

Choke and Kill Equipment

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Contents

	Page
1	Scope 1
2	Normative References 1
3	Terms, Definitions, and Abbreviations 4
3.1	Terms and Definitions 4
3.2	Abbreviations 9
4	Application and Design Requirements 10
4.1	Application 10
4.2	Service Conditions 10
4.3	Product Specification 14
4.4	Design Method 15
4.5	Performance Requirements 18
4.6	Design Validation 19
4.7	Closure Bolting 19
4.8	Clamps 19
4.9	Test, Vent, Pipe Plugs, and Gauge Connectors 19
4.10	Design Documentation 19
5	Material Requirements 20
5.1	General 20
5.2	Metallic Parts 20
5.3	Nonmetallic Parts 20
5.4	Bolting for Choke and Kill Equipment 21
5.5	Flexible Lines 21
5.6	Special Materials 21
5.7	Casting Practices 21
5.8	Hot Work Practices 22
5.9	Chemical Composition 22
5.10	Qualification Test Coupon 23
5.11	Heat Treatment—Equipment and Quenching 23
5.12	Mechanical Testing 23
5.13	Mud Gas Separators (Atmospheric) 24
6	Welding 25
6.1	General 25
6.2	Welding Procedure and Performance Qualification 26
6.3	Pressure-containing Fabrication Weldments 26
6.4	Pressure-containing Repair Weldments 27
6.5	Weld Overlay 28
6.6	Weld NDE 29
6.7	Repair Welds 32
7	Quality Control 32
7.1	Measuring and Testing Equipment 32
7.2	Quality Control Personnel Qualifications 34
7.3	Quality Control Requirements 34
7.4	Hydrostatic and Function Testing 47
7.5	Quality Control Record Requirements 53
8	Marking 54
8.1	General 54
8.2	Low- and High-stress Area Marking 55
8.3	Equipment-specific Marking 55
8.4	Hardness Marking for Bodies, Bonnets, and Flanges 56
9	Storing and Shipping 56
9.1	Storing of Equipment 56

9.2	Equipment and Parts Rust Prevention	57
9.3	Hydraulic Operating System	57
9.4	Storing of Nonmetallic Materials	57
9.5	Storing of Ring Gaskets	57
9.6	Shipping of Equipment	57
10	Equipment-specific Requirements	57
10.1	Choke and Kill System Requirements	57
10.2	End and Outlet Connectors	58
10.3	Ring Gaskets	59
10.4	Well Control Chokes	59
10.5	Actuators for Well Control Chokes	61
10.6	Rigid Choke and Kill Lines	62
10.7	Flexible Choke and Kill Lines	63
10.8	Hydraulic Control System—Well Control Chokes	66
10.9	Articulated Choke and Kill Lines	67
10.10	Choke and Kill Line Valves	69
10.11	Choke and Kill Manifold Assemblies	71
10.12	Buffer Chamber	73
10.13	Operating and Maintenance Manual Requirements	74
10.14	Mud Gas Separators (Atmospheric)	74
10.15	Flexloops	76
Annex A		78
Annex B		99
Annex C		101
Annex D		103
Annex E		106
Annex F		110
Annex G		113

Figures

1	Example: Pressure Line with Cushion Targets	16
2	Example: Pressurized Line with Cushion Target T's	17
3	Total Fluid Cushion Bore Depth Example	17
4	Intersecting Header Example	18
5	Typical Flexible Line Construction	63
6	Typical Bonded and Non-bonded Flexible Line Assemblies	63
7	Typical Flexible Line End Termination and End Connectors	64
8	Example of an Articulated Choke or Kill Line	68
9	Example Illustrating Points of Rotation	68
B.1	Thermocouple Locations	100
E.1	Example Choke Manifold Assembly for 5K Rated Working Pressure Service—Surface BOP Installations	106
E.2	Example Choke Manifold Assembly for 10K or Greater Rated Working Pressure Service—Surface BOP Installations	107
E.3	Example Kill Line Assembly for 2K and 3K Rated Working Pressure Service—Surface BOP Installations	107
E.4	Example Kill Line Assembly for 5K and Greater Rated Working Pressure Service—Surface BOP Installations	107
E.5	Example Kill Line Assembly for 5K and Greater Rated Working Pressure Service—Surface BOP Installations	108
E.6	Example Standpipe Choke Installation	108
E.7	Example Choke and Kill Manifold for Subsea Systems	109

G.1 Location of Charpy V-Notch Impact T 114

Tables

1 Temperature Rating for Metallic and Nonmetallic Materials and Flexible Lines 11

2 Equipment Bore Sizes and Rated Working Pressures 12

3 Union Connector, Swivel Union, and Articulated Line Sizes and Rated Working Pressures..... 13

4 Flexible Line Sizes and Rated Working Pressures 14

5 Bolting Requirements..... 21

6 Pressure-containing Parts Material Composition Limits..... 22

7 Alloying Element Maximum Tolerance Range Requirements 23

8 Acceptance Criteria Charpy V-notch Impact Requirements 24

9 Pressure-containing Parts Material Designation..... 24

10 Pressure-containing Parts Material Property Requirements 25

11 Weld Inclusion Length Acceptance Criteria—Radiographic and Ultrasonic Methods..... 31

12 Quality Control Requirements for Bodies, Bonnets, Flex Loops, Rigid Choke and Kill Lines,
and End and Outlet Connectors 36

13 Minimum Hardness Values 37

14 Castings Acceptance Criteria 40

15 Quality Control Requirements for Stems 40

16 Quality Control Requirements for Nonmetallic Seals 41

17 Quality Control Requirements for Pressure-containing Parts of Flexible Choke and Kill Lines 43

18 Quality Control Requirements for Rigid Piping..... 44

19 Quality Control Requirements for Mud Gas Separators 46

20 Quality Control Requirements—Assembled Equipment 46

21 Metallic Marking Requirements..... 56

22 Quality Control Requirements for Male and Female Subs 59

23 Performance Requirements for Well Control Chokes and Actuators 61

24 Flexible Line Sizes and Pressure Requirements..... 64

25 Flexible Choke and Kill Line Flexible Specification Level (FSL)..... 66

26 Color Coding of Articulated Choke and Kill Line Components 69

27 Corrosion Resistance Level Requirements 70

A.1 Standard Test Fluid 83

A.2 PQL Life Cycle Testing Requirements..... 95

A.3 Subsea Valve and Actuator Hyperbaric Testing..... 96

Choke and Kill Equipment

1 Scope

This specification identifies requirements for the performance, design, materials, testing, inspection, welding, marking, handling, storing, shipment, and purchasing of surface and subsea choke and kill equipment for use in the petroleum and natural gas industries.

These requirements provide for safe and functionally interchangeable surface and subsea choke and kill system equipment. This specification does not apply to field use or field testing. This specification also does not apply to repair of choke and kill equipment, except for weld repair in conjunction with manufacturing.

2 Normative References

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

API Specification 5B, *Specification for Threading, Gauging and Thread Inspection of Casing, Tubing, and Line Pipe Threads*

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

API Specification 5L, *Specification for Line Pipe*

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

API Specification 16A, *Specification for Drill-Through Equipment*

API Specification 16F, *Specification for Marine Drilling Riser Equipment*

API Specification 20D, *Qualification of Nondestructive Examination Services for Equipment Used in the Petroleum and Natural Gas Industry*

API Specification 20E, *Specification for Alloy and Carbon Steel Bolting*

API Specification 20F, *Specification for Corrosion-resistant Bolting*

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

API Recommended Practice 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class 1, Division 1, and Division 2*

API Recommended Practice 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class 1, Zone 0, Zone 2*

ASME Boiler and Pressure Vessel Code (BPVC)¹, Section V, *Non-Destructive Examination*

ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, *Pressure Vessels—Division 1*

ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, Division 2, *Alternate Rules*

ASME Boiler and Pressure Vessel Code (BPVC) 2004, Section VIII, Division 2, Appendix 6

¹ ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME Boiler and Pressure Vessel Code (BPVC), Section IX, *Welding and Brazing Qualifications*

ASME B1.1, *Unified Inch Screw Threads, UN and UNR Thread Form*

ASME B1.2, *Gages and Gaging for Unified Inch Screw Threads*

ASME B31.3, *Process Piping*

ASNT SNT-TC-1A², *Personnel Qualification and Certification in Nondestructive Testing*

ASQ Z1.4³, *Sampling Procedures and Tables for Inspection by Attributes*

ASTM A370⁴, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

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

ASTM A609, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

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

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

ASTM D1708, *Standard Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens*

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

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

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

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

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

ASTM E94, *Standard Guide for Radiographic Examination using Industrial Radiographic Film*

ASTM E110, *Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers*

ASTM E127, *Standard Practice for Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks*

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

ASTM E165, *Standard Practice for Liquid Penetrant Testing for General Industry*

ASTM E213, *Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing*

ASTM E309, *Standard Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation*

² American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

³ American Society for Quality, P.O. Box 3005, Milwaukee, Wisconsin 53201-3005, www.asq.org.

⁴ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

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

ASTM E709, *Standard Guide for Magnetic Particle Testing*

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

ASTM E1001, *Standard Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves*

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

AWS A.5.1⁵, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*

CSWIP-WI-6-92⁶, *Requirements for the Certification of Visual Welding Inspectors (Level 1), Welding Inspectors (Level 2) and Senior Welding Inspectors (Level 3) (fusion welding) in conformance with the requirements of BS EN ISO 17637:2011*

ISO 6506-1⁷, *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*

ISO 9712, *Non-destructive testing – Qualification and Certification of NDT Personnel*

ISO 10893-2, *Non-destructive testing of steel tubes – Part 2: Automated eddy current testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of imperfections*

ISO 10893-3, *Non-destructive testing of steel tubes – Part 3: Automated full peripheral flux leakage testing of seamless and welded (except submerged arc-welded) ferromagnetic steel tubes for the detection of longitudinal and/or transverse imperfections*

ISO 10893-4, *Non-destructive testing of steel tubes – Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections*

ISO 10893-5, *Non-destructive testing of steel tubes – Part 5: Magnetic particle inspection of seamless and welded ferromagnetic steel tubes for the detection of surface imperfections*

ISO 10893-10, *Non-destructive testing of steel tubes—Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*

NACE MR0175/ISO 15156⁸, *Petroleum, petrochemical, and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*

NFPA 496⁹, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*

SAE J 517¹⁰, *Hydraulic Hose*

⁵ American Welding Society, 8669 NW 36th Street, #130, Miami, Florida 33166-6672, www.aws.org.

⁶ CSWIP Regulations, TWI Certification Ltd, Granta Park, Great Abington, Cambridge, CB21 6AL, United Kingdom, www.cswip.com.

⁷ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

⁸ NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77084- 4906, www.nace.org.

⁹ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

¹⁰ SAE International (formerly the Society of Automotive Engineers), 400 Commonwealth Drive, Warrendale, Pennsylvania 15096- 0001, www.sae.org.

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

actuator

A device used to operate a valve or choke by means of applied manual, hydraulic, pneumatic, or electrical energy.

3.1.2

acceptable quality level

AQL

A statistically based acceptance-sampling plan.

NOTE See ASQ Z1.4 or ISO 2859-1 for examples.

3.1.3

articulated choke and kill line

A choke and kill line assembled as a unit, with rigid pipe, swivel unions, and end connectors, designed to accommodate specified relative movement between end terminations.

NOTE Articulated lines used for purposes other than choke and kill lines are outside the scope of this document.

3.1.4

blind flange

A flange with no center bore that is used to close off completely a flanged end or outlet connector.

3.1.5

body

Any portion of API equipment that includes the end connectors and is designed to be exposed to and contain wellbore pressure and fluid.

3.1.6

bolting

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

- Class 2 bolting: Pressure-containing or primary load path bolting not exposed to subsea environment, splash zone, or wellbore fluid.
- Class 3 bolting: Pressure-containing or primary load path bolting exposed to subsea environment or splash zone, but not exposed to wellbore fluid. A failure of class 3 bolting could result in a release of wellbore fluid to the environment.
- Closure bolting: Bolting used to assemble or join wellbore pressure containing parts, including end and outlet connectors.
- Exposed bolting: Bolting in direct contact with wellbore fluid.
- Utility bolting: Bolting required for mounting equipment and accessories not considered exposed, class 2, or class 3.

NOTE Examples include bolting on lifting eye, nameplate, or clamps.

3.1.7**bonnet**

A pressure-containing closure for a body, other than an end or outlet connector.

3.1.8**buffer chamber**

A chamber installed downstream of the chokes to allow manifolding of the outlet lines together.

3.1.9**burst (flexible line)**

A catastrophic failure of the pipe assembly, either by loss of a complete end fitting or by rupture of the complete assembly, such that no flow is possible between the opposing end connectors.

3.1.10**calibration**

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

3.1.11**casting (noun)**

An object at or near its finished shape, obtained by solidification of a substance in a mold.

3.1.12**cast (verb)**

To pour molten metal into a mold to produce an object of desired shape.

3.1.13**certificate of conformance**

A document containing the statement by the manufacturer certifying that the equipment conforms to the requirements of this specification.

3.1.14**check valve**

A valve that permits fluid to flow freely in one direction and contains a mechanism to automatically prevent flow in the other direction.

3.1.15**choke**

Equipment used to restrict and control the flow of fluids.

3.1.16**choke/kill line**

A high-pressure line used for circulation of fluids into and out of the wellbore to control well pressure.

3.1.17**choke/kill manifold**

The assembly of valves, chokes, gauges, and lines used to control the rate of flow and pressure from the well when the BOPs are closed.

3.1.18**corrosion-resistant alloy**

A nonferrous-based alloy in which any one or the sum of the specified amount of the elements titanium, nickel, cobalt, chromium, and molybdenum exceeds 50 % mass fraction.

NOTE This definition is different from that in NACE MR0175/ISO 15156.

3.1.19**corrosion-resistant ring groove**

A ring groove lined with corrosion-resistant alloy or an austenitic stainless steel to resist metal loss corrosion.

3.1.20**critical dimension**

A dimension (with tolerances) identified by the manufacturer or purchaser as essential for proper functioning of the equipment.

3.1.21**date of manufacture**

The date of the manufacturer's final acceptance of finished equipment.

3.1.22**end fitting**

The end assembly containing the termination and end connector.

3.1.23**end and outlet connector**

An integral male or female thread, clamp hub end connector, flange (studded or through-bolted), or any other means to join together equipment that contains or controls pressure.

3.1.24**end termination**

Part of the end fitting that forms the transition between the flexible line construction and the end connector.

3.1.25**equipment**

Any single completed unit that can be used for its intended purpose without further processing or assembly (e.g. a valve, choke, cross, tee, spool, etc.).

3.1.26**fabrication weld**

A weld joining two or more parts.

3.1.27**flange**

A protruding rim with holes to accept bolts and having a sealing mechanism used to join pressure-containing equipment.

3.1.28**flexible line**

The assembly of a pipe body and end-fittings.

NOTE 1 The pipe body comprises a combination of materials that form a pressure-containing conduit.

NOTE 2 The pipe structure allows large deflections without a significant increase in bending stresses.

NOTE 3 Normally, the pipe body is built up of one of the two construction types shown in Figure 5 as non-bonded and bonded flexible lines.

3.1.29**flexloop**

Metallic choke and kill piping designed to accommodate relative deflection between the riser and LMRP.

NOTE A flexloop and a flexible line may be interchangeable in this function.

3.1.30**flow bean**

A replaceable orifice part used in positive chokes to control flow rates.

3.1.31**heat (cast lot)**

Material originating from a final melt.

3.1.32**heat treatment heat treating**

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

3.1.33**job lot traceability**

The ability to trace parts as originating from a job lot that identifies the included heat(s).

3.1.34**leak**

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

3.1.35**other end connector****OEC**

A connector that is not specified in an API specification or standard.

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

3.1.36**pressure-containing part**

A part exposed to wellbore fluids whose failure to function as intended would result in a release of wellbore fluid to the environment.

EXAMPLE Bodies, bonnets, and stems.

3.1.37**pressure-containing weld**

A weld whose absence or failure will reduce or compromise the pressure-containing integrity of the component.

3.1.38**pressure-controlling part**

A part intended to control or regulate the movement of pressurized fluids.

EXAMPLE Valve-bore sealing mechanisms, choke trim.

3.1.39**pressure integrity**

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

3.1.40**rated working pressure**

The maximum internal pressure that equipment is designed to contain and/or control.

3.1.41**relevant indication**

(liquid penetrant or magnetic particle examination)

Any indication with a major dimension over $\frac{1}{16}$ in. (1.6mm).

3.1.42**rigid choke and kill line**

Rigid piping, straight or with bends, with end connectors, for use in choke and kill equipment.

3.1.43**rigid piping**

A tubular piece, of any length, made from a section(s) of fabricated, random length pipe, exclusive of any couplings, flanges, or other end connectors.

3.1.44**stabilized (pressure testing)**

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

NOTE Pressure changes can be caused by such factors as variations in temperature, setting of elastomer seals, or compression of air or fluids, etc.

3.1.45**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 factors as mixing of different-temperature fluids, convection, or conduction.

3.1.46**stainless steel**

Steel containing more than 11 % mass fraction chromium to render the steel corrosion-resistant.

NOTE Other elements can be added to secure special properties.

3.1.47**technical authority****third-party reviewer**

A competent and technically qualified person or organization with evidence to demonstrate the expertise, skills, and experience regarding design, quality, and manufacturing processes necessary to perform the required verification(s).

3.1.48**test, vent, and gauge ports**

Holes drilled and tapped into equipment through which internal pressure can be measured or through which pressure can be applied to test the sealing mechanisms.

3.1.49**weld groove**

The area between two metals to be joined that has been prepared to receive weld filler metal.

3.1.50**weldment**

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

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

3.1.51

well control choke

An adjustable choke that is incorporated into a drilling well control system.

3.1.52

wetted surface

Any surface that will be in contact with pressurized well fluid either by design or because of internal seal leakage.

3.2 Abbreviations

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

AQL	acceptable quality level
ASME	American Society of Mechanical Engineers (currently identified as ASME International)
ASTM	American Society for Testing and Materials (currently identified as ASTM International)
AWS	American Welding Society
CRA	corrosion-resistant alloy
ER	equivalent round
FSL	flexible specification level
HAZ	heat-affected zone
ID	inside diameter
LMRP	lower marine riser package
MGS	mud gas separator
NACE	National Association of Corrosion Engineers (currently identified as NACE International)
NDE	nondestructive examination
OD	outside diameter
OEC	other end connector
OEM	original equipment manufacturer
PQR	procedure qualification record
PSL	product specification level
QTC	qualification test coupon
RWP	rated working pressure

SAE Society of Automotive Engineers

WPS welding procedure specifications

4 Application and Design Requirements

4.1 Application

This specification establishes the minimum requirements for the design and manufacture of the following types of new equipment:

- a) articulated choke and kill lines;
- b) choke and kill manifold buffer chamber;
- c) choke and kill manifold assembly;
- d) well control choke actuators;
- e) well control choke controls;
- f) well control chokes;
- g) flexible choke and kill lines;
- h) union connectors used in choke and kill assemblies;
- i) rigid choke and kill lines;
- j) swivel unions used in choke and kill equipment;
- k) choke and kill flex loops;
- l) choke and kill line valves;
- m) atmospheric mud gas separator;
- n) targeted and fluid cushions.

4.2 Service Conditions

4.2.1 Temperature Ratings

NOTE Minimum temperature is the lowest temperature to which the equipment can be subjected while in service. Maximum temperature is the highest fluid temperature that can flow through the equipment while in service.

Equipment shall be designed to operate within one or more of the temperature ranges shown in Table 1. If the operating temperature of equipment covered by this standard and specified and validated by the manufacturer is broader than temperature rating specified in Table 1, the manufacturer may mark the actual temperature range on the equipment.

For maximum temperature ratings above 250 °F (121 °C), the manufacturer shall refer to API 6A for material property derating.

Table 1—Temperature Rating for Metallic and Nonmetallic Materials and Flexible Lines

Rating	Operating Range °F (°C)
A	–4 to 180 (–20 to 82)
B	–4 to 212 (–20 to 100)
K	–75 to 180 (–60 to 82)
L	–50 to 180 (–46 to 82)
N	–50 to 140 (–46 to 60)
P	–20 to 180 (–29 to 82)
S	0 to 140 (–18 to 60)
T	0 to 180 (–18 to 82)
U	0 to 250 (–18 to 121)
V	35 to 250 (2 to 121)
X	0 to 350 (–18 to 177)
NOTE The use of combined or multiple ratings is permitted.	

4.2.2 Rated Working Pressure

Equipment within the scope of this specification shall be rated in conformance with the rated working pressures specified in Table 2, Table 3, and Table 4.

4.2.3 Fluid Service Conditions

Metallic materials that are exposed to the well fluid shall conform to the requirements of NACE MR0175/ISO 15156, including a partial pressure rating for H₂S of 1.5 psia (10.34 kPa) or higher.

Table 2—Equipment Bore Sizes and Rated Working Pressures

Size (Minimum Through Bore) in. (mm)	Rated Working Pressure psi (MPa)
2 ¹ / ₁₆ (52)	2000 (13.8)
2 ⁹ / ₁₆ (65)	
3 ¹ / ₈ (78)	
4 ¹ / ₁₆ (103)	
2 ¹ / ₁₆ (52)	3000 (20.7)
2 ⁹ / ₁₆ (65)	
3 ¹ / ₈ (78)	
4 ¹ / ₁₆ (103)	
2 ¹ / ₁₆ (52)	5000 (34.5)
2 ⁹ / ₁₆ (65)	
3 ¹ / ₈ (78)	
4 ¹ / ₁₆ (103)	
5 ¹ / ₈ (130)	
1 ¹³ / ₁₆ (46)	10,000 (69.0)
2 ¹ / ₁₆ (52)	
2 ⁹ / ₁₆ (65)	
3 ¹ / ₁₆ (78)	
4 ¹ / ₁₆ (103)	
5 ¹ / ₈ (130)	
1 ¹³ / ₁₆ (46)	15,000 (103.5)
2 ¹ / ₁₆ (52)	
2 ⁹ / ₁₆ (65)	
3 ¹ / ₁₆ (78)	
4 ¹ / ₁₆ (103)	
5 ¹ / ₈ (130)	
1 ¹³ / ₁₆ (46)	20,000 (138)
2 ¹ / ₁₆ (52)	
2 ⁹ / ₁₆ (65)	
3 ¹ / ₁₆ (78)	
4 ¹ / ₁₆ (103)	
NOTE Specific size and pressure rating combinations are not necessarily available for each type of end or outlet connector (e.g. threaded flange and hub).	

Table 3—Union Connector, Swivel Union, and Articulated Line Sizes and Rated Working Pressures

Nominal Size in. (mm)	Rated Working Pressure psi (MPa)
1 (25.4)	3000 (20.7) 6000 (41.4)
1½ (38.1)	
2 (50.8)	
2½ (63.5)	
3 (76.2)	
4 (101.6)	
1 (25.4)	5000 (34.5) 7500 (51.8)
1½ (38.1)	
2 (50.8)	
2½ (63.5)	
3 (76.2)	
4 (101.6)	
1 (25.4)	10,000 (69.0)
2 (50.8)	
3 (76.2)	
4 (101.6)	
4½ (114.3)	
2 (50.8)	15,000 (103.5)
2½ (63.5)	
3 (76.2)	
4 (101.6)	
4½ (114.3)	
2 (50.8)	20,000 (138.0)
2½ (63.5)	
3 (76.2)	

Table 4—Flexible Line Sizes and Rated Working Pressures

Nominal Inner Diameter in. (mm)	Rated Working Pressure psi (MPa)
2 (50.8)	5000 (34.5)
3 (76.2)	
3½ (88.9)	
4 (101.6)	
2 (50.8)	10,000 (69.0)
2½ (63.5)	
3 (76.2)	
4 (101.6)	
2 (50.8)	15,000 (103.5)
2½ (63.5)	
3 (76.2)	
4 (101.6)	
2 (50.8)	20,000 (138.0)
2½ (63.5)	
3 (76.2)	
4 (101.6)	

4.3 Product Specification

The following products shall conform to the requirements of API 6A, PSL 3 (or higher), and shall have a material Class DD, EE, FF, or HH, with an H₂S partial pressure rating of 1.5 psia (10.34 KPa) or higher, and a temperature rating from Table 1 as appropriate for choke and kill system applications:

- a) check valves;
- b) chokes;
- c) crosses and tees;
- d) flanged or studded end and outlet connectors;
- e) full-bore valves;
- f) threaded end connectors.

Hubbed end and outlet connectors shall conform to the requirements of API 16A. Actuators shall conform to the requirements of API 6A.

4.4 Design Method

4.4.1 General

The design method shall be in conformance with one or more of the methods described in 4.4.2, 4.4.3, and 4.4.4, or as specified in Section 10.

4.4.2 API 6X Method

The design methodology shall be in conformance with API 6X. The use of von Mises equivalent stress is permitted.

4.4.3 Distortion Energy Theory Method

The Distortion Energy Theory Method, also known as the von Mises Law, may be used for design calculations for pressure-containing equipment. Rules for the consideration of discontinuities and stress concentrations are beyond the scope of this method. However, the basic pressure-vessel wall thickness may be sized by combining triaxial stresses based on hydrostatic body test pressure and limited by Equation (1):

$$S_E = S_Y \quad (1)$$

where

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

S_Y is the material's specified minimum yield strength.

4.4.4 Experimental Stress Analysis

Experimental stress analysis shall be performed in conformance with ASME BPVC, Section VIII, Division 2, Appendix 6, 2004 Edition.

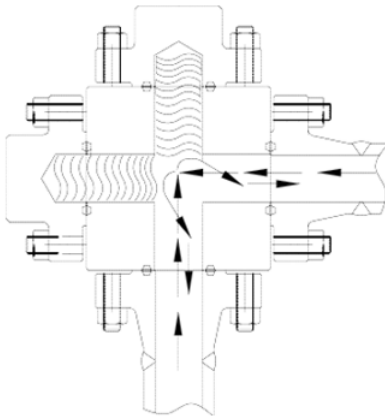
4.4.5 Targeted and Fluid Cushion Connectors

All 90-degree elbows, crosses, and tees shall have fluid cushions in the direction(s) of flow, except when the surrounding geometries do not allow the use of fluid cushions. When surrounding geometries do not allow fluid cushions, the OEM shall recommend maintenance requirements. For examples of fluid cushions, see Figure 1. Filled target flanges shall not be used.

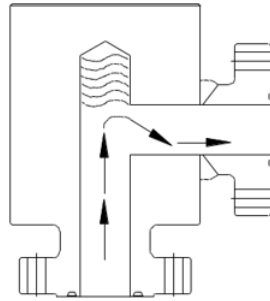
A blind flange or other end connector that blocks flow without a fluid cushion shall be acceptable, provided that the total bore depth from the intersecting bore (L) is one nominal bore diameter or greater.

NOTE An example is a buffer chamber(s) with flanges fitted to downstream connectors. For examples, see Figure 2.

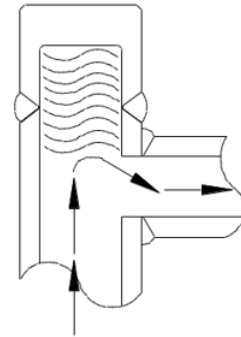
Fluid cushion connectors that include pressure-boundary penetrations shall conform to API 6A requirements for test gauge connectors.

Figure 1A

Fluid Cushion Bi-directional

Figure 1B

Fluid Cushion Single Direction

Figure 1C

Weld Fitting Connector

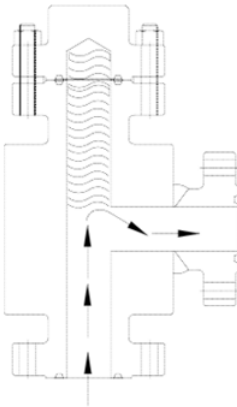
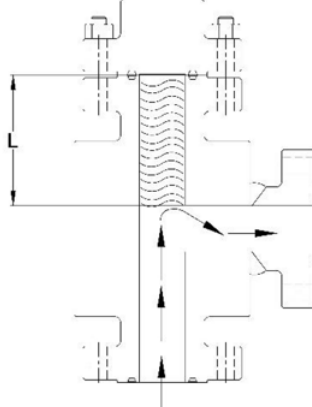
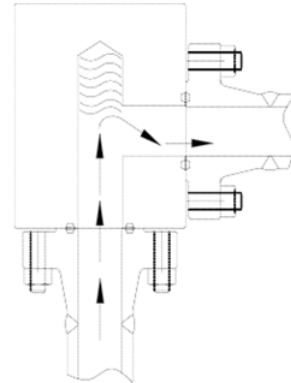
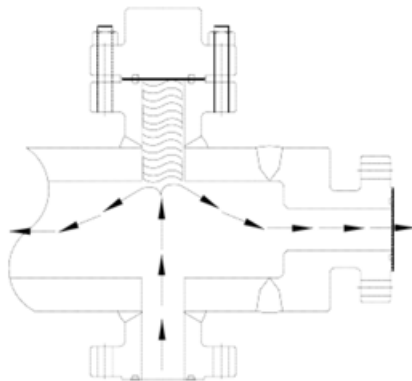
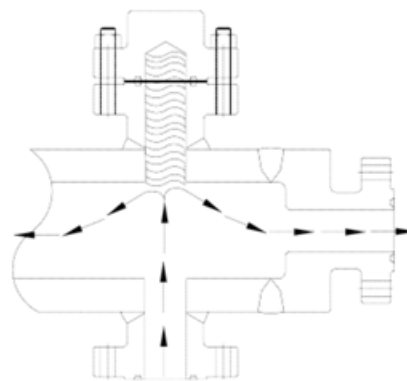
Figure 1DFlanged Tee Connector—
Fluid Cushion**Figure 1E**Flanged Tee Connector—
Blind Flange**Figure 1F**Fluid Cushion—
Single Direction**Figure 1—Example: Pressure Line with Cushion Targets**

Figure 2A

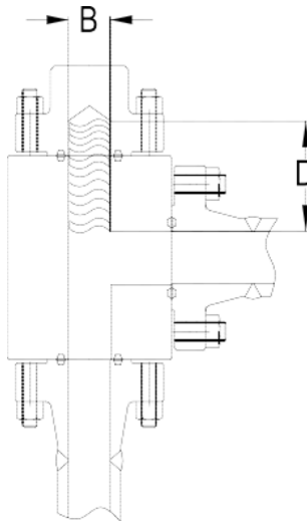
Blind Flange Closure

Figure 2B

Fluid Flange Closure

Figure 2—Example: Pressurized Line with Cushion Target T's

Fluid cushion cavity depth (D) shall be greater than or equal to the nominal diameter of the bore as shown in Figure 3. (B) shall be equal to the nominal bore ID.

**Figure 3—Total Fluid Cushion Bore Depth Example**

The wall thickness of fluid cushion components that are not excluded from design and development shall be analyzed using the design methods specified in 4.4.

In cases where the incoming flow intersects a header, the flow shall be considered targeted if the diameter of the header is greater than or equal to twice the diameter of the inlet end connectors, as in Figure 4.

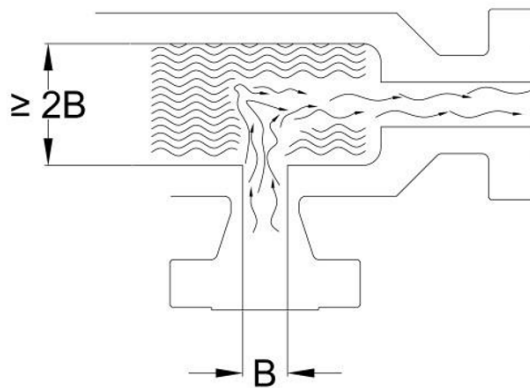


Figure 4—Intersecting Header Example

Use of short radius pipe bends ($R/d < 10$) shall not be permitted except in cases when the surrounding geometries do not allow the use of fluid cushions. In these instances, the OEM shall provide maintenance recommendations.

NOTE 1 R is the radius of the pipe bend measured at the centerline in inches (centimeters).

NOTE 2 d is the ID of the pipe in inches (centimeters).

The bending radius of flexible choke and kill lines shall conform to 10.7.6.

4.5 Performance Requirements

4.5.1 General

Products shall be designed to perform according to the requirements of 4.5 at the temperature rating selected in 4.2.1, the pressure rating selected in 4.2.2, and the material selected in conformance with Section 5.

4.5.2 Pressure Integrity

Products shall be capable of withstanding rated working pressure at rated temperature without deformation to the extent that any other performance requirement is not met.

4.5.3 Thermal Integrity

Products and/or systems shall be capable of functioning throughout the temperature range for which they are rated.

4.5.4 Leakage

No visible leakage shall be allowed.

4.5.5 Load Capability

Products shall be designed to withstand rated loads without deformation to the extent that any other performance requirement is not met.

4.5.6 Cycles

Products shall be capable of performing and operating as intended for the number of operating cycles specified in Section 10 for applicable products.

4.5.7 Operating Force or Torque

The force or torque required to operate products shall be within the manufacturer's written specification, which includes acceptance criteria.

4.6 Design Validation

Design validation shall be performed in conformance with Annex A. The validation testing specified in this section is intended to be performed on prototypes or samples representative of production models.

4.7 Closure Bolting

The maximum tensile stress for closure bolting shall be determined considering: initial make-up torque; operating conditions including pressure loads, external mechanical loads, and thermal stress; and hydrostatic body test pressure conditions.

Bolt stresses, based on the minimum cross-sectional area of the bolt, shall not exceed Equation (2):

$$S_a = 0.83 S_y \text{ and } S_b = 1.0 S_y \quad (2)$$

where

S_a is the maximum allowable tensile stress;

S_y is the bolting material specified minimum yield strength;

S_b is the maximum allowable tensile membrane plus bending stress.

4.8 Clamps

Clamps for API 16BX hubs shall conform to API 16A. Other hubs and clamps shall conform to the manufacturer's written specifications.

4.9 Test, Vent, Pipe Plugs, and Gauge Connectors

Test, vent, pipe plugs and gauge connectors for use on 2000 psi (13.8 MPa), 3000 psi (20.7 MPa), 5000 psi (34.5 MPa), 10,000 psi (69.0 MPa), 15,000 psi (103.5 MPa), and 20,000 psi (138.0 MPa) equipment shall be in conformance with API 6A, as applicable. Vent connectors shall be in conformance with the manufacturer's written specification.

4.10 Design Documentation

Documentation of designs shall include methods, assumptions, calculations, and design requirements. Design documentation media shall be clear, legible, reproducible, and retrievable.

Design documentation shall be reviewed and verified by qualified personnel other than those who created the original design. Design changes shall be reviewed in the same manner as the original design.

Manufacturers shall document their validation procedures and the results of validation of designs. Design validation is not required on API flanges, hubs, and ring gaskets.

Design documentation shall be retained for 10 years after the last unit of that model, size, and rated working pressure is manufactured.

5 Material Requirements

5.1 General

This section shall apply to the material performance, processing, and compositional requirements for all pressure-containing or pressure-controlling parts. Other parts shall be made of materials that satisfy the design requirements in Section 4 when assembled into equipment designed in conformance with this specification. Metallic materials in direct contact with well fluids shall also conform to the requirements for sour service of NACE MR0175/ISO 15156.

5.2 Metallic Parts

A written material specification shall be required for all metallic pressure-containing and pressure-controlling parts. The manufacturer's written specified requirements for metallic materials shall define the following:

- a) material composition with tolerance;
- b) material qualification;
- c) allowable melting practice(s);
- d) forming practice(s);
- e) heat treatment procedure, including cycle time and temperature with tolerances, heat treating equipment and cooling media, and heating and cooling requirements;
- f) NDE requirements;
- g) mechanical property requirements;
- h) weld repair requirements;
- i) material traceability;
- j) furnace calibrations and certification.

5.3 Nonmetallic Parts

The manufacturer shall have written specifications for all nonmetallic materials used in the production of choke and kill equipment. For polymer materials, including thermosets and thermoplastics, these specifications shall include the following:

- a) generic base polymer(s);
- b) hardness in conformance with ASTM D2240 or ASTM D1415 (thermoplastics may use an equivalent standard);
- c) tensile, elastic modulus and elongation properties in conformance with ASTM D412 or ASTM D1414 for thermoset polymers;
- d) tensile, elastic modulus and elongation properties in conformance with ASTM D638 or ASTM D1708 for thermoplastic polymers;
- e) compression set in conformance with ASTM D395 or ASTM D1414 for thermoset polymers;
- f) immersion (fluid compatibility) testing in conformance with ASTM D471 or ASTM D1414:

- 1) test liquid, temperature, and the duration of the test shall be defined;
 - 2) test shall be performed at or above the maximum temperature rating of the nonmetallic sealing components in which the nonmetallic material is used, per Table 1;
- g) material qualifications and physical property changes after testing;
- h) storage requirements;
- i) visual inspection requirements;
- j) acceptance criteria, rejection criteria, or a combination thereof.

5.4 Bolting for Choke and Kill Equipment

For equipment covered in 4.3, bolting shall conform to API 6A bolting specifications.

For equipment not covered in 4.3, the original equipment manufacturers (OEMs) shall have a documented procedure for the qualification of bolting manufacturers that follows the requirements of API 20E and API 20F. Bolting exposed to wellbore fluids shall conform to the requirements of NACE MR0175/ISO 15156. OEMs shall specify the thread form and dimensions of studs, nuts, and bolts. When plating or coating is specified, refer to API 20E or 20F.

Bolting specification levels shall conform to the requirements of Table 5.

Table 5—Bolting Requirements

	Material	Minimum Level
Exposed bolting	Alloy steel and carbon steel Stainless steel and CRA	API 20E BSL-2 API 20F BSL-2
Class 3 bolting	Alloy steel and carbon steel Stainless steel and CRA	API 20E BSL-3 API 20F BSL 3
Class 2 bolting	Alloy steel and carbon steel Stainless steel and CRA	API 20E BSL-1 API 20F BSL-2
Utility bolting	Alloy steel and carbon steel Stainless steel and CRA	Mfg. spec. Mfg. spec.

5.5 Flexible Lines

Material requirements for flexible lines shall be per the manufacturer's written specifications.

5.6 Special Materials

Special materials shall include corrosion-resistant materials, abrasion-resistant materials, and all other materials not listed in Table 6. Special materials shall conform to the manufacturer's written specifications.

5.7 Casting Practices

The manufacturer shall have either:

- a written specification that establishes limits for sand control, core making, rigging, and melting; or

— a casting supplier that establishes limits for sand control, core making, rigging, and melting.

5.8 Hot Work Practices

The materials manufacturer shall have a written specification for hot work practices. Wrought materials shall be formed using a hot work practice that produces a wrought structure throughout the part.

Forgings shall have a minimum 3:1 reduction ratio.

5.9 Chemical Composition

Material composition shall be determined on a per-heat basis (or a remelt ingot basis for remelt grade materials) and shall conform to the requirements of Table 6 and Table 7.

Table 6 specifies element limits, expressed in percentage mass fraction, for carbon, low-alloy, and martensitic stainless steels (other than precipitation-hardening types) used to manufacture pressure-containing parts. If the composition is specified by reference to a recognized industry standard, it is not necessary that those elements specified as residual/trace elements be reported, provided the residual/trace element limits of the industry standard are within the limits of this standard. Table 6 and Table 7 do not apply to other alloy systems. Composition limits of other alloy systems are purposely omitted from these tables, to provide the manufacturer the freedom to utilize alloy systems for the multiplicity of requirements encountered.

If the manufacturer specifies a material by reference to a recognized industry standard that includes chemical composition requirements, the material shall conform to the tolerance ranges of the referenced industry standard. If the manufacturer specifies a material chemistry not covered by a recognized industry standard, the tolerance ranges shall conform to the requirements of Table 7. These tolerances only apply to the material types covered in Table 6, carbon and low alloy steels, and martensitic stainless steels. Applying the tolerances of Table 7 shall not have the result that any limits specified in Table 6 are exceeded.

Table 6—Pressure-containing Parts Material Composition Limits

Alloying Element	Carbon and Low Alloy Steels (mass %)	Martensitic Stainless Steels (mass %)
Carbon	0.45 max.	0.15 max.
Chromium	2.75 max.	11.0 to 14.0
Manganese	1.80 max.	1.00 max.
Molybdenum	1.50 max.	1.00 max.
Nickel	1.00 max.	4.50 max.
Phosphorous	0.025 max.	0.025 max.
Silicon	1.00 max.	1.50 max.
Sulfur	0.025 max.	0.025 max.
Vanadium	0.30 max	N/A

Table 7—Alloying Element Maximum Tolerance Range Requirements
(Values in mass %)

Alloying Element	Carbon and Low Alloy Steels	Martensitic Stainless Steels
Carbon	0.08	0.08
Chromium	0.50	—
Manganese	0.40	0.40
Molybdenum	0.20	0.20
Nickel	0.50	0.50
Silicon	0.30	0.35
Vanadium	0.10	0.10
NOTE These values are the maximum allowable for any specific element, and do not exceed the maximum specified in Table 6		

5.10 Qualification Test Coupon

Qualification test coupons (QTC) shall be in conformance with all requirements in API 6A.

5.11 Heat Treatment—Equipment and Quenching

All heat-treatment operations shall be performed utilizing equipment calibrated and surveyed in conformance with Annex B.

Quenching shall be performed in conformance with the manufacturer's written specifications, in conformance with the following:

- Water quenching: The temperature of the water or water-based quenching medium shall not exceed 100 °F (38 °C) at the start of the quench, nor exceed 120 °F (49 °C) at the completion of the quench.
- Oil quenching: The temperature of any oil medium shall be greater than 100 °F (38 °C) at the start of the quench.
- Polymer quenching: The temperature of the polymer shall be as prescribed by the polymer medium manufacturer.

5.12 Mechanical Testing

5.12.1 Tensile Testing

A minimum of one tensile test shall be performed on a qualification test coupon (QTC) per heat and per heat treat lot at a temperature between 40 °F and 120 °F (4.4 °C and 48.9 °C) in conformance with ASTM A370.

The results of the tensile test(s) shall satisfy the applicable requirements of Table 8 and Table 9. If the results of the first tensile test do not satisfy the applicable requirements, an additional test may be performed to qualify the material. The additional test shall consist of a minimum of two tensile tests without any additional heat treatments. The results of both tests shall satisfy the applicable requirements.

5.12.2 Impact Testing

A minimum of one set of Charpy V-notch impact tests shall be performed on a qualification test coupon (QTC) per heat and per heat treat lot in conformance with ASTM A370. Test temperature shall be at or below the applicable temperature rating in Table 10.

Full-size specimens shall be used except where there is insufficient material. In this case, the largest sub-size specimen obtainable shall be used. Sub-size absorbed energy requirements shall be reduced per ASTM A370.

For rigid piping, when the use of full-size (10 mm × 10 mm) transverse test specimens is not possible, the largest possible sub-size transverse test specimen shall be used. When it is not possible to test using transverse test specimens, the largest possible longitudinal test specimen shall be used. Acceptance criteria shall be per Table 10.

5.13 Mud Gas Separators (Atmospheric)

Materials for mud gas separators shall be in accordance with requirements of NACE MR0175/ISO 15156.

Table 8—Acceptance Criteria Charpy V-notch Impact Requirements

Temperature Rating	Test Temperature °F (°C)	Minimum Average Impact Value for Three Specimens ft-lb. (J)	Minimum Impact Value Permitted for One Specimen Only Per Set ft-lb. (J)
A, B	– 4 (–20)	15 (20) Wrought transverse or castings	10 (14) Wrought transverse or castings
K	–75 (–60)		
L, N	–50 (–46)		
P	–20 (–29)	20 (27) Wrought longitudinal	14 (19) Wrought longitudinal
S, T, U, X, Y	0 (–18)		

Table 9—Pressure-containing Parts Material Designation

API Material Designation						
Part	Rated Working Pressure psi (MPa)					
	2000 (13.8)	3000 (20.7)	5000 (34.5)	10,000 (69.0)	15,000 (103.5)	20,000 (138.0)
Body, bonnet, and rigid piping	36K (248)	36K (248)	36K (248)	36K (248)	45K (248)	60K (413)
	45K (310)	45K (310)	45K (310)	45K (310)	60K (413)	75K (517)
	60K (413)	60K (413)	60K (413)	60K (413)	75K (517)	
	75K (517)	75K (517)	75K (517)	75K (517)		
End and outlet connector	60K (413)	60K (413)	60K (413)	60K (413)	75K (517)	75K (517)
Blind flange	75K (517)	75K (517)	75K (517)	75K (517)		
NOTE Non-standard materials are acceptable if their design stress intensity (Sm) is greater than or equal to that of the lowest-strength grade shown for the component and pressure rating above.						

Table 10—Pressure-containing Parts Material Property Requirements

API Material Designation	Yield Strength Minimum^a psi (MPa)	Tensile Strength Minimum psi (MPa)	Elongation Minimum %	Reduction in Area Minimum %
36K	36,000 (248)	70,000 (483)	21	32
45K	45,000 (310)	70,000 (483)	19	32
60K	60,000 (414)	85,000 (586)	18	35
75K	75,000 (517)	95,000 (655)	18	35
Nonstandard	As specified	As specified	15	25

^a By 0.2 % offset. Alternatively, 0.65 % extension under load method may be used for pipe.

6 Welding

6.1 General

All welding of components exposed to wellbore fluid shall conform to the welding requirements of NACE MR0175/ISO 15156. Verification of conformance shall be established through implementation of the manufacturer's written welding procedure specification (WPS) and the supporting procedure qualification record (PQR). When material specifications for pressure-containing and pressure-controlling components require impact testing, verification of conformance shall be established through implementation of the manufacturer's WPS and supporting PQR.

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

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

6.2 Welding Procedure and Performance Qualification

6.2.1 Welding procedure and performance qualifications for pressure-containing or pressure-controlling parts shall be performed in conformance with ASME BPVC, Section IX, or an equivalent national or international standard.

Welding procedure and performance qualifications for structural, non-pressure-containing, or non-pressure-controlling parts shall be performed in conformance with AWS D1.1, ASME BPVC, Section IX, or an equivalent national or international standard.

6.2.2 Hardness testing methods and locations for welding procedure qualification shall be in conformance with NACE MR0175/ISO 15156, Part 2.

Hardness acceptance criteria for parts exposed to wellbore fluid shall be in conformance with NACE MR0175/ISO 15156, Part 2 or 3, as applicable.

Hardness acceptance criteria for parts not exposed to wellbore fluid shall be in conformance with the manufacturer's specification.

6.2.3 Impact Testing

When impact testing is required by the base material specification, the testing shall be performed in accordance with Annex G, or the alternative method below.

One set of three test specimens each shall be removed at the $\frac{1}{4}$ thickness location of the test weldment for each of the weld metal and base material heat affected zone (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): Include as much HAZ material as possible. 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. Any retest of impact testing shall be in accordance with ASTM A370.

6.3 Pressure-containing Fabrication Weldments

6.3.1 Joint Design

Design of groove and fillet welds with tolerances shall be documented in the manufacturer's specifications.

6.3.2 Materials

6.3.2.1 Welding Consumables

Welding consumables shall conform to ASME BPVC, Section II, Part C, AWS A.5.1, or the manufacturer's written 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 specified by a consumable manufacturer to retain their original low hydrogen properties.

6.3.2.2 Deposited Weld Metal Properties

The deposited weld metal's mechanical properties shall conform to 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 conform to the minimum requirements of the lesser material.

For applications involving multiple PWHT, the mechanical properties of the deposited weld metal after all PWHT is complete shall conform to or exceed the minimum specified mechanical properties for the base material as documented on the applicable PQR.

NOTE A cross-weld metal tensile test conforms to these requirements.

6.3.3 Post-weld Heat Treatment

6.3.3.1 General

The post-weld heat treatment of the test weldment shall be in the same temperature range as that specified on the WPS. Allowable range for the post-weld heat treatment on the WPS shall be a nominal temperature range ± 25 °F (± 13.9 °C). See Annex B for the qualification of heat treating equipment.

6.3.3.2 Local PWHT

Local post-weld heat treatment shall consist of heating a circumferential band around the weld at a temperature within the ranges specified in the qualified welding procedure specification. The minimum width of the controlled band at each side of the weld on the face of the greatest weld width shall be the thickness of the weld, or 2 in. (5.1 cm) from the weld edge, whichever is less. Localized flame-heating is permitted, provided the flame is baffled to prevent direct impingement on the weld and base material.

6.3.4 Welding Controls

Instruments, meters, and gauges used to verify welding parameters shall be calibrated in conformance with 7.1.2.

6.3.5 Chemical Analysis

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

6.3.6 Application

The post-weld heat treatment of the production weldment shall be in the same temperature range as that specified on the WPS. The stress relieving heat-treatment time(s) at temperature of production parts shall be equal to or greater than that of the test weldment.

6.3.7 Quality Control Requirements

Quality control requirements for pressure-containing welds are provided in 6.6.

6.4 Pressure-containing Repair Weldments

6.4.1 Access

Repair welding procedures for bodies, bonnets, drilling riser choke, kill, end connectors, and outlet connectors shall define the WPS and NDE requirements. Welding shall be performed in conformance with the specified WPS.

There shall be adequate access to evaluate, remove, repair, and inspect a nonconforming condition. If a nonconforming condition does not have adequate access to evaluate, remove, repair, and inspect, the part shall be rejected.

6.4.2 Welder/Welding Operator Qualification

6.4.2.1 General

The welder/welding operator shall possess a valid qualification for the materials and processes to be used in conformance with Section 7.

6.4.2.2 Hole Repair Performance Qualification

Bolt hole, tapped hole, and machined blind hole repair performance qualification shall be in conformance with this section. The welder/welding operator shall perform an additional repair welding performance qualification test using a mock-up hole. The repair welding qualification test hole shall be qualified by radiography in conformance with Section 7 or shall be cross-sectioned through the centerline of the hole in two places 90 degrees apart and macro etched to verify complete fusion. One surface of each of the four matching pairs shall be macro etched. This evaluation shall include the total depth of the hole.

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

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

6.5 Weld Overlay

6.5.1 Ring Grooves

6.5.1.1 Application

This section shall apply to loose connectors, integral end connectors, and outlet connectors.

6.5.1.2 Post-weld Heat Treatment

End and outlet connectors with corrosion-resistant weld overlaid ring grooves shall be subjected to post-weld heat treatment in conformance with the weld procedure qualification.

6.5.1.3 Other Weld Preparations

Other weld preparations may be used where the mechanical properties of the deposited weld metal equals or exceeds that of the base metal.

6.5.1.4 Hardness Testing for Ring Groove Overlays

For ring groove overlays made of stainless steel filler metal, hardness testing shall be performed in the weld metal as part of the procedure qualification testing. Test locations shall be within $\frac{1}{8}$ in. (3.2 mm) of the original base material. The average of three or more test results shall be equal to or greater than Rockwell B 83 and recorded as part of the PQR.

NOTE This requirement does not apply to nickel-based overlays.

6.5.2 Corrosion-resistant Overlays Other Than Ring Grooves

Corrosion-resistant weld overlays for bodies, bonnets, drilling riser choke and kill, and end and outlet connectors for purposes other than ring grooves shall be per the manufacturer's written specifications.

6.5.3 Welding Procedure/Performance Qualification

6.5.3.1 General

Qualification shall be in conformance with ASME BPVC, Section IX for weld overlay, hard facing, or other types of overlay as applicable.

6.5.3.2 Mechanical Properties

The base material shall retain the minimum mechanical property requirements after post-weld heat treatment. The manufacturer shall specify the methods to assure these mechanical properties and record the results as part of the PQR.

6.5.3.3 Overlay Mechanical Properties

When the overlay material is not considered as part of the manufacturer's or the API design criteria, a tensile test and a Charpy test of the material are not required. Overlay materials considered a part of the minimum wall thickness shall have mechanical testing performed. Test results for the overlay material properties shall conform to or exceed the specified design requirements.

6.5.3.4 Hardness Testing

Hardness testing methods and locations for welding procedure qualification shall be in conformance with NACE MR0175/ISO 15156, Part 2.

Hardness acceptance criteria for parts exposed to wellbore fluid shall be in conformance with NACE MR0175/ISO 15156, Part 2 or 3 as applicable.

Hardness acceptance criteria for parts not exposed to wellbore fluid shall be in conformance with the manufacturer's specification.

6.5.3.5 Chemical Analysis

Chemical analysis for weld procedure qualifications shall be in conformance with API 6A PSL 3 requirements.

6.6 Weld NDE

6.6.1 General

Completed weldments shall be examined in conformance with the methods and acceptance criteria of this section. Requirements and acceptance criteria for corrosion-resistant weld overlay of bodies, bonnets, and flanges shall

conform to the manufacturer's written specifications. The manufacturer's written specification for corrosion-resistant weld overlay shall include a technique for measuring the specified overlay thickness.

6.6.2 Weld NDE—Visual

Weldments shall be visually examined by the welding inspector for 100 % of the length after post-weld heat treatment and machining operations.

Pressure-containing welds shall have complete joint penetration. Undercut shall not reduce the thickness in the area (considering both sides) to below the minimum thickness. Surface porosity and exposed slag are not permitted on or within $\frac{1}{2}$ in. (12.7 mm) of sealing surfaces.

6.6.3 Weld NDE—Surface

Each pressure-containing fabrication weld or weld overlay shall be examined by either magnetic particle or liquid penetrant (in the case of non-ferrous materials) methods, after welding, post-weld heat treatment, and machining operations. Examinations shall include a minimum of $\frac{1}{2}$ in. (12.7 mm) of adjacent base metal on both sides of the weld.

Magnetic particle examination using the wet fluorescent method shall be performed to procedures specified in ASTM E709. Prods are not permitted on wetted surfaces or sealing surfaces.

Liquid penetrant examination shall be performed on accessible sealing surfaces of each finished part after final heat treatment and after final machining operations. Examination shall be performed as specified in ASTM E165.

The acceptance criterion for pressure-contact (metal-to-metal) sealing surfaces is that there shall be no relevant indications in the pressure-contact (metal-to-metal) sealing surfaces.

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

- a) no relevant indication with a major dimension equal to or greater than $\frac{3}{16}$ in. (5 mm);
- b) no more than 10 relevant indications in any continuous 6 in.² (40 cm²) area;
- c) four or more relevant indications in a line separated by less than $\frac{1}{16}$ in. (1.6 mm) (edge-to-edge) are unacceptable.

6.6.4 Weld NDE—Volumetric

6.6.4.1 General

Pressure-containing fabrication welds shall be examined by either radiography or ultrasonic methods after welding, post-weld heat treatment, and machining operations.

Repair welds in which the repair is greater than 20 % of the original wall thickness or 1 in. (25.4 mm) (whichever is less), or where the extent of the cavity exceeds 10 in.² (64.5 cm²), or where the casting leaks on hydrostatic test, shall be examined by either radiography or ultrasonic methods after welding, post-weld heat treatment, and machining operations.

Examination shall include at least $\frac{1}{2}$ in. (12.7 mm) of adjacent base metal on all sides of the weld.

6.6.4.2 Method—Radiographic Examination

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