gal/min). A 127 mm (5 in) test mandrel shall be used for 279 mm (11 in) and larger blowout preventers. An 88,9 mm (3 1/2 in) test mandrel shall be used for blowout preventers smaller than 279 mm (11 in).

Documentation shall include:

a) wellbore pressure used during the test;

b) record of reciprocating speed;

c) equivalent length of pipe stripped or 15 000 m (50 000 ft), whichever is attained first.

5.7.2.4 Shear ram test

This test determines the shearing and sealing capabilities for selected drill pipe samples. The pipe used for shear test, as a minimum, shall be in accordance with Table 18. These tests shall be performed without tension in the pipe and with zero wellbore pressure.

Documentation shall include the manufacturer's shear ram and blowout preventer configurations, the actual pressure and force required to shear the pipe. Documentation shall also include pipe description (size, mass and grade), actual pipe tensile properties, and impact properties as specified in ISO 11961.

Table 18 — Shear pipe requirements

BOP size	Shear pipe (minimum)
179 mm (7 1/16 in)	3 1/2 in 133 lb/ft Grade E-75
279 mm (11 in)	5 in 19,5 lb/ft Grade E-75
346 mm (13 5/8 in) and larger	5 in 19,5 lb/ft Grade G-105

5.7.2.5 Hang-off test

This test determines the ability of the 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. 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. Testing shall be carried out in the worst-case loading, i.e. with closing pressure maintained or with closing pressure vented using only the ram-locking system to hold the rams closed during the hang-off tests.

Documentation shall include:

a) non-destructive examination (NDE) of ram blocks in accordance with manufacturer’s written procedure;

b) load at which leaks develop or 2,7 MN (600 000 lb) for 125 mm (5 in) and larger pipe, or 2,0 MN (450 000 lb) for pipe smaller than 125 mm (5 in), whichever is less.

5.7.2.6 Ram access test

This test determines the ability of the blowout preventer to undergo repeated ram and/or ram packer changes without affecting operational characteristics. This test shall be carried out by obtaining access to the rams and performing a wellbore pressure test every 20th ram access.

Documentation shall include the number of access cycles to failure or 200 access cycles and 10 wellbore pressure cycles, whichever is less.

5.7.2.7 Ram locking device test

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). This test may be carried out as part of the fatigue or hang-off test. VBRs shall be tested at the minimum and maximum sizes of their range. A 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and full rated working pressure tests shall be performed.

5.7.3 Annular-type blowout preventer

5.7.3.1 Test for sealing characteristics

This test determines the piston closing pressure necessary to maintain a seal as a function of wellbore pressures up to full rated working pressure of the blowout preventer. The test shall be conducted on a drill pipe mandrel and under open-hole conditions. For 279 mm (11 in) and larger blowout preventers, a 125 mm (5 in) mandrel shall be used. For 228 mm (9 in) and smaller blowout preventers, an 88,9 mm (3 1/2 in) mandrel shall be used. This test consists of three parts:

a) Constant wellbore pressure test

   A test shall be carried out to determine the actual closing pressure required to maintain a wellbore pressure seal on the test mandrel. Documentation shall include a record of wellbore pressure vs. closing pressure.

b) constant closing pressure test

   A test shall be carried out to determine the maximum wellbore pressure obtainable for a given closing pressure with the preventer closed on the test mandrel. Documentation shall include a record of wellbore pressure vs. closing pressure.

c) full closure pressure test

   A test shall be carried out to determine the 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. Documentation shall include a record of wellbore pressure vs. closing pressure.

5.7.3.2 Fatigue test

This test determines the ability of an annular packing unit to maintain a 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and rated working pressure seal throughout repeated closings and openings. This test simulates closing and opening the blowout preventer once per day and wellbore pressure testing at 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and full rated working pressure once per week for one year of service.

Documentation shall include:

a) a graph of the packing element inside diameter (ID) after every twentieth cycle vs. time up to 30 min;

b) the number of cycles to failure to maintain a seal, or 364 close/open cycles and 52 pressure cycles, whichever is attained first.

5.7.3.3 Packer access test

This test determines the ability of the blowout preventer to undergo repeated packer changes without affecting operational characteristics. This test shall be accomplished by obtaining access to the packing unit and performing a wellbore pressure test every 20th packing unit access.

Documentation shall include the number of cycles to failure or 200, whichever is attained first.

5.7.3.4 Stripping life test

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 a leak rate of 4 litre/min (1 gal/min).

Documentation shall include:

a) wellbore pressure used during the test;

b) record of reciprocating speed;

c) equivalent length of pipe and number of tool joints stripped, or 5 000 tool joints, whichever is attained first;

d) closing pressure used during the test.

5.7.4 Hydraulic connectors

5.7.4.1 Locking mechanism test

This test verifies the operation of both the primary and (if so equipped) secondary 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 connector shall be stroked to the locked position on and off the stump and be within the manufacturer's stated limits. The functional testing, which verifies operation of the locking mechanism to the manufacturer's written design specifications, shall be documented.

5.7.4.2 Sealing mechanism test

This test shall verify the operation of the 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 seal. This test shall be conducted using an assembled connector with a blind upper connection and a test stump. The wellbore pressure testing shall be done with the connector locked and operator pressure vented. The functional testing which verifies the sealing mechanics to the manufacturer's written design specifications shall be documented.

5.8 Design temperature verification testing for non-metallic sealing materials and moulded sealing assemblies

5.8.1 General

5.8.1.1 Safety

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

5.8.1.2 Intent of procedure

This procedure shall verify performance of non-metallic seals and moulded sealing assemblies used as pressure-controlling and/or pressure-containing members in equipment included in clause 1. The intent of this procedure is to verify the performance of these components during exposure to low and high temperatures.

5.8.1.3 Procedure

All tests shall be performed at the extreme temperatures for the temperature class of the component being tested. Refer to Table 4 for the temperature classes. The manufacturer shall specify the test fluid used. Unless otherwise noted, the closing pressure shall be the pressure recommended by the manufacturer and shall not exceed the designed hydraulic operating system rated working pressure. The manufacturer shall document his procedure and results.

For example, the procedures given in annex D may be used.

5.8.1.4 Acceptance criteria

The acceptance criterion for all pressure tests is that there shall be no leakage.

5.8.1.5 Scaling

If scaling of size and working pressure is utilized, scaling shall conform to Table 17. The manufacturer shall document his technical justifications.

5.8.2 Ram-type blowout preventer

Non-metallic seals and moulded sealing assemblies in ram blowout preventers shall be tested to verify their ability to maintain a seal at the extremes of their temperature classification. Variable-bore packer tests shall be conducted on the minimum and maximum sizes for their range.

Documentation shall include:

a) elastomer records as detailed in the test procedures;

b) record of the temperature of the blowout preventer wellbore fluid during the testing;

c) record of low temperature test performance: a minimum of three pressure cycles at rated working pressure are required;

d) record of high temperature test performance: one pressure cycle at rated working pressure with a minimum pressurization hold time of 60 min is required.

5.8.3 Annular-type blowout preventer

Non-metallic seals and moulded sealing assemblies in annular blowout preventers shall be tested to verify their ability to maintain a seal at the extremes of their temperature classification.

Documentation shall include:

a) elastomer records as detailed in the test procedures;

b) record of the temperature of the blowout preventer wellbore during the testing;

c) record of low temperature test performance: a minimum of three pressure cycles at rated working pressure is required;

d) record of high temperature test performance: one pressure cycle at rated working pressure with a minimum pressurization hold time of 60 min is required.

5.9 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 International Standard. The operating manual shall contain the following information as a minimum and as applicable:

a) operation and installation instructions;

b) physical data;

c) packers and seals information;

d) maintenance and testing information;

e) assembly and disassembly information;

f) parts information;

g) storage information;

h) operational characteristics summary, as applicable;

   1) sealing characteristics test,

   2) fatigue test,

   3) stripping life test,

4) hang-off test,

5) shear ram test,

6) ram locking device test,

7) ram/packer access test,

8) locking mechanism test.

6 Material requirements

6.1 General

This clause describes the material performance, processing and compositional requirements for pressure-containing members. Other parts shall be made of materials which satisfy the design requirements in clause 5 when assembled into equipment specified in this International Standard. Metallic materials shall meet the requirements of NACE MR0175.

6.2 Written specifications

6.2.1 Metallic parts

A written material specification shall be required for all metallic pressure-containing or 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;

f) NDE requirements;

g) mechanical property requirements.

6.2.2 Non-metallic 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 D 2240 or ASTM D 1415;

b) normal stress-strain properties in accordance with ASTM D 412 or ASTM D 1414;

c) compression set in accordance with ASTM D 395 or ASTM D 1414;

d) immersion testing in accordance with ASTM D 471 or ASTM D 1414.

6.3 Pressure-containing members

6.3.1 Property requirements

Pressure-containing members shall be manufactured from materials as specified by the manufacturer that meet the requirements of Table 19 and Table 20.

Charpy V-notch impact testing shall conform to 6.3.4.2.

Table 19 — Material property requirements for pressure-containing members

Material designation	Yield strength 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

Table 20 — Material applications for pressure-containing members

Part	Rated working pressure					
	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)
Body	36K, 45K, 60K, 75K				45K 60K, 75K	60K, 75K
End connections	60K				75K	
Blind flanges	60K				75K	
Blind hubs	60K				75K	

6.3.2 Processing

6.3.2.1 Melting, casting and hot working

6.3.2.1.1 Melting practices

The manufacturer shall select and specify the melting practices for all materials for pressure-containing members.

6.3.2.1.2 Casting practices

The materials manufacturer shall document foundry practices that establish limits for sand control, core-making, rigging and melting.

6.3.2.1.3 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.

6.3.2.2 Heat treating

All heat-treatment operations shall be performed utilizing equipment qualified in accordance with the requirements specified by the manufacturer (see annex E for a recommended practice).

Care should be taken in loading of material within furnaces such that the presence of one part does not adversely affect the heat-treating response of any other part.

Temperature and times for heat treatment shall be determined in accordance with the manufacturer's written specification.

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

The temperature of any oil-quenching medium shall be greater than 38 °C (100 °F) at the start of the quench.

6.3.3 Chemical composition

6.3.3.1 General

The manufacturer shall specify the range of chemical composition of the material used to manufacture pressure-containing members.

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.

6.3.3.2 Composition limits

The chemical composition limits of pressure-containing members manufactured from carbon and low alloy steels or martensitic stainless steels shall comply with Table 21. Limits for non-martensitic alloy systems are not required to conform to Table 21 and Table 22.

6.3.3.3 Tolerance on composition limits

The permitted tolerances on alloy element content shall conform to Table 22.

Table 21 — Steel composition limits (% mass fraction) for pressure-containing members

Alloying element	**Carbon and low alloy steels limit** % mass fraction	**Martensitic stainless steels limit** % mass fraction
Carbon	0,45 max.	0,15 max.
Manganese	1,80 max.	1,00 max.
Silicon	1,00 max.	1,50 max.
Phosphorus	0,025 max.	0,025 max.
Sulfur	0,025 max.	0,025 max.
Nickel	1,00 max.	4,50 max.
Chromium	2,75 max.	11,0 to 14,0
Molybdenum	1,50 max.	1,00 max.
Vanadium	0,30 max.	N/A

Table 22 — Alloying element range — Maximum tolerance requirements

Alloying element	Carbon and low alloy steels limit % mass fraction	Martensitic stainless steels limit % 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 shall not exceed the maximum specified in Table 21.		

6.3.4 Material qualification

6.3.4.1 Tensile testing

Tensile test specimens shall be removed from a qualification test coupon (QTC) as described in 6.3.5. 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 ISO 6892.

A minimum of one tensile test shall be performed. The results of the tensile test(s) shall satisfy the applicable requirements of Table 19. 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 19.

6.3.4.2 Impact testing

Impact testing shall be performed on each heat of material used for pressure-containing members.

Impact test specimens shall be removed from a QTC in accordance with 6.3.5. 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-size specimen obtainable 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.

Impact tests shall be performed in accordance with ASTM A 370 using the Charpy V-notch technique.

In order to qualify material for an ISO temperature rating T-0, T-20 or T-75, the impact tests shall be performed at or below the test temperature shown in Table 23.

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 23. In no case shall an individual impact value fall below 2/3 the required minimum average. No more than one of the three test results shall be below the required minimum average. If a test fails, then 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 average impact value equal to or exceeding the required minimum average.

The values listed in Table 23 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.

Table 23 — 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-0	− 18	0	20	15	14	10
T-20	− 29	− 20	20	15	14	10
T-75	− 59	− 75	20	15	14	10

6.3.5 Qualification test coupons (QTC)

6.3.5.1 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 International Standard.

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).

A QTC may only qualify material and parts produced from the same heat. (Remelt heat may be qualified on a master heat basis.)

6.3.5.2 Equivalent round (ER)

6.3.5.2.1 General

The dimensions of a QTC for a part shall be determined using the following ER method.

6.3.5.2.2 ER methods

Figure 8 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.

6.3.5.2.3 Required dimensions

The ER of the QTC shall be equal to or greater than the dimensions of the part it qualifies, except the size of the QTC is required not to exceed 125 mm (5 in) ER.

6.3.5.3 Processing

6.3.5.3.1 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.

6.3.5.3.2 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.

6.3.5.3.3 Hot-working practices

The manufacturer shall use hot-working ratios on the QTC which 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.

6.3.5.3.4 Welding

Welding on the QTC is prohibited, except for attachment-type welds.

6.3.5.3.5 Heat treating

All heat-treatment operations shall be performed utilizing “production type” equipment certified in accordance with the manufacturer's written specification. “Production type” heat-treatment equipment shall be considered equipment that is routinely used to process parts.

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.

6.3.5.4 Tensile and impact testing

When tensile and/or impact test specimens are required, they shall be removed from a QTC after the final QTC heat-treatment cycle. It is allowable to remove tensile and impact specimens from multiple QTCs as long as the multiple QTCs have had the same heat-treatment cycle(s).

Tensile and impact specimens shall be removed from the QTC such that their longitudinal centreline axis is wholly within the centre core ¼ T envelope for a solid QTC or within 1 mm (¼ in) of the mid-thickness of the thickest section of a hollow QTC (see Figure 8).

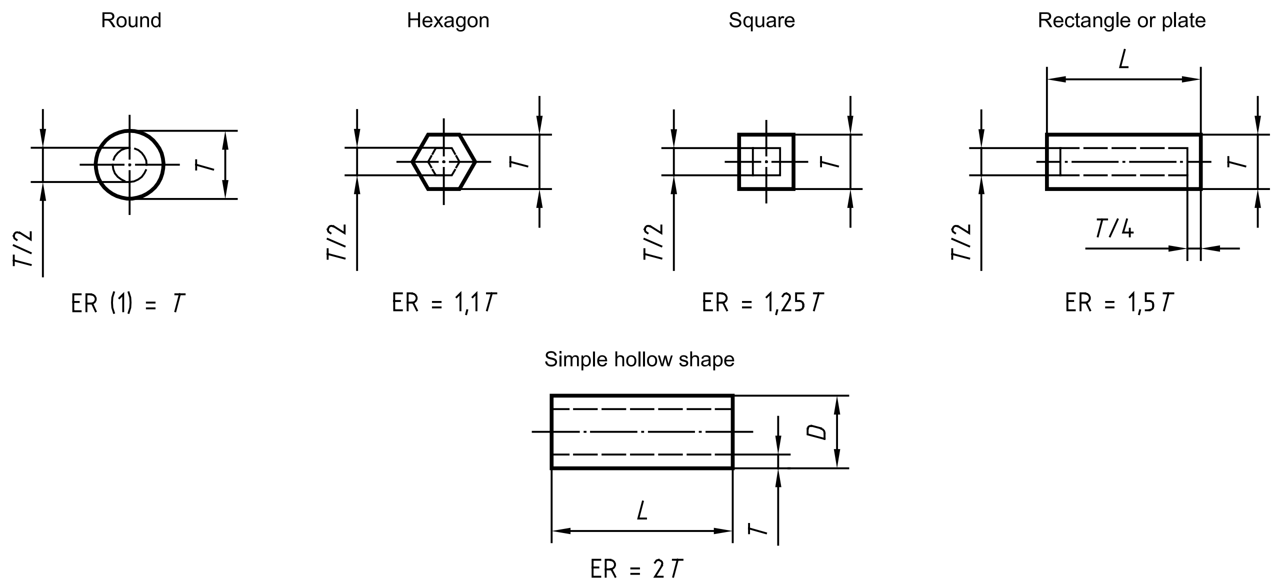
For QTCs larger than the dimensions specified in 7.3.5.2.3, the test specimens need not be removed from a location farther from the QTC surface than would be required if the specified QTC dimensions were used.

When a sacrificial production part is used as the QTC, the test specimens shall be removed from a section of the part meeting the dimensional requirements of the QTC for that production part as described in 7.3.5.2.

6.3.5.5 Hardness testing

A hardness test shall be performed on the QTC after the final heat-treatment cycle.

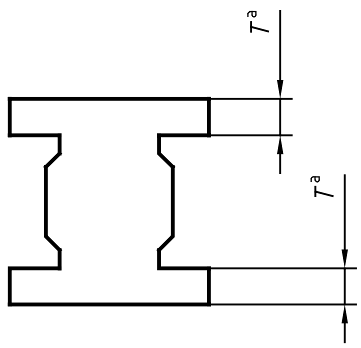
Hardness testing shall be performed in accordance with procedures specified in ISO 6892 or ISO 6506-1 as appropriate.



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

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

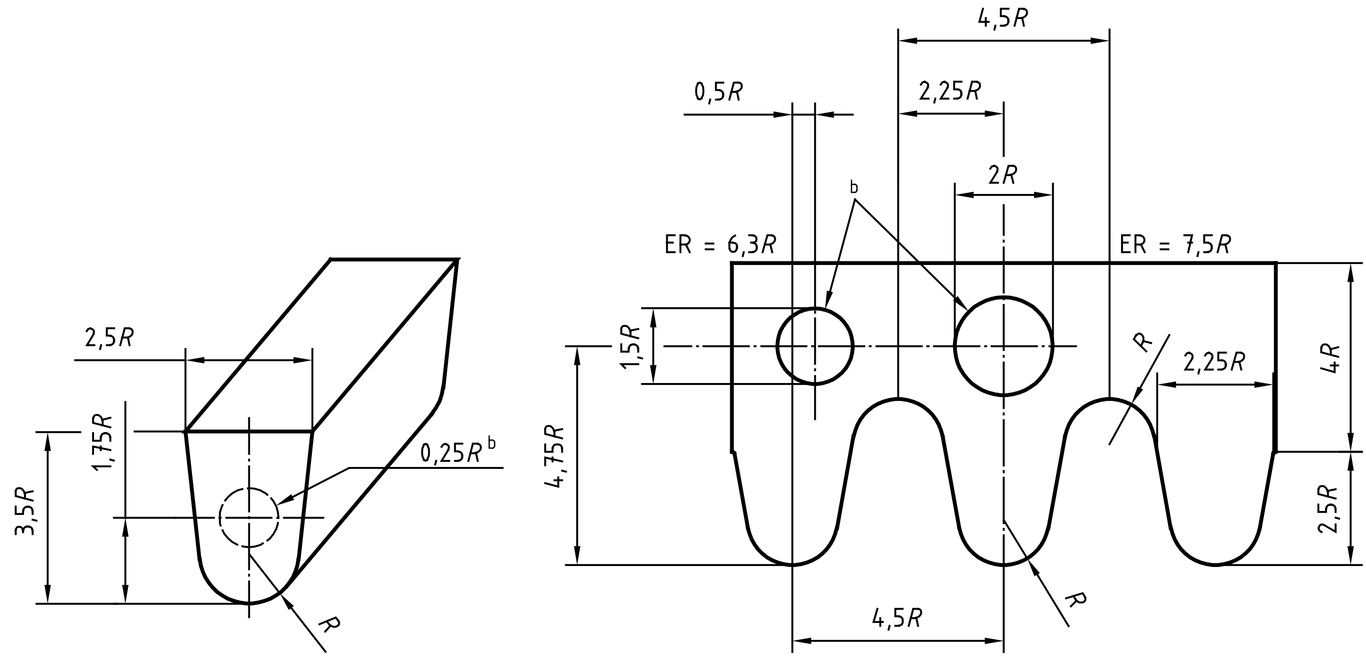
a) **Simple geometric equivalent rounds (ER) sections/shapes having length *L***



When all internal and external surfaces during heat treatment are within 13 mm (1/2 in) of the final surfaces, ER = 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*. On multiflanged components, *T* shall be the thickness of the thickest flange.

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

b) **Complex-shaped components**



b Envelope for test specimen removal.

c) **Keel block configuration, ER = 2,3 R**

Figure 8 — Equivalent round models

7 Welding requirements

7.1 General

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

When material specifications for pressure-containing and pressure-retaining components require impact testing, verification of compliance shall be established through implementation of the manufacturer's WPS and supporting PQR.

7.2 Weldment design and configuration

7.2.1 Pressure-containing fabrication weldments

Pressure-containing fabrication weldments contain and are wetted by wellbore fluid.

Only full penetration welds fabricated in accordance with the manufacturer's written specification shall be used. Figures 9 through 12 are provided for reference.

Welding and completed welds shall meet the quality control requirements of clause 8.

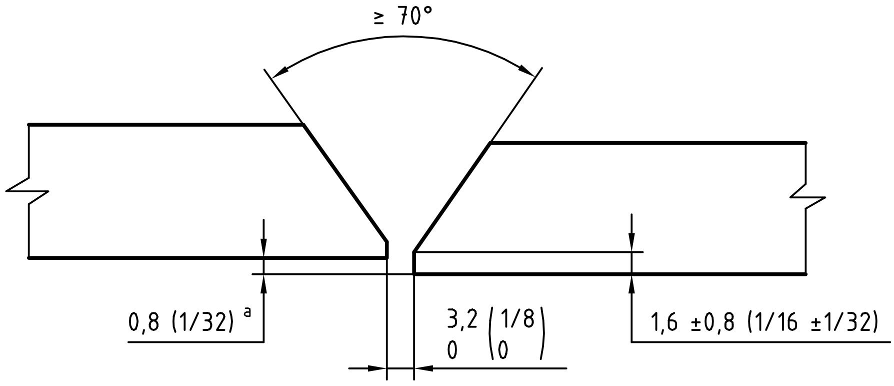
7.2.2 Load-bearing weldments

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

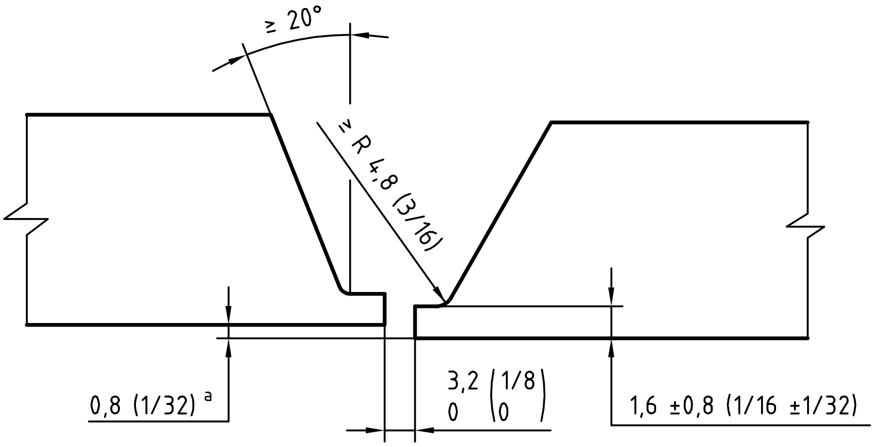
Joint design shall be in accordance with the manufacturer's written procedures.

Welding and completed welds shall meet the quality control requirements of clause 8.

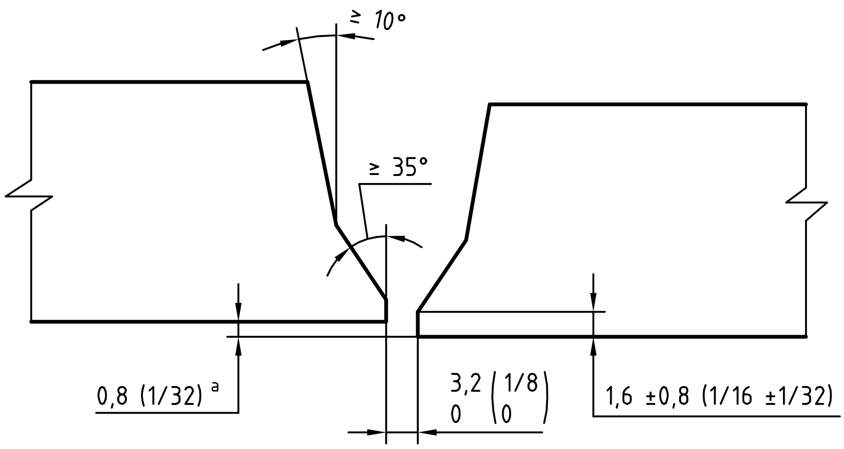
Dimensions in millimetres (inches)



a) **V-groove**



b) **U-groove**

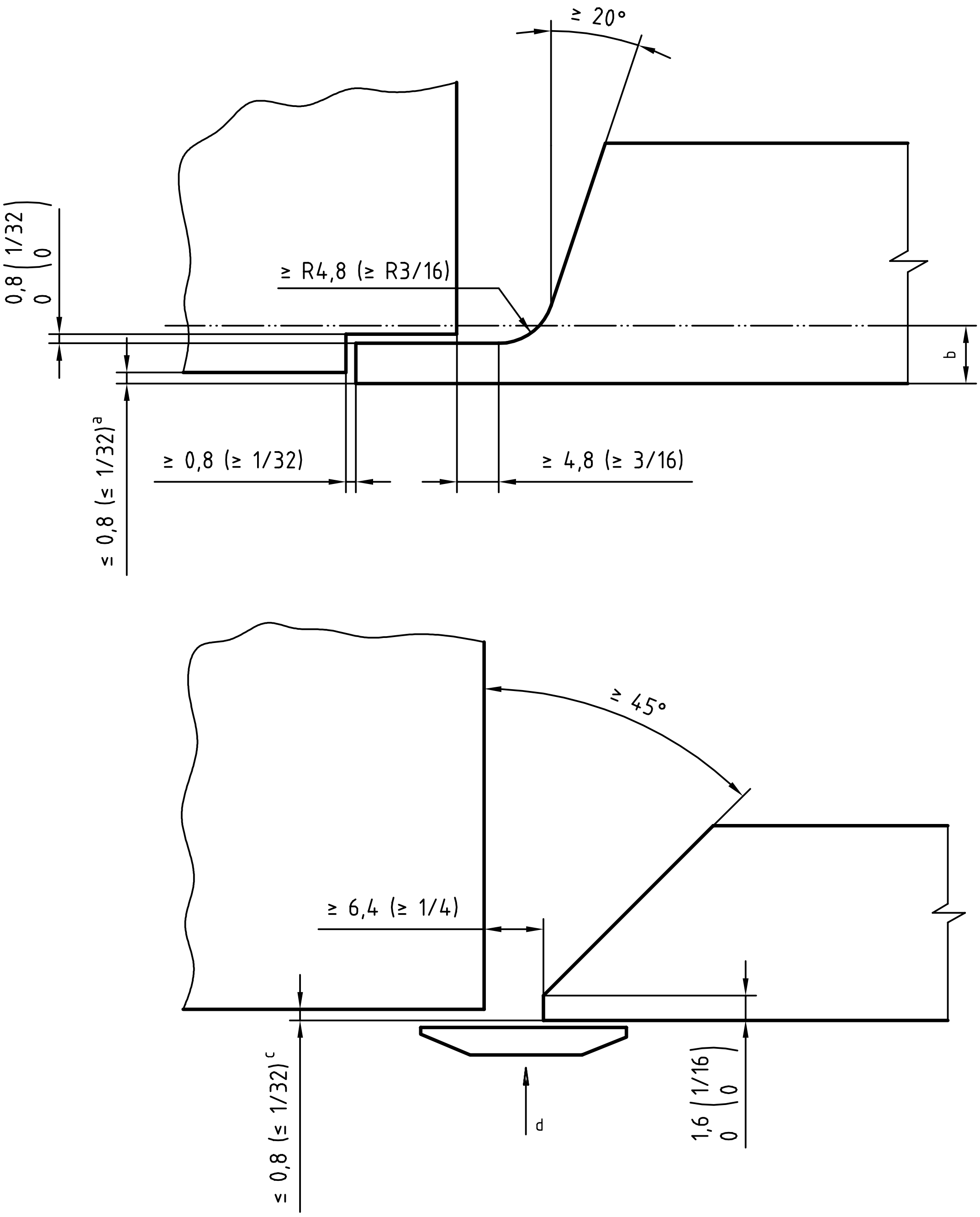


c) **Heavy wall V-groove**

a Maximum misalignment

Figure 9 — Typical weld grooves for pipe butt joints

Dimensions in millimetres (inches)



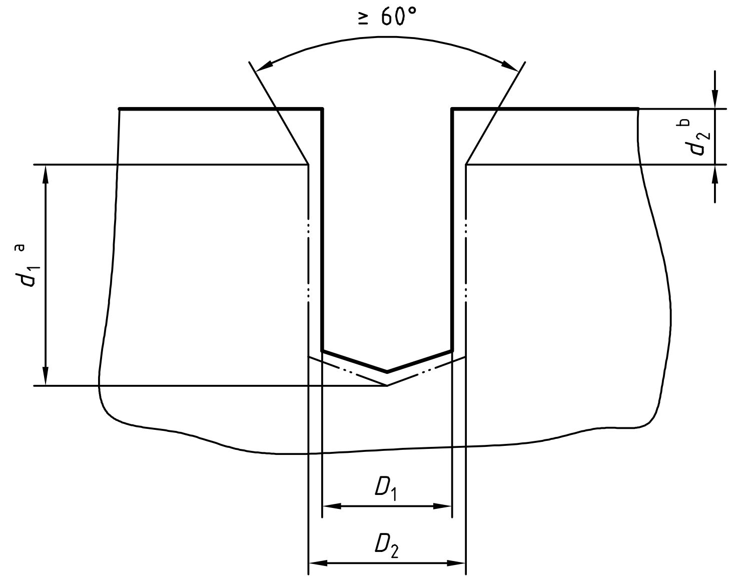
a Mismatch (unless removed by machining)

b Remove to sound metal by machining

c Maximum mismatch

d Backing to be removed. Material to be compatible with base material.

Figure 10 — Typical attachment welds

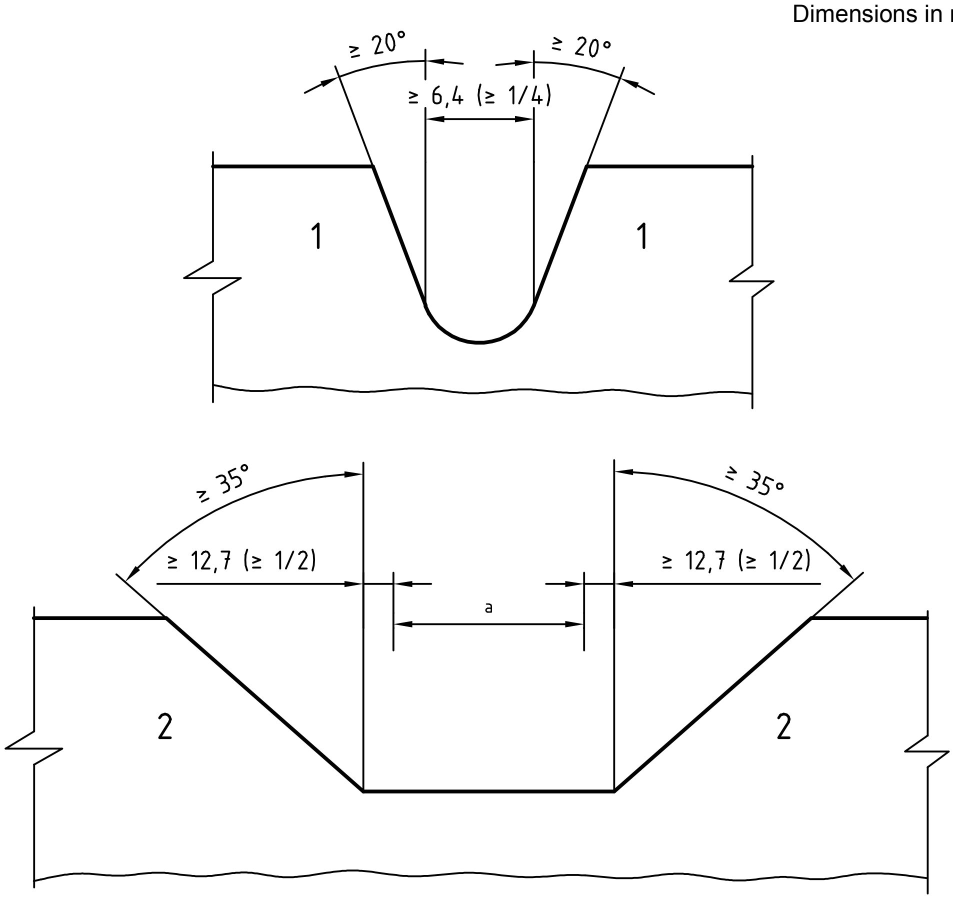


a $d_1 : D_2$ ratio shall not exceed 1,5 : 1;

b d_2 = depth required to maintain a maximum of 1,5 : 1 depth (d_1)-to-diameter (D_2) ratio.

Figure 11 — Typical repair welds

Dimensions in millimetres (inches)



Key

1 Side

2 End

a Original area

Figure 12 — Typical evacuation for repair welds

7.2.3 Repair welds

All repair welding shall be carried out in accordance with the manufacturer's written specification. All major repair welds to pressure-containing members performed subsequent to original heat treatment shall be mapped.

Welding and completed welds shall meet the requirements of clause 8.

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

7.2.4.1 Corrosion-resistant ring grooves

Standard dimensions for the preparation of type SR ring grooves for overlays are specified in 5.3. Standard dimensions for type R and BX ring grooves are specified in ISO 10423.

7.2.4.2 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.

7.2.4.3 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.

7.3 Welding controls

7.3.1 Procedures

The manufacturer's system for controlling welding shall include procedures for monitoring, updating and controlling the qualification of welders, welding operators and the use of welding-procedure specifications.

7.3.2 Application

Welding shall be performed by personnel qualified in accordance with the requirements of 7.4.1.

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

7.3.3 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 9 through 12 depict some typical joint designs.

7.3.4 Preheating

Preheating of assemblies or parts, when required, shall be performed in accordance with the manufacturer's written procedures.

7.3.5 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.

7.3.6 Materials

7.3.6.1 Welding consumables

Welding consumables shall conform to American Welding Society (AWS) or 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.

7.3.6.2 Deposited weld metal properties

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

7.3.7 Post-weld heat treatment

Post-weld heat treatment of components shall be in accordance with the manufacturer's written procedures.

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

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

7.4 Welding procedure and performance qualifications

7.4.1 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.

7.4.2 Base metals

The manufacturer may use ASME Section IX P number materials.

The manufacturer may establish an equivalent P number (EP) grouping for low alloy steels not listed in ASME Section IX with nominal carbon content equal to or less than 0,35 %.

Low alloy steels not listed in ASME Section IX with a nominal carbon content greater than 0,35 % shall be specifically qualified for the manufacturer's specified base material.

Qualification of a base material at a specified strength level also qualifies that base material at all lower strength levels.

7.4.3 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.

7.4.4 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 clause 8.

7.5 Other requirements

7.5.1 ASME Section IX, Article I — Welding general requirements

7.5.1.1 General

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

7.5.1.2 Hardness testing

7.5.1.2.1 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 shall be in conformance with NACE MR0175 requirements. The manufacturer shall specify the hardness testing method to be used. Testing shall be performed on the weld and base material HAZ cross-section in accordance with ISO 6508-1, Rockwell; or ISO 6507-1, Vickers 10 kg. Minimum results shall be converted to Rockwell C as applicable in accordance with ASTM E 140.

7.5.1.2.2 Rockwell method (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 12 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 12 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 1,5 mm (0,06 in) of the weld interface and at least one each within 3 mm (0,125 in) from top and bottom of the weld. See Figure 13 for test locations.

7.5.1.2.3 Vickers method (ISO 6507-1)

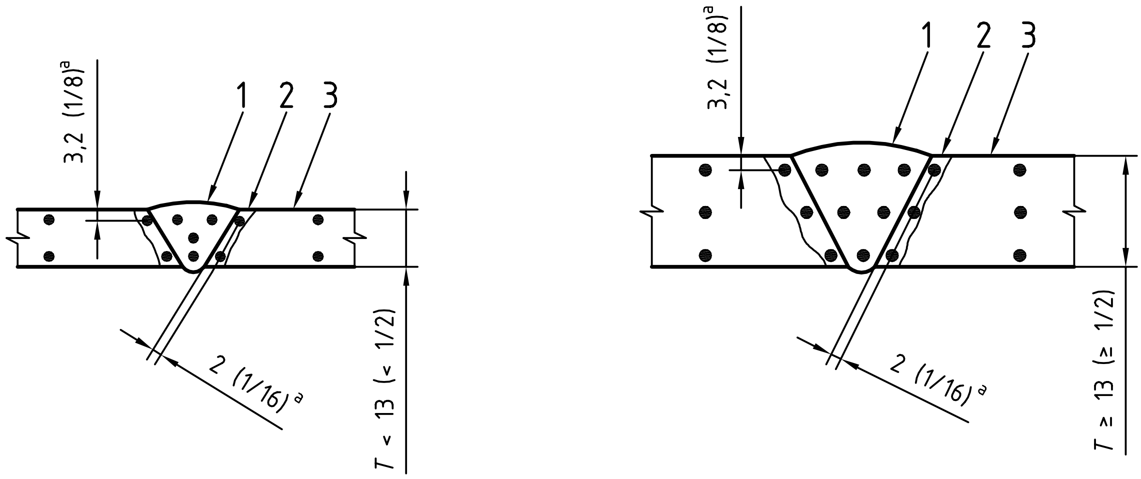
If the Vickers method is selected by the manufacturer, the following procedure shall be used:

a) for a weld cross-section thickness less than 12 mm (1/2 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 12 mm, six hardness tests each shall be made in the base material(s) and the weld;

c) multiple HAZ hardness tests equally spaced 3 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 1,5 mm (0,06 in) from the top and the bottom of the weld. See Figure 14 for test locations.

Dimensions in millimetres (inches)



Key

1 Weld

2 HAZ

3 Base

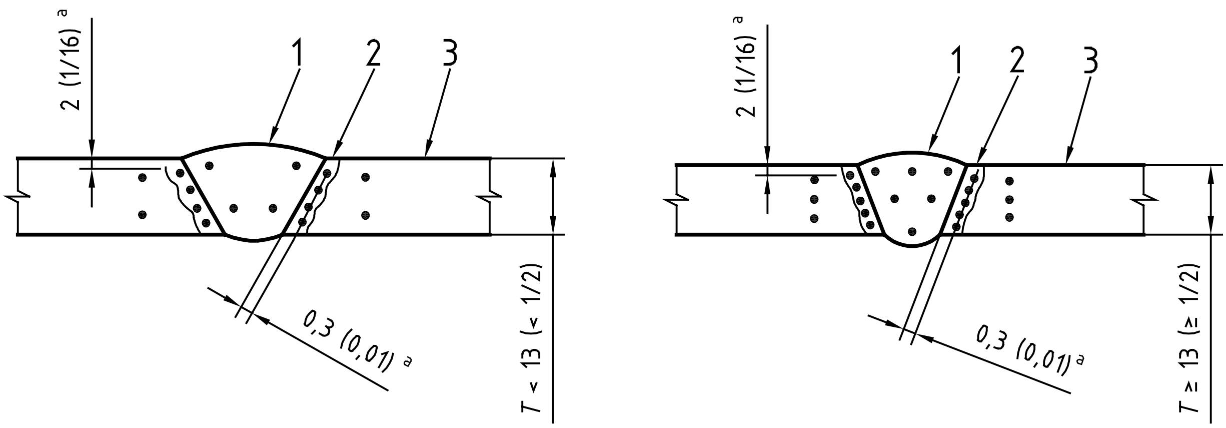
a Typical

Figure 13 — Rockwell hardness test locations

7.5.1.2.4 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 8.5.1.4 by the method shown in the same subclause.

Dimensions in millimetres (inches)



Key

1 Weld

2 HAZ

3 Base

a Typical

Figure 14 — Vickers hardness test locations

7.5.1.3 Impact testing

When impact testing is required by the base material specification, the testing shall be performed in accordance with ASTM A 370 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.

7.5.2 ASME Section IX, Article II — Welding procedure qualifications

7.5.2.1 General

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

7.5.2.2 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.

7.5.2.3 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 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 austentic 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.

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

7.5.3 ASME Section IX, Article III — Welding performance qualifications

7.5.3.1 General

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

7.5.3.2 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 11). The repair welding qualification test hole shall be qualified by radiography according to clause 8, or shall be cross-sectioned through the centreline of the hole and both faces shall be examined by NDE in accordance with clause 8. This evaluation shall include the total depth of the hole.

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

a) The hole diameter used for the performance qualification test is the minimum diameter qualified. Any hole with a diameter greater than that used for the test shall be considered qualified.

b) The depth-to-diameter ratio of the test hole shall qualify all repairs to holes with the same or smaller depth-to-diameter ratio.

c) The performance qualification test shall have straight parallel walls. If any taper, counter-bore or other aid is used to enhance the hole configuration of the performance test, that configuration shall be considered an essential variable.

For welder performance qualification, ASME Section IX P-1 base metals may be used for the test coupon in place of the low alloy steels covered by this International Standard (Table 20).

7.5.4 ASME Section IX, Article IV — Welding data

Article IV of ASME Section IX shall apply as written.

8 Quality control requirements

8.1 General

This clause specifies the requirements relative to quality control. The following subjects are covered:

a) measuring and test equipment (8.2);

b) quality control personnel qualifications (8.3);

c) quality control requirements for equipment and parts (8.4);

d) quality control requirements for specific equipment and parts (8.5):

   1) pressure-containing, pressure-controlling products and parts wetted by well-fluids (8.5.1);

   2) studs and nuts (8.5.2);

   3) closure bolting (8.5.3);

   4) ring gaskets (8.5.4);

   5) non-metallic sealing materials and moulded sealing assemblies (8.5.5);

   6) annular packers shipped separately (8.5.6);

   7) all other BOP parts (8.5.7);

   8) assembled drill-through equipment (8.5.8).

e) quality control records (8.6).

8.2 Measuring and testing equipment

8.2.1 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 International Standard.

8.2.2 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.

Pressure gauges shall have a minimum face diameter of 100 mm (4 in). Pressure measurements shall be made at not less than 25 % or more than 75 % of the full-pressure span of the gauge.

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 manufacturer and new intervals established.

8.3 Quality control personnel qualifications

8.3.1 Non-destructive examination (NDE) personnel

NDE personnel shall be qualified in accordance with requirements specified in ISO 9712.

8.3.2 Visual examination personnel

Personnel performing visual examinations shall have an annual eye examination in accordance with ISO 9712.

8.3.3 Welding inspectors

Personnel performing visual inspection of welding operations and completed welds shall be qualified and certified as follows:

a) AWS certified welding inspector; or

b) AWS certified associate welding inspector; or

c) welding inspector certified by the manufacturer's documented training programme.

8.3.4 Other personnel

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

8.4 Quality control requirements for equipment and parts

8.4.1 General

All equipment exposed to wellbore fluid shall comply with the requirements of NACE MR0175 in addition to the specific requirements of this International Standard.

8.4.2 Materials

Subclause 8.5.1 includes detailed qualification requirements for parts and qualification test coupons. It also includes heat-treatment equipment qualification requirements.

8.4.3 Quality control instructions

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

8.4.4 Non-destructive examination (NDE)

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

8.4.5 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.

8.5 Quality control requirements for specific equipment and parts

8.5.1 Pressure-containing and pressure-controlling parts

8.5.1.1 General

Pressure-containing and pressure-controlling parts include those exposed to wellbore fluid (except for studs and nuts, closure bolting, ring gaskets, non-metallic sealing materials, moulded sealing assemblies and metallic inserts in moulded assemblies; see 8.5.2 through 8.5.5).

8.5.1.2 Tensile testing

8.5.1.2.1 Pressure-containing parts

Methods and acceptance criteria shall be in accordance with 6.3.4.

8.5.1.2.2 Pressure-controlling parts exposed to wellbore fluid

Methods shall be in accordance with 6.3.4 and acceptance criteria shall be in accordance with the manufacturer's written specifications.

8.5.1.3 Impact testing

8.5.1.3.1 Pressure-containing parts

Methods and acceptance criteria shall be in accordance with 6.3.4.

8.5.1.3.2 Pressure-controlling parts exposed to wellbore fluid

Methods shall be in accordance with 6.3.4 and acceptance criteria shall be in accordance with the manufacturer's written specifications.

8.5.1.4 Hardness testing

Hardness testing methods shall be in accordance with ISO 6892, 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.

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

Hardness measurements on parts manufactured from carbon low alloy and martensitic stainless type steels shall exhibit maximum values in accordance with NACE MR0175 and minimum values equal to or greater than those specified in Table 24.

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 average tensile strength, as determined from the tensile tests 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:

$$HBW_{\mathrm{C}} = \left[\frac{UTS}{UTS_{\mathrm{QTC}}} \right] \cdot HBW_{\mathrm{QTC}}$$

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 average ultimate tensile strength determined from the QTC tensile tests;

HBW_{QTC} is the average of the Brinell hardness values observed among all tests performed 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 E 140.

Table 24 — Minimum hardness requirements

API material designation	Hardness (Brinell)
36K	140 HBW
45K	140 HBW
60K	174 HBW
75K	197 HBW

8.5.1.5 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 8.6. The manufacturer shall define and document the extent to which dimensions shall be verified.

8.5.1.6 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.

8.5.1.7 Chemical analysis

8.5.1.7.1 Sampling

Chemical analysis shall be performed on a heat basis.

8.5.1.7.2 Procedure

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

8.5.1.7.3 Acceptance criteria

The chemical composition shall meet the requirements of 6.3.3.

8.5.1.8 Visual examination

8.5.1.8.1 Sampling

Each part shall be visually examined.

8.5.1.8.2 Procedure

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

8.5.1.8.3 Acceptance criteria

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

Non-wellfluid-wetted and non-sealing surfaces shall be examined in accordance with visual examination methods described in this clause.

8.5.1.9 Surface NDE

8.5.1.9.1 General

All accessible surfaces of each finished part shall be inspected in accordance with this clause.

8.5.1.9.2 Surface NDE of ferromagnetic materials

All accessible wellfluid-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.

8.5.1.9.3 Surface NDE of non-ferromagnetic materials

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

8.5.1.9.4 Procedures

8.5.1.9.4.1 General

MP examination shall be in accordance with procedures specified in ISO 13665. Prods are not permitted on wellfluid-wetted surfaces or sealing surfaces.

LP examination shall be in accordance with procedures specified in ASTM E 165.

8.5.1.9.4.2 Acceptance criteria for MP and LP

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

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

— No relevant indication with a major dimension equal to or greater than 5 mm (0,2 in).

— No more than ten relevant indications in any continuous 10 cm^2 (2,5 in^2) area.

— Four or more relevant indications in a line separated by less than 1,5 mm (0,06 in) (edge to edge) are unacceptable.

8.5.1.9.4.4 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.

8.5.1.10 Weld NDE — General

When examination is required herein, essential welding variables and equipment shall be monitored, and completed weldments [a minimum of 12 mm (0,5 in) of surrounding base metal] and the entire accessible weld shall be examined in accordance with the methods and acceptance criteria of this clause.

8.5.1.11 Weld prep NDE — Visual examination

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

Examinations shall include a minimum of 12 mm (0,5 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.

8.5.1.12 Post-weld visual examination

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

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

Surface porosity and exposed slag are not permitted on or within 3 mm (0,125 in) of sealing surfaces.

8.5.1.13 Weld NDE — Surface examination (other than visual)

8.5.1.13.1 General

100 % 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.

The examination shall include 12 mm (0,5 in) of adjacent base material on both sides of the weld.

8.5.1.13.2 Procedures

Methods and acceptance criteria for MP and LP examinations shall be the same as in 8.5.1.9.4 except:

a) magnetic particle examination shall reveal

- no relevant linear indications,
- no rounded indications greater than 3 mm (0,125 in) for welds whose depth is 16 mm (0,63 in) or less or 5 mm (0,2 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 (0,125 in) for welds whose depth is 16 mm (0,63 in) or less or 5 mm (0,2 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.

8.5.1.14 Repair welds

All repair welds shall be examined using the same methods and acceptance criteria used in examining the base metal (8.5.1.9).

Examination shall include 12 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 (8.5.1.11).

8.5.1.15 Weld NDE — Volumetric examination of fabrication weld

8.5.1.15.1 General

100 % 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 12 mm (0,5 in) of adjacent base metal on all sides of the weld.

8.5.1.15.2 Radiography

8.5.1.15.2.1 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.

8.5.1.15.2.2 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 25;

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.

Table 25 — Weld inclusion criteria

Weld thickness t		Inclusion length	
mm	(in)	mm	(in)
< 19	$< 0{,}76$	6,4	0,25
$19 \leqslant t \leqslant 57$	$0{,}76 \leqslant t \leqslant 2{,}25$	0,33 t	0,33 t
> 57	$> 2{,}25$	19,0	0,75

8.5.1.15.3 Ultrasonic examination

8.5.1.15.3.1 Procedure

Ultrasonic examinations shall be performed in accordance with procedures specified in ASME Boiler and Pressure Vessel Code, Section V, Article 5.

8.5.1.15.3.2 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 25.

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

8.5.1.15.4 Acoustic emission examination

8.5.1.15.4.1 Procedure

Acoustic emission (AE) examinations shall be performed in accordance with procedures specified in ASTM E 569. The acoustic emission examination shall be conducted throughout the duration of the hydrostatic “in-plant” test.

8.5.1.15.4.2 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 8.5.1.15.4.2 a) shall apply and, in addition, the following AE indications shall not be accepted:

   1) any AE event during any pressure hold;

   2) any single AE event that produces more than 500 counts, or that produces a single attribute equivalent to 500 counts;

   3) three or more AE events from any circular area whose diameter is equal to the weld thickness or 25 mm (1 in), whichever is greater;

   4) two or more AE events from any circular area (having a diameter equal to the weld thickness or 25 mm (1 in), whichever is greater) that emitted multiple AE events during the first pressurization;

Welds that produce questionable acoustic emission response signals (i.e. AE signals that cannot be interpreted by the AE examiner) shall be evaluated by radiography in accordance with 8.5.1.15.2. 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 8.5.1.15.3. Final acceptance (or rejection) of such welds shall be based on the radiographic or ultrasonic results, as applicable.

8.5.1.16 Weld NDE — Hardness testing

8.5.1.16.1 Sampling

All accessible pressure-containing, non-pressure-containing and major repair welds shall be hardness tested.

8.5.1.16.2 Methods

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

a) those procedures specified in ISO 6506-1;

b) those procedures specified in 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.

8.5.1.16.3 Acceptance criteria

Hardness values shall meet the requirements of 8.5.1.4.

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

8.5.2 Studs and nuts (other than closure bolting)

Studs and nuts shall conform to the requirements of ISO 10423.

8.5.3 Closure bolting

Closure bolting shall conform to the requirements of ISO 10423, plus:

a) material in closure bolts shall be traceable to the heat or identified in accordance with ASTM A 193, ASTM A 320 or ASTM A 453;

b) the thread form and dimensions of closure bolts shall conform to the manufacturer's written specification.

8.5.4 Ring gaskets

Ring gaskets shall conform to the requirements of ISO 10423.

8.5.5 Non-metallic sealing materials and moulded sealing assemblies

8.5.5.1 Ram and annular BOP packers and seals

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 D 1415 or ASTM D 2240;

b) tensile data in accordance with ASTM D 1414 or ASTM D 412;

c) elongation data in accordance with ASTM D 1414 or ASTM D 412;

d) modulus data in accordance with ASTM D 1414 or ASTM D 412.

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

8.5.5.2 Metallic inserts in moulded assemblies

8.5.5.2.1 Dimensional verification

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

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

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

8.5.5.2.2 Hardness testing

Sampling shall be in accordance with 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 ISO 6506-1 or ISO 6508-1.

Acceptance shall be in accordance with manufacturer's written requirements and NACE MR0175.

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

8.5.6 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 8.5.8.7.2.

When shipped separately (not part of an assembled BOP), annular packers shall be drift-tested following the pressure test. Drift tests shall comply with 8.5.8.4.

8.5.7 All other drill-through equipment not covered in 8.5.1 through 8.5.6

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

8.5.8 Assembled equipment

8.5.8.1 General

The quality control requirements for assembled equipment shall include drift tests, pressure tests and hydraulic operating system tests.

8.5.8.2 Serialization

Serialization is required on all assembled equipment and shall be carried out in accordance with the manufacturer's written specification.

8.5.8.3 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).

8.5.8.4 Drift test

8.5.8.4.1 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 with a tolerance of ${}^{+0,25}_{\ \ 0}$ mm $\left({}^{+0,01}_{\ \ 0}\,\text{in}\right)$.

Drift mandrel gauge length shall be at least 51 mm (2 in) longer than any cavity that intersects the bore, but not less than 300 mm (7,6 in).

8.5.8.4.2 Acceptance

The drift mandrel shall pass through the bore within 30 min without being forced.

8.5.8.5 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 8.2. The record shall identify the recording device, and shall be dated and signed.

8.5.8.6 Hydrostatic proof testing

8.5.8.6.1 General

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

8.5.8.6.2 In-plant hydrostatic body or shell 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 26. For equipment with end or outlet connections having different working pressures, the lowest rated working pressure shall be used to determine the shell test pressure.

Table 26 — Hydrostatic test pressures

Rated working pressure		Hydrostatic test pressure	
MPa	(psi)	MPa	(psi)
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

8.5.8.6.3 Hydraulic operating-chamber test

The hydraulic operating system test shall be tested on each assembled blowout preventer and hydraulic connector.

The hydraulic operating chamber shall be tested at a minimum test pressure equal to 1,5 times the operating chamber's rated working pressure.

8.5.8.6.4 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 min;

b) reduction of the pressure to zero;

c) a second pressure-holding period of not less than 15 min.

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

The acceptance criterion shall be zero leakage.

8.5.8.7 Closed-preventer test

8.5.8.7.1 General

8.5.8.7.1.1 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 8.5.8.6.1.

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.

8.5.8.7.1.2 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 min after stabilization.

8.5.8.7.1.3 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 min after stabilization (see exception for annular packing units in 8.5.8.7.2).

8.5.8.7.1.4 Acceptance criterion

There shall be no visible leakage.

8.5.8.7.2 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 27.

The stage two test shall require pressure-testing without drill pipe in the preventer, i.e. on the open hole. The high pressure test for this stage shall be as specified in 8.5.8.7.1.3, except as a minimum it shall be performed at 50 % of the rated working pressure of the preventer.

Table 27 — Pipe size requirements

Bore size		Pipe diameter	
mm	(in)	mm	(in)
179 and 228	7 1/16 and 9	88,9	3 ½
279 and larger	11 and larger	127,0	5

8.5.8.7.3 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.

8.5.8.7.4 Blind-shear rams

Each preventer equipped with blind-shear rams shall be subjected to a shearing test. The minimum size shear pipe used shall conform to Table 18. 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. The piston-closing pressure shall not exceed the manufacturer's rated working pressure for the operating system. Documentation shall include the manufacturer's shear ram and blowout preventer configurations, the actual pressure and force to shear the pipe. Documentation shall also include pipe description (size, mass and grade), actual pipe tensile properties, and impact properties as specified in ISO 11961.

8.5.8.7.5 Hydraulic ram-locking system

The closed-preventer test for each blowout preventer equipped with a hydraulic 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 8.5.8.7.1.2 and 8.5.8.7.1.3 after the rams are closed, the locks engaged and then all operating pressure(s) released.

8.5.8.8 Hydraulic connector tests

8.5.8.8.1 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 8.5.8.6.1.

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

The tests shall conform to 8.5.8.8.2 and 8.5.8.8.3, with the low pressure test always preceding the high pressure test.

8.5.8.8.2 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 min after stabilization.

8.5.8.8.3 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 min after stabilization.

8.5.8.8.4 Acceptance criterion

There shall be no visible leakage.

8.5.8.8.5 Procedure

The connector pressure test shall be in two stages.

During stage one, the connector shall be locked on the appropriate test stump using the manufacturer's recommended operating pressure, and then the operating pressure shall be removed prior to the pressure test.

During stage two, the connector shall be locked on the appropriate test stump using the manufacturer's recommended operating pressure, and then pressure-tested.

8.6 Requirements for quality control records

8.6.1 General

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

8.6.2 NACE records requirements

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

8.6.3 Records control

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

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

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

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

8.6.4 Records to be maintained by manufacturer

8.6.4.1 Records

The manufacturer shall retain all documents and records as required in clause 5 through clause 8.

8.6.4.2 Parts or components covered in 8.5.1

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) welding process records:

   1) welder identification;

   2) weld procedures;

   3) filler materials;

   4) post-weld heat treatments;

h) heat treatment records:

   1) actual temperature;

   2) actual times at temperature;

i) volumetric NDE records;

j) hydrostatic pressure test records;

k) critical dimensions as defined by the manufacturer.

8.6.4.3 Closure bolting

The manufacturer shall retain individual-heat-traceability records for closure bolting, as required.

8.6.4.4 Non-metallic sealing materials and moulded sealing assemblies

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

8.6.4.5 Annular packers shipped separately

The following records shall be retained:

a) pressure test records (8.5.8.5);

b) drift test record (8.5.6).

8.6.4.6 Assembled drill-through equipment

The following records shall be retained:

a) pressure test records (8.5.8.5);

b) drift test record (8.5.8.4).

8.6.5 Records to be furnished to original purchaser upon product delivery

A manufacturer's certificate of compliance stating that equipment conforms to the current edition of the International Standard.

9 Marking requirements

9.1 General

All equipment, as listed in clause 1, manufactured in accordance with this International Standard shall be marked in accordance with the procedure and requirements of this clause and Table 28.

Equipment shall be stamped on the product with the product description code (PDC) or alphanumeric code, followed by "ISO 13533".

9.2 Types of identification stamping

9.2.1 Metallic components

9.2.1.1 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.

9.2.1.2 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.

9.2.1.3 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.

9.2.2 Non-metallic components

9.2.2.1 Wellbore non-metallic components

For identification of wellbore non-metallic 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.

9.2.2.2 Non-wellbore non-metallic components

Identification of non-wellbore non-metallic components, such as elastomeric seals used in ram and annular type BOP actuation systems, shall be in accordance with the manufacturer's written specification.

9.3 Specific codification requirements of equipment

9.3.1 Gaskets

Ring gaskets shall be marked in accordance with ISO 10423.

Table 28 — Marking requirements and location

Marking	Ram blowout preventer	Annular blowout preventer	Hydraulic connector	Drilling spools and adapters	Loose connector	OECs (integral & loose) [d]	Clamps	Ram blocks	Annular & ram packers & top seals
ISO 13533	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) (9.4.2.1)	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	
ISO size designation (Table 33)	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 34)	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 35)	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 (9.4)	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								
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]			
Alphanumeric codification system (9.3.4)									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 ISO 10423.

[c] If the ring groove is overlaid with corrosion-resistant material, the ring groove number shall be followed with "CRA".

[d] All ISO 10423 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 15. If the clamp number is used, the rated working pressure code shall be replaced by the letters "CC".

9.3.2 Studs and nuts

Studs and nuts shall be marked in accordance with ISO 10423.

9.3.3 Closure bolting

Closure bolting shall be marked in accordance with the manufacturer's written specification.

9.3.4 Packers and seals

Wellbore non-metallic components, as described in 9.2.2.1, 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 29. In addition, the manufacturer's part number shall be marked on the component.

AA BBBB CCCC DDDD EE

Table 29 — Code system for non-metallic sealing materials

Code	Description
AA	Compound hardness (Durometer)
BBBB	Generic type of compound (see Table 30 and ASTM D 1418)
CCCC	Date of manufacture (see 9.4.2.5)
DDDD	Lot/serial number (in accordance with manufacturer's spec)
EE	Temperature class (see Table 4)

Table 30 — Elastomer compound marking code

Common name/ trade name	Chemical name	Code ASTM D 1418
Butyl	Isobutylene, Isoprene	IIR
	Epichlorohydrin	CO
	Epichlorohydrin-ethylene oxide	ECO
Kel-F [a]	Chlorofluoro elastomer	CFM
Hypalon [a]	Chlorosulfonated polyethylene	CSM
EPR	Ethylene-propylene copolymer	EPM
EPT	Ethylene-propylene diene monomer	EPDM
Viton[a]	Fluoro elastomer	FKM
Natural rubber	Polyisoprene	NR
Isoprene (natural or synthetic)	Polyisoprene	IR
Nitrile rubber	Butadiene-acrylonitrile	NBR
Acrylic	Polyacrylic	ACM
Diene rubber	Polybutadiene	BR
Neoprene[a]	Polychloroprene	CR
Vistanex[a]	Polyisobutylene	IM
Thiokol	Polysulfide	—
Silicone	Polysiloxanes	Si
SBR (GR-S)	Styrene-butadiene	SBR
Urethane	Diisocyanates + polyols	—

[a] This is the trade name of a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of this product. Equivalent products may be used if they can be shown to lead to the same results.

9.4 Product description code (PDC)

9.4.1 General

The product description code (PDC) is used as an aid in describing equipment manufactured to this International Standard. The PDC is a twelve-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 31.

AA BB CC DD EEEE

Table 31 — Product description code

Code	Description
AA	Equipment type (see 9.4.2.1)
BB	Size designation (see 9.4.2.2)
CC	Rated working pressure (see 9.4.2.3)
DD	Temperature rating (see 9.4.2.4)
EEEE	Date of manufacture (see 9.4.2.5)

9.4.2 Code designations

9.4.2.1 Equipment type (AA)

The equipment type code provides a basic description of the equipment. See Table 32 for codification.

9.4.2.2 Size designation (BB)

The size designation provides the bore size of the equipment. See Table 33 for codification.

9.4.2.3 Rated working pressure (CC)

The rated working pressure is the maximum pressure at which the equipment is designed to operate. See Table 34 for codification.

9.4.2.4 Temperature rating for metallic materials (DD)

The temperature rating, of the metallic materials only. See Table 35 for codification.

9.4.2.5 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).

Table 32 — 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
Other	99

Table 33 — ISO equipment size designation

ISO 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

Table 34 — Rated working pressure

Rated working pressure		Code CC
MPa	(psi)	
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

Table 35 — Temperature ratings (metallic materials)

Operating temperature range		Code DD
°C	(°F)	
− 59 to 121	− 75 to 250	75
− 29 to 121	− 20 to 250	20
− 18 to 121	0 to 250	00

10 Storing and shipping

10.1 Storing for periods greater than 30 days

10.1.1 Draining after testing

All equipment shall be drained after testing and prior to storage.

10.1.2 Rust prevention

Prior to storage, parts and equipment shall have exposed metallic surfaces protected with a rust preventative which will not become fluid at temperatures below 50 °C (125 °F).

10.1.3 Connection-surface protection

All connection faces and ring gasket grooves shall be protected with durable covers.

10.1.4 Hydraulic operating system

The hydraulic operating system shall be flushed with a non-freezing, corrosion-inhibiting fluid in accordance with the manufacturer's written procedures. Ports shall be plugged prior to storing.

10.1.5 Elastomeric seals

Elastomeric seals shall be stored in accordance with the manufacturer's written procedures.

10.1.6 Ring gaskets

Loose ring gaskets shall be wrapped or boxed for storage and shipping.

10.2 Shipping

All equipment shall be shipped in accordance with the manufacturer's written procedures.

Annex A
(normative)

Qualification of heat-treating equipment

A.1 General

All heat treatment of parts and QTCs shall be performed with equipment meeting the requirements of this annex.

A.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 which are used for tempering, ageing 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.

A.3 Furnace calibration

A.3.1 General

Heat treatment of production parts shall be performed with heat-treating equipment that has been calibrated and surveyed.

A.3.2 Records

Records of furnace calibration and surveys shall be maintained for a period not less than two years.

A.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 A.1 and A.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, centre and rear, or at the top, centre and bottom of the furnace working zone.

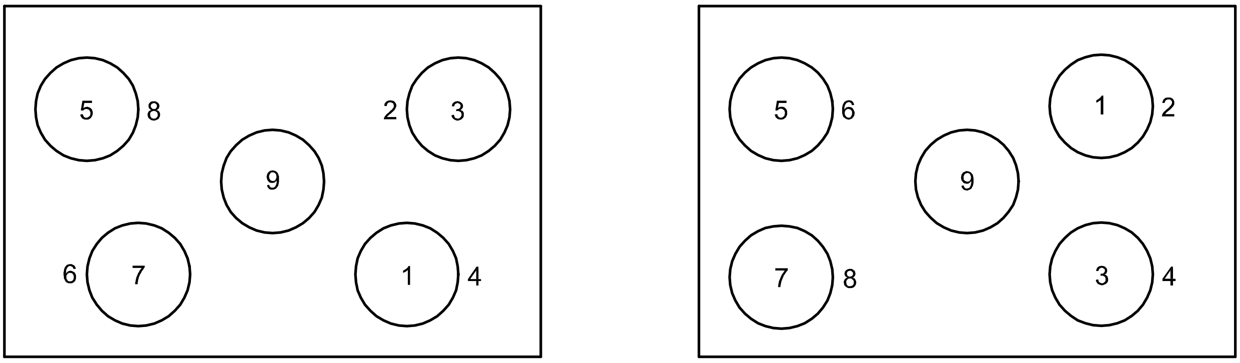
After insertion of the temperature-sensing devices, readings shall be taken at least once every 3 min to determine when the temperature of the furnace working zone approaches the bottom of the temperature range being surveyed.

Once the furnace temperature has reached the set-point temperature, the temperature of all test locations shall be recorded at 2-min intervals, maximum, for at least 10 min. Then readings shall be taken at 5-min intervals, maximum, for sufficient time (at least 30 min) 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).

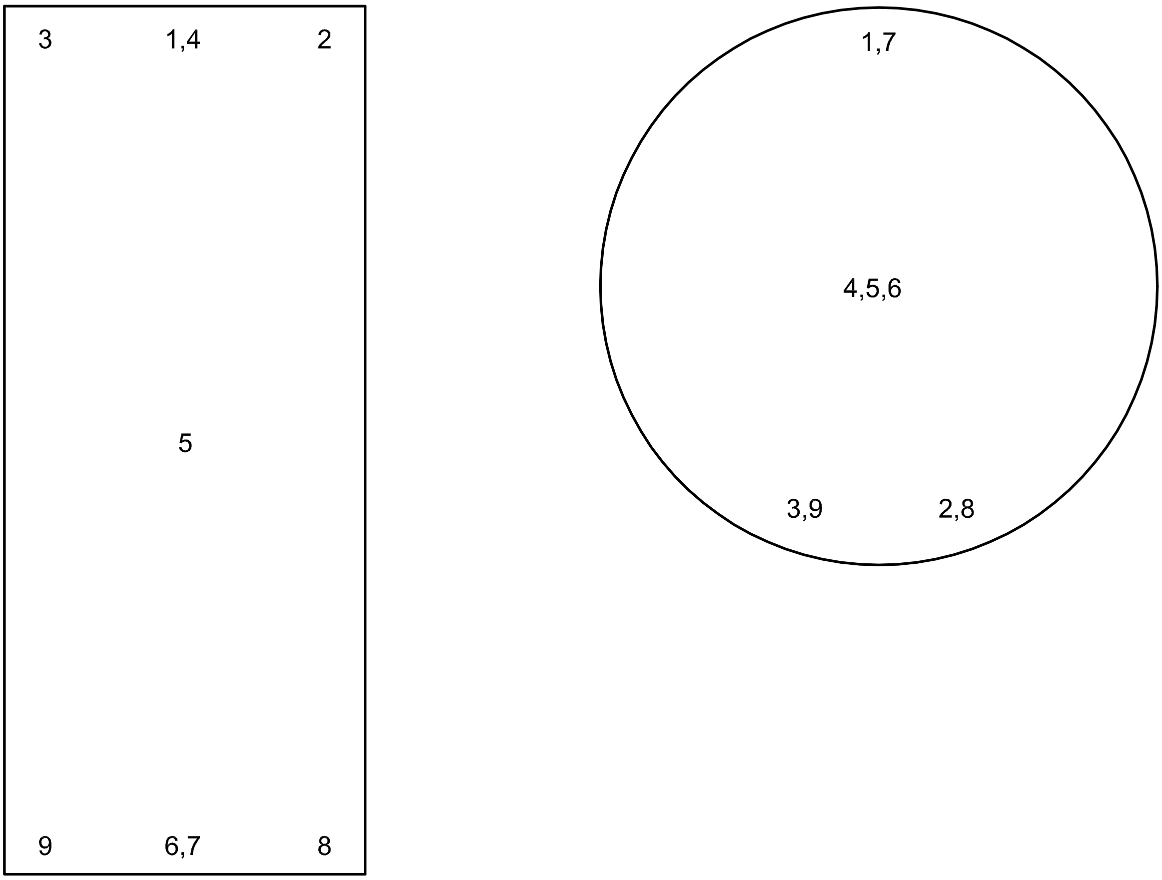
After the furnace control set-point temperature is reached, no temperature reading shall vary beyond the limits specified. The temperatures within each furnace shall be surveyed within one year prior to use of the furnace for heat treatment.

When a furnace is repaired or rebuilt, a new temperature survey shall be carried out before the furnace is used for heat treatment.



a) **Top view**   b) **Side view**

Figure A.1 — Thermocouple locations — Rectangular furnace (working zone)



a) **Side view**   b) **Top view**

Figure A.2 — Thermocouple locations — Cylindrical furnace (working zone)

A.3.4 Continuous-type furnaces method

Furnaces used for continuous heat treatment shall be calibrated in accordance with procedures specified in SAE AMS-H-6875F.

A.4 Instruments

A.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.

A.4.2 Accuracy

The controlling and recording instruments used for the heat-treatment processes shall be accurate to ± 1 % of their full-scale range.

A.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 B
(normative)

Requirements for repair and remanufacture

B.1 General

This annex defines the requirements for repair and remanufacture of drill-through equipment originally manufactured in accordance with this International Standard. Field repair with or without the replacement of parts and modification of equipment is outside the scope of this annex.

B.2 Repair and remanufacture

B.2.1 Personnel

Personnel performing repair and remanufacture operations described in this annex shall be qualified in accordance with written requirements of the repairer/remanufacturer which include specified minimum training and qualification requirements.

B.2.2 Equipment identification

Identification shall be determined through markings or records traceable to markings in accordance with the following list. All information shall be documented.

a) Original manufacturer;

b) size and working pressure;

c) material class and temperature rating;

d) serial number and any other traceable information, as applicable;

e) comments as to general condition from visual examinations;

f) product design status.

B.2.3 Repair of equipment

Repair of equipment shall not include remanufacturing of pressure-containing part(s) or pressure-controlling part(s) or member(s). Repair may include remanufacturing of other parts when necessary to return the equipment to working condition.

Repair of equipment shall be carried out as follows.

a) Disassembly and cleaning shall be performed in accordance with repairer's/remanufacturer's documented requirements. Control features shall be included to segregate or identify components of each assembly to avoid mixing or mismatching of parts.

b) Complete disassembly shall be carried out.

c) Visual examination shall be performed in accordance with documented specifications which include acceptance criteria. Results of the examination shall be documented.

d) All dimensions controlled by this International Standard and the critical dimensions as defined by the original equipment manufacturer (OEM) shall be verified. Verification of ring groove diameters is excluded from this requirement. Results of the verification shall be documented and maintained.

e) Hardness testing shall be carried out in accordance with this annex.

f) Replacement or remanufacture shall be carried out of those parts necessary to return the equipment to working condition. Remanufacture of parts other than bodies, bonnets and ram blocks shall be in accordance with the quality control requirements of the original design specifications.

g) Equipment shall be reassembled in accordance with documented specifications of the repairer/remanufacturer.

h) Equipment shall be tested in accordance with the requirements of clause 8, except that hydrostatic proof testing in accordance with 8.5.8.6 shall use pressures equal to the equipment rated working pressure.

B.2.4 Remanufacture of equipment

Remanufacture of equipment shall include remanufacturing of pressure-containing part(s) and pressure-controlling part(s) or member(s). Remanufacturing of other parts to return the equipment to working condition may also be performed.

All remanufactured parts and replacement parts shall meet or exceed the original equipment design requirements of the OEM, such as mechanical properties of the material.

Remanufacturing of equipment shall include the following.

a) Disassembly and cleaning shall be performed in accordance with repairer's/remanufacturer's documented requirements. Control features shall be included to segregate or identify components of each assembly to avoid mixing or mismatching of parts.

b) Complete disassembly shall be carried out.

c) Visual examination shall be performed in accordance with documented specifications, which includes acceptance criteria. Results of the examination shall be documented.

d) All dimensions controlled by this International Standard and the critical dimensions as defined by the OEM shall be verified. Verification of ring groove diameters is excluded from this requirement. Results of the verification shall be documented and maintained.

e) Hardness testing shall be carried out in accordance with this annex.

f) Dimensional inspection and non-destructive examination of remanufactured parts in accordance with the requirements of this annex. Results of inspections, tests, and examinations shall be documented.

g) All parts that do not meet acceptance criteria shall be replaced or remanufactured. Remanufacture of parts shall be in accordance with the quality control requirements of this annex.

h) Equipment shall be reassembled in accordance with documented specifications of the repairer/remanufacturer.

i) Equipment shall be tested in accordance with the requirements of clause 8.

B.3 Design and performance requirements

B.3.1 Design of replacement parts

Replacement parts shall be designed and manufactured by the OEM and shall meet or exceed design requirements of the original parts.

B.3.2 Design of remanufactured parts

Remanufactured parts shall be in accordance with the design requirements of the OEM.

B.3.3 Design status

Equipment designs established as no longer suitable for repair and remanufacture by the OEM as a result of design changes, such as designs for materials, processes, physical features or application, shall be deemed unacceptable for repair or remanufacture in accordance with this annex.

B.4 Material requirements

Requirements for materials used to manufacture replacement parts shall conform to the requirements of clause 6.

B.5 Welding

The material being welded shall be identified and welding shall be performed in accordance with the requirements of clause 7 corresponding to the equipment or part being repaired.

B.6 Quality control

B.6.1 Personnel

Personnel performing quality control activities shall be qualified in accordance with the requirements of 8.3.

B.6.2 Measuring and testing equipment

Measuring and testing equipment shall be maintained and calibrated in accordance with the requirements of 8.2.

B.6.3 Pressure-containing and pressure-controlling parts (reused parts)

B.6.3.1 Hardness testing

All parts that are to be reused shall be hardness tested in accordance with 8.5.1.4.

B.6.3.2 Verification of dimensions

All dimensions controlled by this International Standard and the critical dimensions as defined by the OEM shall be verified, except for ring grooves.

All dimensions affected by remanufacturing shall be verified to documented design specifications.

B.6.3.3 Visual examination

All accessible surfaces shall be visually examined in accordance with documented procedures that include acceptance criteria.

B.6.3.4 Surface NDE

All accessible wetted surfaces and all accessible sealing surfaces affected by remanufacturing shall be examined in accordance with 8.5.1.9.

B.6.3.5 Weld NDE

Quality control requirements for welding shall be in accordance with 8.5.1.10.

All welds shall be examined in accordance with 8.5.1.11 and 8.5.1.12.

Weld-surface NDE shall be performed in accordance with 8.5.1.13. Additionally, all accessible wetted and sealing surfaces shall be examined after final heat treatment and machining.

All repair welds shall be examined in accordance with 8.5.1.14. Additionally, all accessible wetted and sealing surfaces shall be examined after final heat treatment and machining.

All pressure-containing welds and all repair welds where the repair is greater than 25 % of the wall thickness or 25 mm (1 in) (whichever is less) shall be examined in accordance with 8.5.1.15.

All pressure-containing welds and all repair welds shall be hardness-tested in accordance with 8.5.1.16.

B.6.4 Studs and nuts (reused parts)

Studs and nuts that are intended for reuse shall be examined in accordance with specified requirements of the repairer/remanufacturer.

B.6.5 Non-metallic sealing materials and moulded sealing assemblies (reused parts)

Non-metallic sealing materials and moulded sealing assemblies that are intended to be reused shall be examined in accordance with specified requirements of the repairer/remanufacturer.

B.6.6 Assembled equipment

The quality control requirements for assembled equipment shall be in accordance with 8.5.8.

Assembled equipment shall be tested in accordance with 8.5.8.

B.6.7 Quality control records

Quality control records for replacement parts shall conform to 8.6.

Quality control records for reused parts shall conform to 8.6, except that material test records are not required.

Quality control records for assembled equipment shall conform to 8.6.

Quality control records required to be furnished to the purchaser shall conform to 8.6. The certificate of compliance shall state that the equipment was repaired or remanufactured in accordance with the requirements of this International Standard.

B.7 Equipment marking

B.7.1 General

Equipment repaired or remanufactured shall be marked in accordance with the requirements of this annex. These marking requirements are in addition to and do not replace marking requirements of clause 9, which are applicable to the repair or remanufacture.

B.7.2 Repair and remanufacture markings

Location of marking for metallic equipment which is repaired or remanufactured shall be in accordance with Table 28.

The following marking shall be added to the parts:

a) “RMFR” for remanufacture or “RPR” for repair;

b) repairer's/remanufacturer's name or mark;

c) date of repair or remanufacture (month and year).

B.8 Storage and shipment

Storing and shipping shall be in accordance with the requirements of clause 10.

Annex C
(informative)

Operational characteristics test procedure

C.1 Pressure-related testing

C.1.1 Pressure-loss measurement

The pressure shall be allowed to stabilize before timing of the pressure test on drill-through equipment begins.

C.1.2 Calibration

Each gauge or pressure transducer used shall be calibrated in accordance with 8.2.

C.1.3 Pressure-recording technique

All tests shall be carried out in conjunction with a data acquisition system. The information shall be identified, dated, and signed/verified by the tester and witnesses as applicable.

C.2 Ram-type BOP

C.2.1 Sealing characteristics test

C.2.1.1 Ram closure against zero initial wellbore pressure

C.2.1.1.1 Install the preventer on the test stump. Connect opening and closing lines to BOP. Connect line from the high-pressure test pump to the stump or BOP side outlet.

C.2.1.1.2 The opening, closing and wellbore pressure lines shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system which provides a permanent record.

C.2.1.1.3 Install a new set of ram rubber goods onto the blocks. Durometer measurements on the ram rubber face seal shall be made and recorded.

C.2.1.1.4 Disengage any automatic locking system on the ram closing device.

C.2.1.1.5 Install test mandrel in the BOP for pipe ram tests. No test mandrel is used for blind/shear ram tests.

C.2.1.1.6 Close the rams using manufacturer's recommended closing pressure.

C.2.1.1.7 Initially apply 3,45 MPa (500 psi) wellbore pressure and then reduce the closing pressure slowly until a leak develops. If rams do not leak at zero closing pressure, slowly increase opening pressure until a leak occurs or maximum recommended opening pressure is attained. Note the operating pressure at which the leak occurs.

C.2.1.1.8 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 (or increase opening pressure) until a well leak occurs. Record the operating pressure at which the leak occurs.

C.2.1.1.9 Repeat C.2.1.1.8 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).

C.2.1.2 Ram closure against elevated wellbore pressure

C.2.1.2.1 Install the preventer on the test stump. Connect opening and closing lines to the BOP. Connect line from the high-pressure test pump to the stump.

C.2.1.2.2 The closing line and wellbore pressure line shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system to provide a permanent record.

C.2.1.2.3 Install test mandrel in the BOP. Install a test flange to close the top of preventer. The piping out of the top flange shall include a bleed vent, pressure transducer, 75 l to 150 l (20 gal to 40 gal) capacity of accumulator bottles, and a pressure regulator. Fill the preventer test assembly with water until no more air comes out the bleed vent.

NOTE When the wellbore fluid volume difference between closing position and opening position of the BOP is less than 40 l (10 gal), use a 75 l (20 gal) accumulator system; when the difference is greater than 40 l (10 gal), use a 150 l (40 gal) accumulator system.

C.2.1.2.4 With the accumulator bottle precharge set at about one-half of the wellbore pressure to be applied for this test step, close the vent and then apply the test-step wellbore pressure [initially the wellbore pressure is 3,45 MPa (500 psi)].

C.2.1.2.5 Close preventer with manufacturer's recommended closing pressure (adjust upward if required).

C.2.1.2.6 Check that the top flange system pressure is equal to the wellbore pressure and adjust if necessary.

C.2.1.2.7 Increase the wellbore pressure by 3,45 MPa (500 psi) above the level in C.2.1.2.4.

C.2.1.2.8 Confirm a wellbore pressure seal.

C.2.1.2.9 Lower the closing pressure until a leak develops, as monitored by fluid discharge from the top flange regulator.

C.2.1.2.10 Bleed off wellbore and top flange pressures and open preventer.

C.2.1.2.11 Repeat C.2.1.2.4 through C.2.1.2.10, increasing the wellbore pressure in steps until it 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).

C.2.2 Fatigue test

C.2.2.1 Install the preventer on the test stump. Connect opening and closing lines to the BOP. Connect line from high-pressure test pump to the stump or BOP side outlet.

C.2.2.2 The closing line and wellbore pressure lines shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system to provide a permanent record.

C.2.2.3 The ram blocks shall be inspected prior to testing. The inspection shall include

a) MP inspection of ram blocks,

b) durometer measurements on ram rubber.

C.2.2.4 Install test mandrel in BOP for pipe ram tests. No test mandrel is required in blind/shear ram tests. A 127 mm (5 in) OD test mandrel shall be used in testing 279 mm (11 in) and larger blowout preventers. A 88,9 mm (3 ½ in) OD mandrel shall be used in testing blowout preventers smaller than 279 mm (11 in).

C.2.2.5 Close and open the rams seven times using 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 lock the locks, then relieve all hydraulic pressure prior to performing the test. Test pressures shall each be held for a period of 3 min.

C.2.2.6 Repeat C.2.2.5 until the rams fail the seal check or until 546 openings and closings have been completed (78 pressure tests).

C.2.2.7 Repeat inspection as in C.2.2.3.

C.2.2.8 Document any observed wear following the test.

C.2.3 Shear ram test

C.2.3.1 Install the preventer on the test stump. Connect opening and closing lines to BOP. Connect line from the high-pressure test pump to the stump or BOP side-outlet.

C.2.3.2 The opening, closing and wellbore pressure lines shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system to provide a permanent record.

C.2.3.3 Install a new set of ram packers onto the blocks; durometer measurements on the ram rubber seal shall have been made and recorded.

C.2.3.4 Suspend a section [approximately 1,2 m (4 ft) in length] of drill pipe as specified in 5.7.2.4 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 the rams to prevent excessive bending of the pipe during shearing.

C.2.3.5 Set closing unit manifold pressure to manufacturer's recommended pressure for shearing. Close the rams and shear the pipe in a single operation. The pressure at which the pipe is sheared will be obvious from the rapid pressure change at the instant of shearing.

C.2.3.6 Raise the wellbore pressure to 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and hold for 3 min, examining for leaks.

C.2.3.7 Raise wellbore pressure to maximum rated working pressure of preventer and again examine for leaks during 3 min.

C.2.3.8 Reduce wellbore pressure to zero, open rams, inspect and document any wear on the preventer.

C.2.3.9 Repeat C.2.3.4 through C.2.3.8 for two additional samples of drill pipe. Ram packers may be replaced as necessary.

C.2.4 Hang-off test

C.2.4.1 Install the preventer on a pull-down test stump. Connect opening and closing lines to the BOP. Connect line from the high-pressure test pump to the stump or BOP side outlet.

C.2.4.2 The closing line and wellbore pressure line shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system to provide a permanent record.

C.2.4.3 The ram blocks, a simulated 18° API tool-joint mandrel, and rubber packer metal inserts shall be inspected and the results recorded prior to testing. The dimensional and hardness specifications of the simulated tool joint(s) used shall be in accordance with API Spec 7 [1].

The inspection shall include:

a) MP inspection of ram blocks;

b) hardness measurement of the ram packer steel segments;

c) hardness measurement of ram blocks;

d) hardness measurement of the simulated tool joint;

e) durometer measurements on ram packer.

C.2.4.4 Raise the simulated tool-joint so that the 18° taper is immediately above the ram blocks. Close ram on the pipe with the manufacturer's recommended closing pressure.

C.2.4.5 Pressure test to 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and to maximum rated working pressure of preventer.

C.2.4.6 Bleed wellbore pressure to zero psi, increase the load incrementally and repeat C.2.4.5 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 (440 000 lb) load for pipe less than 125 mm (5 in).

C.2.4.7 Repeat C.2.4.5 and C.2.4.6 using only the locking mechanism provided with the preventer to maintain the closed position.

C.2.4.8 Document any wear or deformation of the ram blocks, simulated tool-joint and the metal inserts of the ram packer.

C.2.5 Ram access test

C.2.5.1 Assemble the blowout preventer on a test stump with pipe rams and an appropriate-size test mandrel or with blind rams. Connect pressure transducers to the closing line and test stump. Connect the transducer output to an appropriate data acquisition system.

C.2.5.2 Perform the manufacturer's recommended procedure for opening all closures required for ram and packer access, removing closures or opening them to their full extent, as required for ram removal.

C.2.5.3 Perform the manufacturer's recommended procedure for closing all ram-access closures, including manufacturer's recommended maintenance procedures and replacement parts.

C.2.5.4 Repeat C.2.5.2 and C.2.5.3 for a total of 200 times. Every twentieth time, pressure-test the BOP to rated working pressure for a minimum of 3 min.

C.2.6 Test for stripping life

C.2.6.1 Measure and record the durometer hardness of the packer rubber. Install BOP on the reciprocation machine. Connect opening and closing lines to BOP. Connect line from the high-pressure test pump to the stump or BOP side-outlet.

C.2.6.2 Connect accumulator [20 l (5 gal) minimum] to the wellbore (stump) and precharge to 75 % of the wellbore pressure to be used during the tests. The closing line and wellbore pressure line shall each be equipped, as minimum instrumentation, with a pressure transducer. Connect all pressure transducers to a data acquisition system to provide a permanent record.

C.2.6.3 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 ½ in) OD test mandrel (no tool joint).

C.2.6.4 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 4 l/min (1 gal/min) (to wet the test mandrel wall).

C.2.6.5 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 elements.

C.2.6.6 Bleed off wellbore pressure, and open the rams.

C.2.6.7 As the severity of the leak increases, raise the closing pressure, as needed, to the manufacturer's recommended value and repeat C.2.6.5 through C.2.6.7.

C.2.6.8 Repeat C.2.6.4 through C.2.6.6 until the leak rate exceeds 4 l/min (1 gal/min) or an equivalent of 15 000 m (50 000 ft) of pipe has passed through the packer elements.

C.2.6.9 Document any wear on all ram packers as they are removed during the tests.

C.2.6.10 Repeat C.2.6.4 through C.2.6.9 using wellbore pressures of 13,79 MPa (2 000 psi) and then 20,68 MPa (3 000 psi), providing these pressures do not exceed the working pressure of the BOP.

C.2.7 Ram locking device test

The ram locking device test may be accomplished as part of both the fatigue and hang-off tests.

C.3 Annular-type BOP

C.3.1 Sealing characteristics test

C.3.1.1 Install the preventer on the test stump. Connect opening and closing lines to the BOP. Connect line from the high pressure test pump to the stump or the BOP side outlet.

C.3.1.2 The closing line and wellbore pressure line shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system to provide a permanent record.

C.3.1.3 Install the test mandrel in the BOP. For blowout preventers of the 279 mm (11 in) size and larger, use a 127 mm (5 in) OD test mandrel. For blowout preventers smaller than 279 mm (11 in), use an 88,9 mm (3 ½ in) OD or smaller test mandrel. Fill the preventer body with water to just above the top of the packer element.

C.3.1.4 Carry out the constant wellbore-pressure test using the following steps.

a) Close preventer using 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 C.3.1.4 a) through C.3.1.4 d), increasing wellbore pressure in 10 equal pressure increments until wellbore pressure equals the rated working pressure of the preventer.

C.3.1.5 Carry out the constant closing-pressure test using the following steps.

a) Apply 3,45 MPa (500 psi) closing pressure.

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

c) Bleed off wellbore pressure and open preventer.

d) Repeat C.3.1.5 a) through C.3.1.5 c), increasing closing pressure 0,69 MPa (100 psi) each time until closing pressure reaches the level recommended by the manufacturer.

C.3.1.6 Carry out the full closure pressure test using the following steps.

a) Remove the drill pipe mandrel. Fill the BOP body with water to just above the top of the packer element.

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

c) Apply wellbore pressure of 1,4 MPa to 2,1 MPa (200 psi to 300 psi) and hold for 3 min. If leakage occurs, increase the closing pressure as needed. Do not exceed manufacturer's recommended maximum operating pressure.

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

C.3.2 Fatigue test

C.3.2.1 Install preventer on test stump. Connect opening and closing lines to BOP. Connect line from high-pressure test pump to the stump.

C.3.2.2 The closing line and wellbore pressure line shall each be equipped, as minimum instrumentation, with a pressure transducer. All transducers shall be connected to a data acquisition system to provide a permanent record.

C.3.2.3 Install test mandrel in the BOP. Use a 127 mm (5 in) OD test mandrel for 279 mm (11 in) and larger blowout preventers. For blowout preventers 228 mm (9 in) and smaller, use an 88,9 mm (3 ½ in) OD test mandrel or smaller. Fill the preventer body with water to just above the top of the packer.

C.3.2.4 Close and open the BOP six times with the manufacturer's recommended closing pressure. Close the BOP a seventh time with the manufacturer's recommended closing pressure.

C.3.2.5 Apply 1,4 MPa to 2,1 MPa (200 psi to 300 psi) wellbore pressure, hold for 3 min, then increase wellbore pressure to the full rated working pressure of the preventer and hold for 3 min. Bleed off wellbore pressure.

C.3.2.6 Open the blowout preventer. C.3.2.4 to C.3.2.6 constitute one pressure cycle and seven function cycles.

C.3.2.7 Every twentieth pressure cycle, measure the ID of the packing element when the operating piston reaches the fullly open position (this can be detected by a rapid pressure rise on the operating-system pressure gauge). Then continue to measure the ID of the packer at 5-min intervals until the packer ID reaches the bore size of the BOP or until 30 min has elapsed. Record the ID.

C.3.2.8 Repeat C.3.2.4 through C.3.2.7 until packer leaks or until 364 function cycles (52 pressure cycles) have been completed.

C.3.3 Packer access test

C.3.3.1 Install the blowout preventer on a test stump.

C.3.3.2 Perform the manufacturer's recommended procedures for removing closure as required for packer access.

C.3.3.3 Perform the manufacturer's recommended procedures, including recommended maintenance and replacement parts, for closing the packer access closure.

C.3.3.4 Repeat C.3.3.2 and C.3.3.3 for 200 times. Every twentieth time, pressure-test the BOP closed on the test mandrel to rated working pressure for a 3-min holding period.

C.3.4 Test for stripping life

C.3.4.1 Measure and record the durometer hardness of the packer rubber. Install BOP on stripping machine. Connect opening and closing lines to the BOP. Connect line from the high pressure test pump to the stump or BOP side outlet.

C.3.4.2 Connect an accumulator [19 l (5 gal) minimum] to the wellbore (stump) and precharge to 75 % of the wellbore pressure to be used during the tests. The closing line and wellbore line each shall be equipped, as minimum instrumentation, with a pressure transducer. Connect all pressure transducers to a data acquisition system to provide a permanent record.

C.3.4.3 For 279 mm (11 in) and larger blowout preventers, install a 127 mm (5 in) OD test mandrel with a simulated 18° API 6 3/8-inch tool joint profile; for 228 mm (9 in) and smaller, install a 88,9 mm (3 ½ in) OD test mandrel with a simulated 18° API 5-inch tool joint profile.

C.3.4.4 Close the preventer 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 4 l/min (1 gal/min) (to wet the test mandrel wall).

C.3.4.5 Reciprocate the test mandrel at speed of approximately 600 mm/s (2 ft/s), 1 500 mm (5 ft) in each direction and at 4 cycles per min. Wellbore pressure should vary no more than ± 10 % during the stripping operation. Increase the closing pressure, as needed, to maintain only a slight lubricating leak. Continue testing until a leak rate of 4 l/min (1 gal/min) develops at the manufacturer's recommended closing pressure, or 5 000 cycles have been completed.

C.3.4.6 Document any wear on all packer elastomers.

C.4 Hydraulic connectors

C.4.1 Locking mechanism test

C.4.1.1 Install connector on the appropriate test stump.

C.4.1.2 Lock connector using the manufacturer's maximum lock pressure.

C.4.1.3 Determine the pressure required to unlock the connector with the primary unlock system. Record required pressure.

C.4.1.4 Repeat C.4.1.2 and C.4.1.3 with 67 % of manufacturer's lock pressure.

C.4.1.5 Repeat C.4.1.2 and C.4.1.3 with 33 % of manufacturer's lock pressure.

C.4.1.6 Repeat C.4.1.2 through C.4.1.5 twice more.

C.4.1.7 If connector is equipped with a secondary unlock system, repeat C.4.1.2 through C.4.1.6 using only the secondary unlock system.

C.4.1.8 Document any locking and unlocking pressures.

C.4.1.9 Inspect and document any wear of locking mechanism.

C.4.2 Sealing mechanism test

C.4.2.1 Install the connector on the appropriate test stump.

C.4.2.2 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 min, reduce the wellbore pressure to zero and unlock the connector. Repeat this for five cycles.

C.4.2.3 After the fifth cycle, lift the connector off of the test stump after unlocking it and then return it to the stump.

C.4.2.4 On every sixth cycle, lock the connector and perform the wellbore pressure tests with the locking pressure removed.

C.4.2.5 Continue testing until the connector fails to seal or 24 pressure cycles have been completed.

C.4.2.6 Document the load required to remove the connector from the stump.

Annex D
(informative)

Procedure for design temperature verification testing

D.1 Test parameters

D.1.1 Pressures

Low and high pressure tests are required at each temperature. The low pressure test shall be carried out at 1,4 MPa to 2,1 MPa (200 psi to 300 psi). The high pressure test shall be carried out at the rated working pressure of the equipment.

D.1.2 Hold period

The hold period shall begin when the specified pressure and temperature have been reached and have stabilized. The minimum hold time shall be as specified.

D.1.3 Monitoring techniques

All tests shall be carried out in conjunction with a suitable data acquisition system for both the pressure and the temperature. The data acquisition shall be in accordance with the manufacturer's written specification. The information shall be identified, dated and signed/verified by the tester and witnesses as applicable.

All devices used to measure or monitor pressure shall be in accordance with 8.2.

The blowout preventer (BOP) shall have a minimum of one thermocouple. The thermocouple shall be within 12 mm (0,5 in) of the through-bore, and shall be located as close as practical to the component being tested. All devices used to measure or monitor temperature shall be calibrated in accordance with the manufacturer's written specification.

D.1.4 Records

Measurements on the non-metallic seals and/or moulded sealing assemblies shall be made and recorded prior to installing them in the BOP.

D.2 High-temperature testing of ram-type blowout preventers

D.2.1 Install the BOP on the test apparatus.

D.2.1.1 Connect the hydraulic operating lines.

D.2.1.2 Connect the lines from the high-pressure test pump and the high-temperature heating device(s) to the test apparatus or to suitable connections on the BOP.

D.2.2 The closing pressure and wellbore pressure lines shall each be equipped, as minimum instrumentation, with pressure transducers. All transducers shall be connected to a data acquisition system to provide a permanent record.

D.2.3 Install the non-metallic seals and/or moulded sealing assembly in the BOP and secure them in accordance with the manufacturer's written procedure.

D.2.4 Install the required test mandrel in the BOP.

D.2.4.1 A 127 mm (5 in) OD test mandrel shall be used for testing 279 mm (11 in) or larger bore size BOPs.

D.2.4.2 An 88,9 mm (3 ½ in) OD test mandrel shall be used in testing BOPs with a bore size smaller than 279 mm (11 in).

D.2.4.3 Variable-bore rams shall be tested on both the minimum and maximum size mandrels for their range.

D.2.4.4 No test mandrel is required for testing blind or shear rams.

D.2.5 Open the BOP and begin heating the test fluid until the test temperature is reached and has stabilized.

D.2.6 After the test temperature has stabilized, close the BOP using the manufacturer's recommended operating pressure.

D.2.7 Apply 1,4 MPa to 2,1 MPa (200 psi to 300 psi) wellbore pressure and hold for a minimum of 3 min after pressure stabilization.

D.2.8 Decrease the wellbore test pressure to zero.

D.2.9 Apply the full rated working pressure of the BOP and hold for a minimum of 60 min after pressure stabilization.

D.2.10 Decrease the wellbore test pressure to zero.

D.2.11 Document the results of the tests.

D.3 High-temperature testing of annular blowout preventers

D.3.1 Install the BOP on the test apparatus.

D.3.1.1 Connect the hydraulic operating lines.

D.3.1.2 Connect the lines from the high-pressure test pump and the high-temperature heating device to the test apparatus or to suitable connections on the BOP.

D.3.2 The closing pressure and wellbore pressure lines shall each be equipped, as minimum instrumentation, with pressure transducers. All transducers shall be connected to a data acquisition system to provide a permanent record.

D.3.3 Install the non-metallic seals and/or moulded sealing assembly in the BOP and secure them in accordance with the manufacturer's written procedure.

D.3.4 Install the required test mandrel in the BOP.

D.3.4.1 A 127 mm (5 in) OD test mandrel shall be used for testing 279 mm (11 in) or larger bore size BOPs.

D.3.4.2 An 88,9 mm (3 ½ in) OD test mandrel shall be used in testing BOPs with a bore size smaller than 279 mm (11 in).

D.3.5 Open the BOP and begin heating the test fluid until the test temperature is reached and has stabilized.

D.3.6 Close the BOP using the manufacturer's recommended operating pressure.

D.3.7 Apply the full rated working pressure of the BOP and hold for a minimum of 60 min after pressure stabilization.

D.3.8 Decrease the wellbore test pressure to zero.

D.3.9 Open the BOP.

D.3.10 Document the results of the tests.

D.4 Low-temperature cycle testing of ram blowout preventers

D.4.1 Install the BOP on the test apparatus.

D.4.1.1 Connect the hydraulic operating lines.

D.4.1.2 Connect the lines from the high-pressure test pump to the test apparatus or to a suitable connection on the BOP.

D.4.2 The closing pressure and wellbore pressure lines shall each be equipped, as minimum instrumentation, with pressure transducers. All transducers shall be connected to a data acquisition system to provide a permanent record.

D.4.3 Install the non-metallic seals and/or moulded sealing assembly in the BOP and secure them in accordance with the manufacturer's written procedure.

D.4.4 Install the required test mandrel in the BOP.

D.4.4.1 A 127 mm (5 in) OD test mandrel shall be used for testing 279 mm (11 in) or larger bore-size BOPs.

D.4.4.2 An 88,9 mm (3 ½ in) OD test mandrel shall be used in testing BOPs with a bore size smaller than 279 mm (11 in).

D.4.4.3 Variable-bore rams shall be tested on both the minimum and maximum size mandrels for their range.

D.4.4.4 No test mandrel is required for testing blind or shear rams.

D.4.5 Open the BOP and begin the cooling cycle. Continue cooling until the test temperature is reached and has stabilized.

D.4.6 Close and open the BOP seven times using the manufacturer's recommended operating pressure.

D.4.7 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 min after pressure stabilization.

D.4.7.1 Decrease the wellbore test pressure to zero.

D.4.7.2 Apply the full rated working pressure of the BOP and hold for a minimum of 3 min after pressure stabilization.

D.4.7.3 Decrease the wellbore test pressure to zero.

D.4.7.4 Open the BOP.

D.4.8 Repeat D.4.6 and D.4.7 twice more for a total of 21 close/open cycles and three pressure-test cycles. The test mandrel may be changed during the testing of variable-bore packers without increasing the number of test cycles in order to accommodate the need to test on the minimum and maximum sizes of their range. There shall be a minimum of three cycles on any size mandrel.

D.4.9 Document the results of the tests.

D.5 Low-temperature cycle testing of annular blowout preventers

D.5.1 Install the BOP on the test apparatus.

D.5.1.1 Connect the hydraulic operating lines.

D.5.1.2 Connect the lines from the high-pressure test pump to the test apparatus or to a suitable connection on the BOP.

D.5.2 The closing pressure and wellbore pressure lines shall each be equipped, as minimum instrumentation, with pressure transducers. All transducers shall be connected to a data acquisition system to provide a permanent record.

D.5.3 Install the non-metallic seals and/or moulded sealing assembly in the BOP and secure them in accordance with the manufacturer's written procedure.

D.5.4 Install the required test mandrel in the BOP.

D.5.4.1 A 127 mm (5 in) OD test mandrel shall be used for testing 279 mm (11 in) or larger bore-size BOP .

D.5.4.2 An 88,9 mm (3 ½ in) OD test mandrel shall be used in testing BOPs with a bore-size smaller than 279 mm (11 in).

D.5.5 Open the BOP and begin the cooling cycle. Continue cooling until the test temperature is reached and has stabilized.

D.5.6 Close and open the BOP seven times using the manufacturer's recommended operating pressure.

D.5.7 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 min after pressure stabilization.

D.5.7.1 Decrease the wellbore test pressure to zero.

D.5.7.2 Apply the full-rated working pressure of the BOP and hold for a minimum of 3 min after pressure stabilization.

D.5.7.3 Decrease the wellbore test pressure to zero.

D.5.7.4 Open the blowout preventer.

D.5.8 Repeat D.5.6 through D.5.7 twice more for a total of 21 close/open cycles and three pressure-test cycles.

D.5.9 Document the results of the tests.

Annex E
(informative)

Purchasing guidelines

E.1 General

This annex provides recommended guidelines for enquiry and purchase of equipment covered by the scope of ISO 13533.

E.2 Blowout preventers and drilling spools

E.2.1 Size designation

The size designation consists of the vertical through-bore dimension. A list of standard sizes is included in Table 1.

E.2.2 Service conditions

E.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 ISO 13533 are given in 5.2.1.

E.2.2.2 Temperature ratings

E.2.2.2.1 General

Minimum temperature is the lowest ambient temperature to which the equipment may be subjected. Maximum temperature is the highest temperature of the fluid that may flow through the equipment.

E.2.2.2.2 Metallic materials

Metallic parts will be designed to operate in one of three temperature ratings, which should be designated by the purchaser. These ratings can be found in Table 3.

E.2.2.2.3 Wellbore elastomeric materials

The purchaser should provide the temperature range for which wellbore elastomeric materials must operate.

E.2.2.2.4 All other elastomeric seals

The purchaser should provide the temperature range for which all other elastomeric materials must operate.

E.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.

E.2.4 Equipment details/data book

A data book should be supplied upon the request of the purchaser, and should contain the following information:

a) purchase order number/sales order number;

b) product identification, type, part number, serial number;

c) date of completion and inspection;

d) assembly drawings, actual overall package dimensions, pressure rating, end connection/outlet description, mass, centre of gravity, list of materials for components defined in 8.5.1 and the location of their use;

e) manufacturer's statement of compliance to current edition of ISO 13533;

f) material certificates;

g) welding procedure qualification;

h) NDE reports;

i) pressure test reports.

Annex F
(informative)

Failure reporting

F.1 User recommendations

The operator of drill-through equipment manufactured to this International Standard should provide a written report to the equipment manufacturer of any malfunction or failure which occurs. This report should include as much information as possible on the operating conditions that existed at the time of the malfunction or failure, as accurate a description as possible of the malfunction or failure, and any operating history of the drill-through equipment leading up to the malfunction or failure (e.g. field repair, modifications made to the drill-through equipment, etc.).

F.2 Manufacturer's recommendations

F.2.1 Manufacturer's internal recommendations

All significant problems experienced with drill-through equipment furnished to this International Standard noted during its manufacture, testing or use should be formally communicated to the individual or group within the manufacturer's organization responsible for the design and specification documents. The manufacturer should have a written procedure that describes forms and procedures for making this type of communication, and should provide written records of progressive design, material changes or other corrective actions taken for each model and size of drill-through equipment.

F.2.2 Manufacturer's external recommendations

All significant problems experienced with drill-through equipment furnished to this International Standard should be reported in writing to each and every operator of the drill-through equipment within six weeks after the occurrence. Design changes resulting from a malfunction or failure history of drill-through equipment manufactured to this International Standard should be communicated within thirty days after the design change by the manufacturer to each and every operator using the model or size drill-through equipment having the malfunctions or failures, and all models of other drill-through equipment that could have similar potential problems.

Annex G
(informative)

Conversion of US Customary units to the SI system (metric)

G.1 General

The purpose of this annex is to document the rules for conversion of US Customary (USC) units into the SI system (metric).

The rules of conversion and rounding are based upon the rules defined in ASTM SI 10:1997[2]. The units obtained by application of the conversion rules in this annex may be different from the results that would be obtained by exact conversion of the units in API Specification 16A, upon which this International Standard is based. 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 See also, for information, ISO 31 (all parts).

G.2 Conversion rules

USC dimensions are converted from the dimensional tables of API Specification 16A in the following manner:

a) First convert from decimal inch to exact fraction. This is done to account for the fact that API design originated in the fractional inch system. Therefore, a dimension of 7,06 in the tables actually means 7 1/16 in or 7,062 5 in.

b) The next step is to multiply the resulting exact decimal equivalent of the fractional-inch dimension by 25,4 mm to obtain the exact millimeter dimension. Example: 7 1/16 in = 7,062 5 in = 179,387 5 mm.

c) The next step is the rounding process for the particular dimension. Rounding rules differ for different dimensions, depending on the function of the dimension and involves several steps.

   1) Determine the precision required of the USC dimension. The precision should normally be smaller than one-tenth of the tolerance range. For example, a dimension with a ± 0,015 in tolerance would require a converted dimension precision of 1/10 × 0,030 in × 25,4 mm/in = 0,0762 mm. Therefore, the precision of the converted dimension should be smaller than the 0,0762 mm in this example.

   2) In accordance with good industry practice, the converted dimension should be rounded to units that are multiples of 1, 2 or 5, e.g. 0,01; 0,02; 0,05; 0,1; 0,2 or 0,5. As in the previous example, the 0,076 2 mm would be rounded down to 0,05 mm increments.

   3) During the rounding process, for critical or interface dimensions, the absolute extremes of the converted (SI) value should not fall outside the absolute extremes of the USC values.

Example: 7 1/16 in + 0,031 / 0 in bore

The precision of the converted dimension should be
1/10 × 1/32 in × 25,4 mm/in = 0,079 375 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 = 7,093 75 in = 180,181 25 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 (0,034 474 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	13,789 514	13,858 462	0,01	13,79	13,85
3 000	3 015	20,684 271	20,787 692	0,01	20,68	20,77
5 000	5 025	34,473 785	34,646 154	0,02	34,48	34,64
10 000	10 050	68,947 570	69,292 308	0,02	68,94	69,26
15 000	15 075	103,421 355	103,938 462	0,05	103,40	103,85
20 000	20 100	137,895 140	138,584 616	0,05	137,90	138,55

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 in	**min.** in	**max.** in	**min.** mm	**max.** mm	mm	**min.** mm	**max.** mm
1 13/16	1,812 5	1,843 5	46,037 5	46,824 9	0,05	46,05	46,80
2 1/16	2,062 5	2,093 5	52,387 5	53,174 9	0,05	52,40	53,15
2 9/16	2,562 5	2,593 5	65,087 5	65,874 9	0,05	65,10	65,85
3 1/16	3,062 5	3,093 5	77,787 5	78,574 9	0,05	77,80	78,55
3 1/8	3,125 0	3,156 0	79,375 0	80,162 4	0,05	79,40	80,15
4 1/16	4,062 5	4,093 5	103,187 5	103,974 9	0,05	103,20	103,95
7 1/16	7,062 5	7,093 5	179,387 5	180,174 9	0,05	179,40	180,15
9	9,000	9,031	228,600 0	229,387 4	0,05	228,60	229,35
11	11,000	11,031	279,400 0	280,187 4	0,05	279,40	280,15
13 5/8	13,625	13,656	346,075 0	346,862 4	0,05	346,10	346,85
16 3/4	16,750	16,781	425,450 0	426,237 4	0,05	425,45	426,20
18 3/4	18,750	18,781	476,250 0	477,037 4	0,05	476,25	477,00
21 1/4	21,250	21,281	539,750 0	540,537 4	0,05	539,75	540,50

G.5 Conversion factors

G.5.1 Length

1 inch (in) = 25,4 millimetres (mm), exactly.

G.5.2 Pressure/stress

1 pound per square inch (psi) = 0,006 894 757 megapascals (MPa).

G.5.3 Impact energy

1 foot-pound (ft-lb) = 1,355 818 joules (J).

G.5.4 Torque

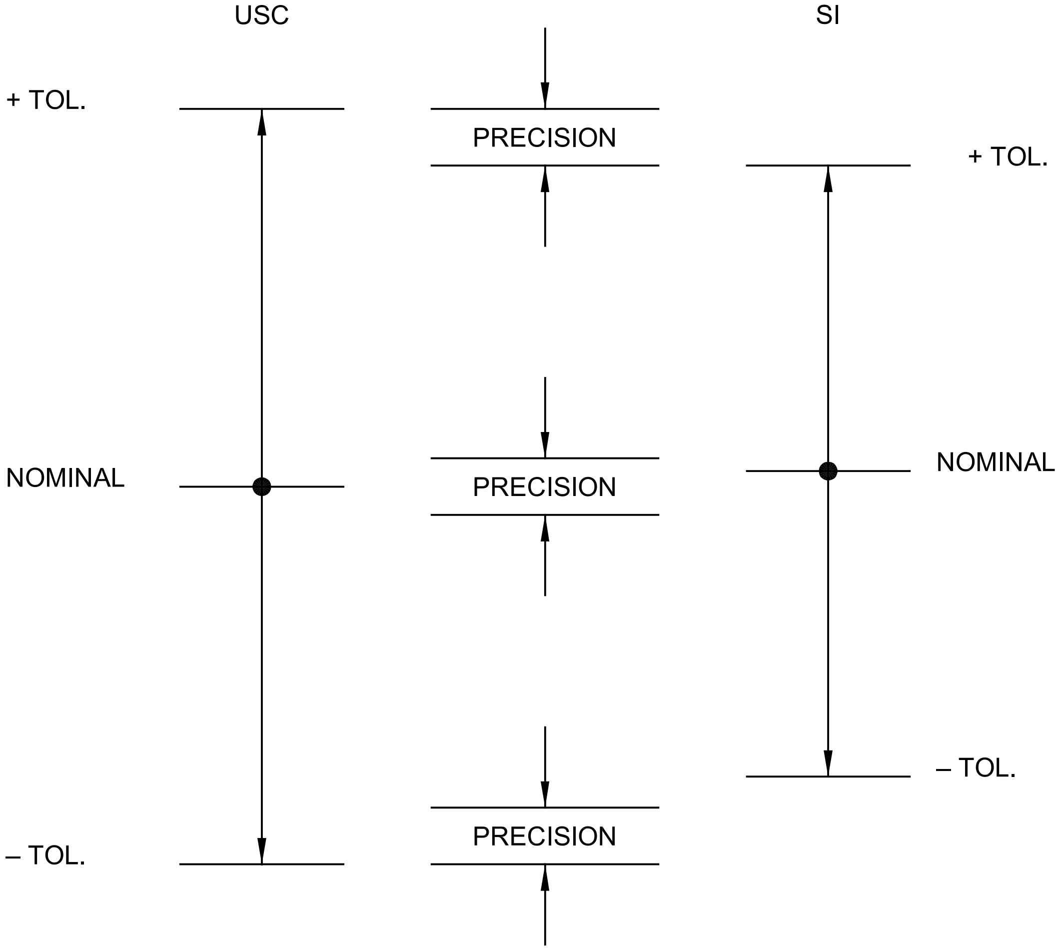
1 foot-pound (ft-lb) = 1,355 818 newton metres (N·m).

G.5.5 Force

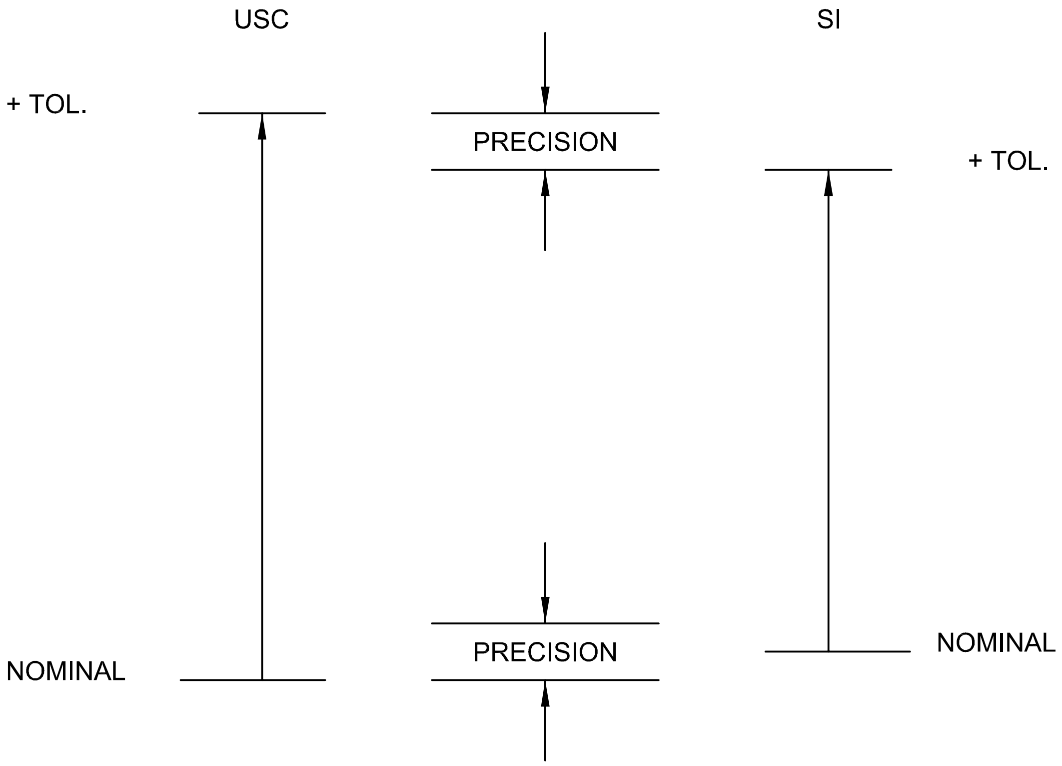
1 pound-force (lbf) = 4,448 222 newtons (N).

G.5.6 Mass

1 pound-mass (lb) = 0,453 592 4 kilograms (kg).



a) **Bilateral tolerance**



b) **Unilateral tolerance**

Figure G.1 — Metric conversions

Annex H
(informative)

List of national/regional standards applicable in context

The following provides a list of normative International Standards cited in clause 2 along with the national or regional standard which may optionally be used in its place in the context of the requirement for which the International Standard is cited in the text.

ISO 6506-1 ASTM E 10:1998, *Standard Test Method for Brinell Hardness of Metallic Materials*.

ISO 6507-1 ASTM E 92:1997, *Standard Test Method for Vickers Hardness of Metallic Materials*.

ISO 6508-1 ASTM E 18:1998, *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*.

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1) It is planned to replace API Spec 7 with ISO 10424 (currently under development).

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