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Introduction

The International System of Units (SI) is used in this specification. However, nominal sizes are shown as fractions in the inch system.

The fractions and their decimal equivalents are equal and interchangeable. Metric conversions and inch dimensions in this specification are based on the original fractional inch designs. Functional dimensions have been converted into the metric system to ensure interchangeability of products manufactured in metric or inch systems; see also Annex C.

An “—” symbol when used in tables means that the applicable size, value, or dimension does not apply.

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

Specification for Wellhead and Tree Equipment

1 Scope

This specification identifies requirements and gives recommendations for the performance, dimensional and functional interchangeability, design, materials, testing, inspection, welding, marking, handling, storing, shipment, and purchasing of wellhead and tree equipment for use in the petroleum and natural gas industries.

This specification does not apply to field use or field testing. This specification also does not apply to repair of wellhead and tree equipment except for weld repair in conjunction with manufacturing. Tools used for installation and service (e.g. running tools, test tools, wash tools, wear bushings, and lubricators) are outside the scope of this standard.

This specification is applicable to the equipment identified in 4.1 and Section 14.

This specification establishes requirements for four product specification levels (PSLs): PSL 1, PSL 2, PSL 3, and PSL 4. A supplemental designation of PSL 3G applies to PSL 3 products that have satisfied the additional requirements of gas testing. The PSL designations define different levels of technical quality requirements.

Subject matter of Annexes B, C, D, E, F, G, H, I, J, K, L, and M has been arranged in a way that minimizes the impact of changes on users of this document.

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, except that new editions may be used on issue and shall become mandatory upon the effective date specified by the publisher or 12 months from the date of the revision (where no effective date is specified).

API Recommended Practice 5A3, *Recommended Practice on Thread Compounds for Casing, Tubing, Line Pipe, and Drill Stem Elements*

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

API Specification 5CT, *Casing and Tubing*

API Standard 6ACRA, *Age-hardened Nickel-based Alloys for Oil and Gas Drilling and Production Equipment*

API Standard 6AV1, *Validation of Safety and Shutdown Valves for Sandy Service*

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

API Recommended Practice 14F, *Design, Installation, and Maintenance of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class 1, Division 1 and Division 2 Locations*

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

API Specification 17D, *Design and Operation of Subsea Production Systems—Subsea Wellhead and Tree Equipment*

API Specification 20A, *Carbon Steel, Alloy Steel, Stainless Steel, and Nickel Base Alloy Castings for Use in the Petroleum and Natural Gas Industry*

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

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

ASME B1.1¹, *Unified Inch Screw Threads (UN and UNR Thread Form)*

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

ASME B1.3, *Screw Thread Gaging Systems for Acceptability: Inch and Metric Screw Threads (UN, UNR, UNJ, M, and MJ)*

ASME B1.5, *Acme Screw Threads*

ASME B1.8, *Stub Acme Screw Threads*

ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*

ASME Boiler and Pressure Vessel Code, Section V, *Nondestructive Examination*

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, *Rules for Construction of Pressure Vessels*

ASME Boiler and Pressure Vessel Code:2004 with 2005 and 2006 addenda, Section VIII, Division 2, *Alternative Rules*

ASME Boiler and Pressure Vessel Code, Section IX, *Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators*

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

ASTM A193/A193M³, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A194/A194M, *Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM A320/A320M, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service*

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

ASTM A388/A388M, *Standard Practice for Ultrasonic Examination of Steel Forgings*

ASTM A453/A453M, *Standard Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels*

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

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

³ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, 19428, www.astm.org.

ASTM A609/A609M, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

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

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

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

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

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

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

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 E92, *Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials*

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

ASTM E186, *Standard Reference Radiographs for Heavy-Walled (2 to 4¹/₂ in. (50.8 to 114 mm)) Steel Castings*

ASTM E280, *Standard Reference Radiographs for Heavy-Walled (4¹/₂ to 12 in. (114 to 305 mm)) Steel Castings*

ASTM E446, *Standard Reference Radiographs for Steel Castings up to 2 in. (50.8 mm) in Thickness*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ISO 148-1⁴, *Metallic materials—Charpy pendulum impact test—Part 1: Test method*

ISO 3834 (all parts), *Quality requirements for fusion welding of metallic materials*

ISO 5208, *Industrial valves—Pressure testing of metallic valves*

ISO 6506 (all parts), *Metallic materials—Brinell hardness test*

⁴ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

ISO 6507 (all parts), *Metallic materials—Vickers hardness test*

ISO 6508 (all parts), *Metallic materials—Rockwell hardness test*

ISO 6892-1, *Metallic materials—Tensile testing—Part 1: Method of test at room temperature*

ISO 9606 (all parts), *Qualification testing of welders—Fusion welding*

ISO 9712, *Non-destructive testing—Qualification and certification of NDT personnel*

ISO 14732, *Welding personnel—Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

ISO 15609 (all parts), *Specification and qualification of welding procedures for metallic materials—Welding procedure specification*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials—Welding procedure test—Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 15614-7, *Specification and qualification of welding procedures for metallic materials—Welding procedure test—Part 7: Overlay welding*

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

ISO 2859-1:1999, *Sampling procedures for inspection by attributes—Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

NACE MR0175/ISO 15156⁵, *Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*

SAE AMS-H-6875⁶, *Heat Treatment of Steel Raw Materials*

SAE AS568A, *Aerospace Size Standard for O-Rings*

SAE AMS2750, *Pyrometry*

3 Terms, Definitions, Abbreviated Terms, and Symbols

3.1 Terms and Definitions

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

3.1.1

accessible wetted surface

Wetted surface for purposes of nondestructive examination (NDE) that can be viewed by direct line of sight.

NOTE This excludes test ports, control line ports, lockdown screw holes, and other penetrations of these types.

3.1.2

actuator

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

⁵ NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

⁶ SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, www.sae.org.

3.1.3**annular packoff**

Mechanism that seals off annular pressure between the outside diameter of a suspended tubular member or hanger and the inside diameter of the head or spool through which the tubular member passes or hanger is suspended.

3.1.4**back-pressure valve**

Unidirectional or bidirectional check valve that is installed through the tree, into the tubing hanger, and prevents well fluids from flowing out of the well.

3.1.5**ball valve**

Valve with a spherical closure member that rotates on an axis perpendicular to the direction of flow.

3.1.6**blind flange**

Flange with no through-bore, which may or may not include a test and gauge connector port, used to close off a flanged or studded end or outlet connector.

NOTE A blind flange with a test and gauge connector port is sometimes called a test flange.

3.1.7**boarding shutdown valve****BSDV**

Automatic valve assembly installed between an underwater production system and a surface facility that closes on loss of power supply.

NOTE Where used in this specification, the term is understood to include a BSDV valve and BSDV actuator.

3.1.8**body**

Any portion of wellhead and tree equipment that includes one or more end connectors and is designed to be exposed to and contain well bore pressure and fluid.

3.1.9**bonnet**

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

3.1.10**bottom casing packoff**

Mechanism that seals off annular pressure between the outside diameter of a suspended tubular member or hanger and the inside diameter of the spool or tubing-head adapter placed over the suspended tubular or hanger.

3.1.11**bullplug**

Pressure-containing closure for a female-threaded end or outlet connector that may have an internal counterbore and/or test and gauge connector port.

3.1.12**casing-head housing**

Equipment attached to the uppermost end of the surface casing that serves to suspend and seal a casing string.

3.1.13**casing-head spool**

Equipment attached to another casing head that serves to suspend and seal a secondary casing string.

3.1.14**casting (noun)**

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

NOTE Parts made by hot isostatic pressing are not considered to be a casting.

3.1.15**certificate of conformance**

Document containing the statement by the manufacturer certifying that the equipment meets the requirements of this specification.

3.1.16**check valve**

Valve that permits fluid to flow in one direction and includes a mechanism to automatically prevent flow in the opposite direction.

3.1.17**choke**

Equipment used to restrict and control the flow rate and pressure of fluids.

3.1.18**choke bean****flow bean**

Replaceable orifice part used in positive chokes to control flow rate.

3.1.19**choke trim**

Pressure-controlling choke part, including choke beans, used to control or regulate the flow of fluids.

3.1.20**clamp hub**

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

3.1.21**closure bolting**

Threaded fastener used to assemble well bore pressure-containing parts or join end or outlet connectors.

EXAMPLE Studs, nuts, bolts, and capscrews.

3.1.22**corrosion-resistant alloy****CRA**

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.

3.1.23**corrosion-resistant ring groove**

Ring groove lined with a CRA to resist metal-loss corrosion.

3.1.24**critical dimensions**

Toleranced dimensions of features determined by the manufacturer to be essential to the function of the equipment.

3.1.25**cross**

Pressure-containing part with a minimum of four end connectors.

3.1.26**crossover connector**

Product with a restricted-area sealing means and with a top connector pressure rating above that of the lower connector.

NOTE Types of crossover connectors may include crossover spools, multistage crossover spools, crossover adapters, and crossover tubing-head adapters.

3.1.27**date of manufacture**

Date of manufacturer's final acceptance of finished equipment.

3.1.28**end connector****outlet connector**

Any integral feature of a body used as a means to join together equipment that contains pressure, permits flow of retained fluid between the joined equipment, and provides a seal at the joint.

NOTE 1 End and outlet connectors include, but are not limited to, internal or external thread, clamp hub, studded outlet, and studded or through-bolted flange.

NOTE 2 A bonnet connector or a weld preparation is not an end connector.

3.1.29**equipment**

Any product included in the scope of this specification.

3.1.30**equivalent round****ER**

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

3.1.31**exposed bolting**

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

3.1.32**fitting**

Type of pressure boundary penetration that is used for the purpose of lubrication, maintenance, venting, monitoring, or testing another part.

NOTE A fitting is not an end connector.

3.1.33**flange**

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

3.1.34**forging (noun)**

Shaped metal part formed by the forging method.

3.1.35**full overlay**

Referring to a welding procedure, welding operations, or equipment where all retained fluid-wetted surfaces are weld overlaid or weld clad with a corrosion-resistant alloy.

3.1.36**full-bore valve**

Valve whose closure mechanism has a bore dimension the same as or larger than the valve body.

3.1.37**fusion face**

Surface of the base metal that will be melted during welding.

3.1.38**gate valve**

Valve assembly with a closure mechanism operating within the body, 90° to the conduit, to affect a closure.

3.1.39**hanger mandrel**

Portion of a casing or tubing hanger that is attached by a threaded connector to the tubular string and forms the upper end of that tubular string.

3.1.40**hanger (mandrel-type)**

Mechanism used to support a casing or tubing string in a casing or tubing head by means of a male or female thread attached to the casing.

3.1.41**hanger (slip-type)**

Mechanism used to support a casing string in a casing head by gripping the pipe with wedge-type members.

3.1.42**heat****heat lot**

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

3.1.43**heat-treat lot, batch furnace**

Material placed on loading or carrying devices and moved through a heat-treat cycle in the same furnace, including the same quenching practice.

3.1.44**heat-treat lot, continuous furnace**

Group of pieces of material with the same nominal size that is moved sequentially through the heat-treatment process using the same process parameters.

3.1.45**heat-treatment****heat-treat**

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

3.1.46**heat-affected zone****HAZ**

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

3.1.47**heat-sensitive lock-open device**

Device installed on a surface safety valve (SSV) actuator to maintain the SSV valve in a full-open position until exposed to sufficient heat to cause the device to release and allow the SSV valve to close.

3.1.48**hot isostatic pressing**

Special forming process used to compact and metallurgically bond metal powder.

NOTE This process takes place within a flexible, metal container whose contents are formed into the desired shape by subjecting the container to high temperature and pressure in an autoclave. It produces a fully wrought structure.

3.1.49**hydrostatic test**

Any pressure test performed with a liquid-state test fluid.

3.1.50**instrument flange**

Spacer flange with a through-bore and one or more test and gauge connector ports from the outside diameter to the through-bore.

3.1.51**job-lot traceability**

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

3.1.52**linear indication**

Surface NDE indication whose length is equal to or greater than three times its width.

3.1.53**lock screw****tie-down screw**

Threaded pin extending through the wall of a casing-head or tubing-head connector used to lock down hangers or energize seals.

3.1.54**loose connector****loose flange**

Connector, as-manufactured, that is not intended to be made integral with equipment conforming to this specification.

EXAMPLE Types of loose connectors are blind, threaded, weld-neck, flanged, studded, or other end connectors.

3.1.55**manufacturer**

Organization that produces equipment that meets the requirements of this specification.

3.1.56**multistage crossover spool**

Flanged or other connected equipment with more than one restricted-area sealing means to provide suitable capability to suspend and seal around multiple inner strings of casing or tubing at several stages.

3.1.57**objective evidence**

Documented field experience, test data, publications, finite element analysis, or calculations that confirm performance characteristics, as applicable.

3.1.58**other end connector****OEC**

End or outlet connector of a design not fully specified in this or other reference API specification.

3.1.59**part**

Individual piece used in the assembly of single equipment units.

EXAMPLE Body, bonnet, gate, stud, handwheel, etc., are parts of a valve.

NOTE A part may also be a piece not in finished form.

3.1.60**partial overlay**

Referring to a welding procedure, welding operations or equipment where some, but not all, retained fluid-wetted surfaces are weld overlaid or weld clad with a corrosion-resistant alloy.

3.1.61**plug valve**

Valve assembly with a closure mechanism mounted across the conduit so that, when rotated 90°, it effects a closure.

EXAMPLE Plugs may be straight or tapered.

3.1.62**post-weld heat-treatment**

Any heat-treatment subsequent to welding for the purpose of stress relief.

3.1.63**pressure boundary penetration**

Device that penetrates directly into or communicates with the well bore.

3.1.64**pressure-containing part**

Part whose failure to function as intended results in a release of retained fluid to the atmosphere.

EXAMPLE Bodies, bonnets, one-piece stems, and that segment of multipiece stems that passes through the pressure boundary, are pressure-containing parts.

3.1.65**pressure-containing weld**

Closure weld that is part of the pressure envelope of the part and contributes to the retention of pressure.

3.1.66**pressure-controlling part**

Part intended to control or regulate the movement of pressurized fluids.

EXAMPLE Valve bore sealing mechanisms, choke trim, and hangers.

3.1.67**pressure integrity**

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

3.1.68**primary equipment**

Pieces of equipment that cannot normally be isolated from well fluid or well pressure.

3.1.69**prolongation**

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

3.1.70**proration bean**

Type of positive choke bean of fixed length used to regulate the flow of fluid from a well.

NOTE Proration is a system of allocating the amount of oil or gas a well or field is allowed to produce within a given period by a regulatory agency.

3.1.71**purchaser**

Organization that buys equipment from the manufacturer.

3.1.72**rated working pressure**

Maximum internal pressure that the equipment is specified to contain and/or control when in operation.

3.1.73**reduced-opening valve**

Valve with an opening through the valve bore sealing mechanism, where that opening is smaller in area than the minimum bore as specified in 14.11.

3.1.74**relevant indication**

Surface NDE indication with major dimensions greater than 1.6 mm ($1/16$ in.).

NOTE An indication not associated with a surface rupture is not considered to be a relevant indication.

3.1.75**repair weld**

Welding used to restore a part to design requirements or to improve appearance.

3.1.76**restricted-area sealing means**

Packoff or other device used to isolate an area at higher pressure from one at lower pressure.

NOTE This device serves to limit pressure-induced loads on connectors or areas of a lower-pressure rating. It may also be a seal that encloses a pressure-containment area smaller than the adjacent ring gasket or connector seal.

3.1.77**retained fluid**

Actual fluid produced by a well or injected into a well.

3.1.78**rounded indication**

Surface NDE indication that is circular or elliptical, having a length less than 3 times its width.

3.1.79**safety valve**

Surface safety valve (SSV) or underwater safety valve (USV) or boarding shutdown valve (BSDV), as defined in this specification.

NOTE A safety valve is any one of the valves of 3.1.87 assembled with the corresponding actuator of 3.1.86.

3.1.80**safety valve actuator**

Any one of the actuators of 3.1.86.

3.1.81**sandy service**

Application where the retained fluid could contain particulates such as sand.

3.1.82**secondary equipment**

Piece of equipment that can normally be isolated from the well fluid or well pressure.

3.1.83**serialization**

Assignment of a unique code to an individual part and/or piece of equipment to maintain records.

3.1.84**shell test**

Hydrostatic test required by this specification that exceeds the rated working pressure.

3.1.85**slip bowl**

Piece of equipment between the wedge type members and casing-head bowl.

3.1.86**SSV actuator****USV actuator****BSDV actuator**

Device that causes the SSV/USV/BSDV to open when power is supplied and to close automatically when power is lost or released.

3.1.87**SSV valve****USV valve****BSDV valve**

Portion of the SSV/USV/BSDV that contains the well stream and shuts off flow when closed.

3.1.88**stainless steel**

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

NOTE Other elements may be added to secure special properties.

3.1.89**studded connector**

End or outlet connector in which thread-anchored studs screwed into tapped holes replace the holes for bolt studs.

3.1.90**substantive change**

Change identified by the manufacturer that affects the performance of the product in the intended service.

3.1.91**surface safety valve****SSV**

Automatic wellhead valve assembly that closes upon loss of power supply.

NOTE Where used in this specification, the term is understood to include an SSV valve and SSV actuator.

3.1.92**supply pressure rating**

Maximum hydraulic or pneumatic pressure specified to operate an actuator.

3.1.93**swab valve****crown valve**

Uppermost valve on the vertical bore of the tree above the flowline outlet.

3.1.94**tee**

Pressure-containing part with three end connectors; two openings opposite one another form the run portion of the tee, and one opening is at 90° to the line of the run.

NOTE Tees may be equipped with threads, flanges, studs, or other end connectors.

3.1.95**test agency**

Independent party that provides a test facility and administers a testing program that meets the SSV/USV/BSDV valve-validation testing requirements of API 6AV1.

3.1.96**test and gauge connector port**

Port in wellhead and tree equipment for attachment of a fitting (see 3.1.32).

3.1.97**threaded flange**

Flange having a sealing face on one side and a female thread on the other for joining flanged connectors to threaded connectors.

3.1.98**top connector****tree cap**

Uppermost part of a tree that allows access to the vertical bores of the tree.

3.1.99**tree**

Assembly of equipment, including tubing-head adapters, valves, tees, crosses, top connectors, and chokes attached to the uppermost connector of the tubing head, used to control well production.

NOTE This is sometimes referred to as a "christmas tree."

3.1.100**tubing hanger mandrel**

Mechanism used to support a tubing string in a tubing head by means of a male or female thread attached to the tubing.

3.1.101**tubing-head adapter**

Equipment that adapts the uppermost connector of a tubing head to the lowermost valve of the tree.

3.1.102**tubing-head spool**

Piece of equipment attached to the uppermost casing head or smallest casing string that serves to suspend the tubing and to seal the annular space between the tubing and casing.

3.1.103**underwater safety valve****USV**

Automatic valve assembly installed at an underwater wellhead location that closes on loss of power supply.

NOTE Where used in this specification, the term is understood to include a USV valve and USV actuator.

3.1.104**user**

User of this specification.

3.1.105**valve bore sealing mechanism**

Internal valve parts that close off the flow through the valve bore.

EXAMPLE Gates, balls, plugs, poppets, flappers, and their respective seats.

3.1.106**valve-removal plug**

Threaded plug that can be installed in the wellhead to enable gate valve removal under pressure.

3.1.107**visible leakage**

Leakage of test fluid seen during a pressure test, either through direct observation or with the use of video equipment.

NOTE Leakage may be observed through or past a pressure boundary or at an interface.

3.1.108**wear bushing**

Retrievable cylindrical device that protects the internal surfaces of wellhead equipment and the top of the last casing suspended.

3.1.109**weld-neck flange**

Flange with a neck on the side opposite the sealing face terminating in a weld preparation.

3.1.110**well bore**

Cavity that contains retained fluid.

3.1.111**wellhead**

All permanent equipment between the uppermost portion of the surface casing and the tubing-head adapter connector.

3.1.112**wetted surface**

Any surface that has contact with pressurized well fluid, either by design or because of internal seal leakage.

3.1.113**wrought**

Product, structure, or material that contains no cast dendritic elements.

3.1.114**yield strength**

Stress level at which material plastically deforms and does not return to its original dimensions when the load is released based on the 0.2 % offset method in accordance with ISO 6892-1 or ASTM A370.

3.2 Abbreviated Terms

AQL	acceptance quality limit
BSDV	boarding shutdown valve
BSL	bolting specification level
CRA	corrosion-resistant alloy
CSL	casting specification level
DAC	distance amplitude curve
ER	equivalent round
H ₂ S	hydrogen sulfide
HAZ	heat-affected zone
HBW	Brinell hardness
HRBW	Rockwell hardness scale B
HRC	Rockwell hardness scale C
HPVR	high-pressure valve removal (plug)
HVOF	high-velocity oxygen fuel
MT	magnetic particle test
NA	not applicable
NDE	nondestructive examination
NPT	American national standard taper pipe thread
NS	nonstandard
OD	outside diameter
OEC	other end connector
PMR	per manufacturer's requirement
PQR	procedure qualification record
PR	performance requirement
psi	pounds per square inch (gauge)
psia	pounds per square inch absolute
PSL	product specification level

PT	penetrant test
QTC	qualification test coupon
RMS	root mean square
ROE	radius of exposure
RT	radiographic test
SCC	stress corrosion cracking
SI	International System of Units
SSC	sulfide stress cracking
SSV	surface safety valve
TPI	threads per inch
UNS	unified numbering system
USC	US Customary
USV	underwater safety valve
UT	ultrasonic test
VR	valve removal (plug)
WPQ	welder performance qualification
WPQR	welder performance qualification record
WPS	welding procedure specification

3.3 Symbols

A_s	stress area
E_{ty}	elevated-temperature yield strength
R_m	ultimate tensile strength
R_{ty}	room-temperature yield strength
S_A	allowable tensile stress
S_e	de-rated material yield strength
S_E	maximum allowable equivalent stress at the most highly stressed distance into the pressure vessel wall

S_{my}	minimum specified room-temperature yield strength
S_Y	material-specified minimum yield strength
T	thickness
Y_r	yield reduction ratio at temperature
τ	torque

4 Application and Performance

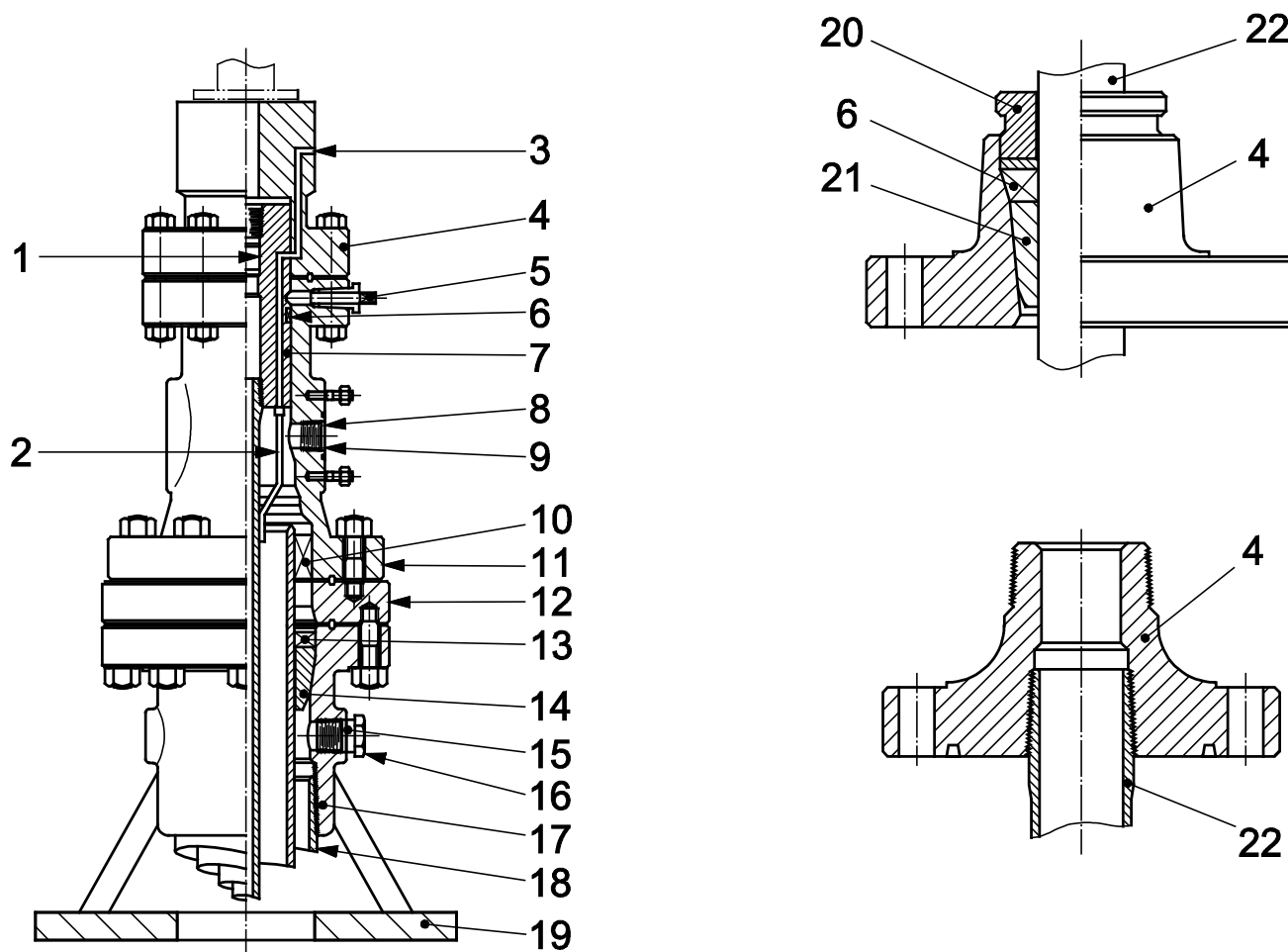
4.1 Applicability

NOTE The nomenclature used in this specification for typical equipment is shown in Figure 1, Figure 2, and Figure 3.

This specification shall be applicable to the following specific equipment:

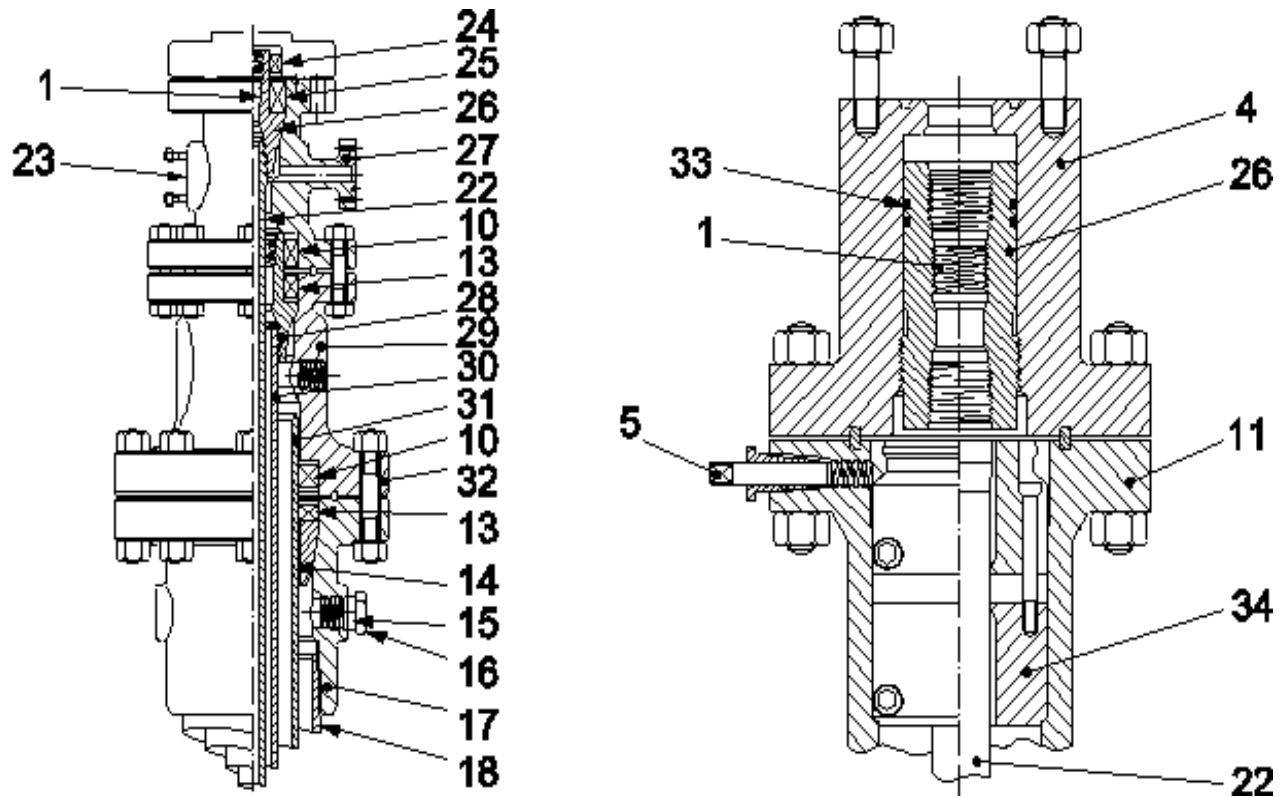
- a) plugs, connectors, and gaskets—API defined (applicable product-specific sections referenced as follows):
 - integral, blind, and test flanges (see 14.1);
 - ring gaskets (see 14.2);
 - threaded connectors (see 14.3);
 - tees and crosses (see 14.4);
 - bullplugs (see 14.5);
 - valve-removal plugs (see 14.6);
 - top connectors (standard) (see 14.7);
- b) plugs and connectors—manufacturer-defined (applicable product-specific sections referenced as follows):
 - top connectors (nonstandard) (see 14.7);
 - crossover connectors (single- or double-studded, single- or multistage) (see 14.8);
 - other end connectors (OECs) (see 14.9);
 - spools (adapter and spacer) (see 14.10);
- c) valves (all types except back-pressure valves) (see 14.11):
 - gate, plug, and ball valves;
 - single and multiple valves;
 - actuated valves (manual and remote);
 - valves prepared for actuators;

- check valves (swing- and lift-type);
- back-pressure valves (see 14.12);
- d) casing and tubing hangers (see 14.13):
 - slip-type;
 - mandrel-type;
- e) casing and tubing heads (housings and adapters) (see 14.14);
- f) chokes (fixed, manually actuated, remotely actuated) (see 14.15);
- g) actuators (for valves and chokes) (see 14.16);
- h) safety valves, shutdown valves, and actuators (see 14.17):
 - surface safety valve (SSV) assemblies, valves prepared for actuators, and actuators;
 - underwater safety valve (USV) assemblies, valves prepared for actuators, and actuators;
 - boarding shutdown valve (BSDV) assemblies, valves prepared for actuators, and actuators;
- i) tree assemblies (see 14.18);
- j) other:
 - packing mechanisms for lock screws, alignment pins, and retainer screws (see Section 9);
 - fittings and pressure boundary penetrations (see Section 9);
 - test, gauge, vent, and injection connector ports (see Section 9);
 - weld-neck flanges (see Annex J).

**Key**

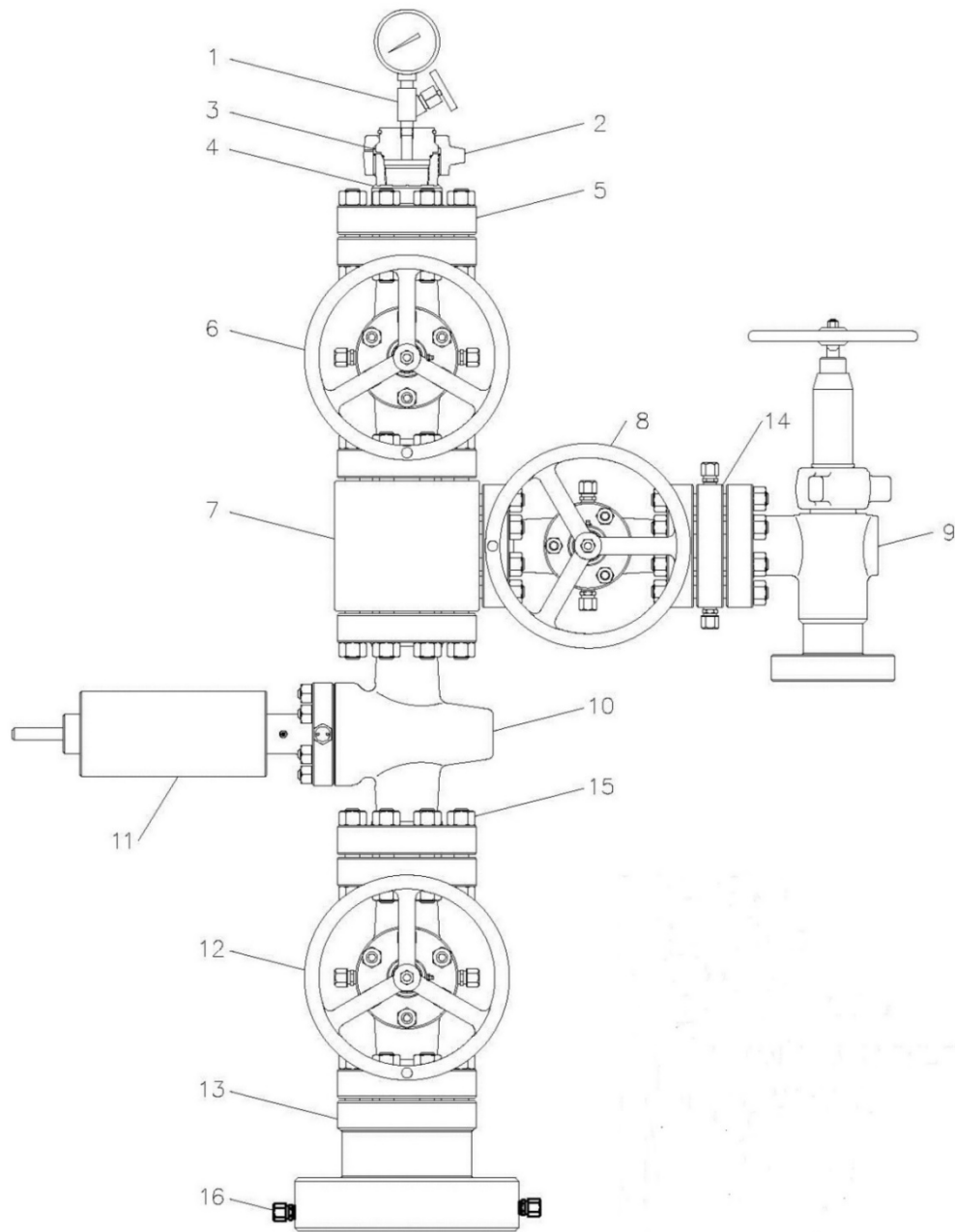
- | | |
|---|---|
| 1 back-pressure valve preparation | 12 adapter spool (double-studded) |
| 2 subsurface safety valve control line | 13 annular casing packoff |
| 3 subsurface safety valve control line outlet | 14 casing hanger (slip style) |
| 4 tubing-head adapter | 15 threaded outlet connection |
| 5 lock screw | 16 bullplug |
| 6 tubing hanger packoff | 17 casing-head housing |
| 7 extended neck tubing hanger with subsurface safety valve control line | 18 surface casing |
| 8 studded side outlet | 19 wellhead support plate or landing base |
| 9 valve-removal preparation | 20 tubing packoff retainer |
| 10 bottom casing packoff | 21 tubing hanger (slip style) |
| 11 tubing-head spool | 22 tubing |

Figure 1—Typical Wellhead Assembly Nomenclature

**Key**

- | | |
|-----------------------------------|-------------------------------------|
| 1 back-pressure valve preparation | 23 studded side-outlet connector |
| 4 tubing-head adapter | 24 extended neck tubing hanger seal |
| 5 lock screw | 25 annular tubing hanger seal |
| 10 bottom casing packoff | 26 tubing hanger mandrel |
| 11 tubing-head spool | 27 flanged outlet connector |
| 13 annular casing packoff | 28 casing hanger mandrel |
| 14 casing hanger (slip style) | 29 casing-head spool |
| 15 threaded outlet connection | 30 inner casing |
| 16 bullplug | 31 intermediate casing |
| 17 casing-head housing | 32 flanged end connector |
| 18 surface casing | 33 tubing hanger mandrel seals |
| 22 tubing | 34 wrap-around hanger packoff |

Figure 2—Typical Wellhead Assembly Nomenclature



Key

- | | | |
|-----------------------|-----------------------------------|--|
| 1 gauge valve | 7 tee | 13 tubing-head adapter |
| 2 bonnet nut | 8 wing valve (manual or actuated) | 14 instrument flange |
| 3 blanking plug | 9 choke | 15 closure bolting |
| 4 body | 10 surface safety valve | 16 test port-pressure boundary penetration |
| 5 top connector | 11 SSV actuator | |
| 6 swab or crown valve | 12 master valve | |

Figure 3—Typical Tree Nomenclature

4.2 Performance Requirements—General

All equipment shall be designed to perform according to the requirements of Section 4 and Section 5 and the relevant requirements specified in Section 14 while in the pressure and temperature ranges and used with the test fluids consistent with the material class (see 4.3.3) for which they are rated.

NOTE 1 There are two performance requirements (PR1 and PR2) that are specific and unique to the product in the as-shipped condition.

NOTE 2 See Annex B for other requirements that may be specified by the purchaser.

PR1 or PR2 shall apply to products when specified in Section 14. Equipment identified as PR2F shall have design validation completed in accordance with Annex F of this specification, including criteria for scaling.

NOTE 3 PR2F is a designation identifying one specific validation to PR2. Other methods of validating products to PR2 are possible.

4.3 Service Conditions

4.3.1 Pressure Ratings

4.3.1.1 General

Equipment, except actuators, shall be designed to operate at only the following rated working pressures:

- 13.8 MPa (2000 psi);
- 20.7 MPa (3000 psi);
- 34.5 MPa (5000 psi);
- 69.0 MPa (10,000 psi);
- 103.5 MPa (15,000 psi);
- 138.0 MPa (20,000 psi).

4.3.1.2 Threaded Equipment Limitations

Equipment designed with internally threaded end and outlet connectors shall be limited to the thread sizes and rated working pressures in Table 1. Table 1 shall not apply to tubing and casing hangers.

4.3.1.3 Design Inputs

Designs shall account for the effects of pressure containment and other pressure-induced loads, including (but not limited to) pressure rating changes in crossover connectors, pressurizing with temporary test plugs, or other applicable special conditions.

NOTE The capacity for external loading (e.g. bending moments, tensions, etc.) on the rating of equipment is not explicitly addressed by this specification (see B.2).

Table 1—Pressure Ratings for Internal Threaded End or Outlet Connectors

Type of Thread	Nominal Sizes of Pipe, Tubing, or Casing in.	Rated Working Pressure	
		MPa	psi
NPT	$1/2$	69.0	10,000
	$3/4$ to $1 1/2$	34.5	5000
Line pipe	$1/2$	69.0	10,000
	$3/4$ to 2	34.5	5000
	$2 1/2$ to 6	20.7	3000
Tubing, nonupset, and external upset round thread	1.050 to $4 1/2$	34.5	5000
Casing (8 round, buttress, and extreme line)	$4 1/2$ to $10 3/4$	34.5	5000
	$11 3/4$ to $13 3/8$	20.7	3000
	16 to 20	13.8	2000

4.3.2 Temperature Ratings

Equipment shall be designed to operate in one or more of the specified temperature classes with minimum and maximum temperatures as shown in Table 2, or to minimum and maximum temperature ratings as agreed between the purchaser and manufacturer.

Table 2—Temperature Ratings

Temperature Class	Temperature Range			
	°C		°F	
	min.	max.	min.	max.
K	−60	82	−75	180
L	−46	82	−50	180
N	−46	60	−50	140
P	−29	82	−20	180
S	−18	60	0	140
T	−18	82	0	180
U	−18	121	0	250
V	2	121	35	250

NOTE Minimum temperature is the lowest ambient temperature to which the equipment can be subjected. Maximum temperature is the highest temperature of the fluid that can directly contact the equipment.

Design for temperature ratings above 121 °C (250 °F), e.g. classifications X and Y (see Table G.1), shall account for the effects of temperature on material strength (see Annex G for guidelines).

4.3.3 Material Classes

4.3.3.1 General

Equipment shall be designed with materials that meet the requirements specified in Table 3.

Table 3—Material Requirements

Material Class		Body, Bonnet, End and Outlet Connectors	Mandrel Hangers, Valve Bore Sealing Mechanisms, Choke Trim, and Stems
AA	General service	Carbon or low-alloy steel, or stainless steel or CRA ^d	Carbon or low-alloy steel, or stainless steel or CRA ^d
BB	General service	Carbon or low-alloy steel, or stainless steel or CRA ^d	Stainless steel or CRA ^d
CC	General service	Stainless steel or CRA ^d	Stainless steel or CRA ^d
DD	Sour service ^a	Carbon or low-alloy steel or CRA ^{b,d}	Carbon or low-alloy steel, or stainless steel or CRA ^{b,d}
EE	Sour service ^a	Carbon or low-alloy steel or CRA ^{b,d}	Stainless steel or CRA ^{b,d}
FF	Sour service ^a	Stainless steel or CRA ^{b,d}	Stainless steel or CRA ^{b,d}
HH	Sour service ^a	CRA ^{b,c,d}	CRA ^{b,c,d}
FOOTNOTES ^a As defined by NACE MR0175/ISO 15156. ^b In accordance with NACE MR0175/ISO 15156 and 4.3.3.2. ^c CRA required on retained fluid-wetted surfaces only; CRA cladding of low-alloy or stainless steel is permitted (see 7.5.1.2). ^d CRA as defined in 3.1.22; NACE MR0175/ISO 15156 definition of CRA does not apply.			

4.3.3.2 Material Classes for Sour Service

For material classes DD, EE, FF, and HH, the manufacturer shall meet the requirements of NACE MR0175/ISO 15156 for material processing and material properties (e.g. hardness).

NOTE 1 Choosing material class and specific materials for specific conditions is ultimately the responsibility of the purchaser.

Material classes DD, EE, FF, and HH shall include as part of the designation and marking the maximum allowable partial pressure of hydrogen sulfide (H₂S), when a value is specified by NACE MR0175/ISO 15156, in units consistent with the rated working pressure markings and prefixes. Where no H₂S limit is defined by NACE MR0175/ISO 15156 for the partial pressure, no partial pressure shall be marked. The maximum allowable partial pressure shall be in accordance with NACE MR0175/ISO 15156 at the designated temperature rating (see Table 2) for the limiting part(s) in the equipment assembly. When the rated working pressure is marked in pounds per square inch, the H₂S partial pressure limit shall be marked in pounds per square inch.

EXAMPLE 1 “FF-10” on equipment with the rated working pressure marked in megapascals indicates material class FF rated at 10 kPa H₂S maximum allowable partial pressure when used within the environmental limits specified in NACE MR0175/ISO 15156.

EXAMPLE 2 “FF” would be marked on a tee with a body constructed from a material that does not have an H₂S limit specified in NACE MR0175/ISO 15156 with a pH ≥ 3.5.

NOTE 2 API 6A requires the manufacturer to mark only the H₂S partial pressure and not the other parameters specified in NACE MR0175/ISO 15156 to define the environmental limits for H₂S service. Resistance to cracking caused by H₂S is influenced by several other factors, some of the limits for which are given in NACE MR0175/ISO 15156. These include, but are not limited to, the following:

- pH;
- temperature;
- chloride concentration;
- elemental sulfur.

NOTE 3 In making the material selections, it is the responsibility of the purchaser to consider the various environmental factors and production variables listed in Annex B.

NOTE 4 Other forms of cracking may result from the presence of chlorides (such as seawater) and or hydrogen (such as cathodic protection).

4.3.3.3 Material Class ZZ

NOTE NACE MR0175/ISO 15156 includes provisions by means of testing or documented field history for the qualification of materials for a specific sour-service application that is outside the parameters defined in NACE MR0175/ISO 15156. This can include the use of materials in fluid conditions exceeding the limits defined in NACE MR0175/ISO 15156, or the use of materials not addressed in NACE MR0175/ISO 15156. For such sour-service applications, equipment may be described and marked as material class ZZ.

It shall be the responsibility of the purchaser to evaluate and determine the applicability of the documented data for the intended application. For material class ZZ, the manufacturer shall meet material specifications supplied or approved by the purchaser and shall maintain traceable records to document the materials of construction, regardless of PSL.

4.3.4 Product Specification Level

4.3.4.1 Application

PSL designations shall define different levels of technical quality requirements as identified in this specification. Products manufactured to the requirements of this specification shall satisfy the material, welding, quality, and testing requirements for a PSL (PSL 1, PSL 2, PSL 3, and PSL 4), when applicable. PSLs shall be applied to products as designated in Table 4.

NOTE PSL does not apply to all products of this specification.

A supplemental designation of PSL 3G shall apply to PSL 3 products that have satisfied the PSL 3 requirements in addition to the requirements of gas testing.

4.3.4.2 PSL Application

The PSL applied to equipment shall be limited to those listed in Table 5 for the combination of material class and rated working pressure of the equipment.

NOTE Annex B provides guidelines (not requirements) for selecting a PSL.

For crossover connectors, the PSL shall be based on the higher-pressure rating and material class. For mandrel hangers, the PSL should be based on the pressure rating and material class of the spool or tubing-head adapter placed over the suspended hanger.

Table 4—Applicability of Product Specification Levels

Equipment Category and Type (Reference Section)	Applicable PSLs	Equipment Category and Type (Reference Section)	Applicable PSLs
Plugs, Connectors, Gaskets		Valves and Chokes	
Flanges (blind, test) ^a (see 14.1)	1, 2, 3, 4	Valves (gate, plug, ball) (see 14.11)	1, 2, 3 ^e , 4
Ring gaskets ^b (see 10.4.5 and 14.2)	NA	Valves (prepared for/and actuated) (see 14.11)	1, 2, 3 ^e , 4
Threaded connectors ^a (see 14.3)	1, 2, 3, 4	Check valves (see 14.11)	1, 2, 3 ^e , 4
Tees and crosses (see 14.4)	1, 2, 3 ^e , 4	Back-pressure valves ^b (see 14.12)	NA
Bullplugs ^b (see 14.5)	NA	SSVs and USVs ^c (see 14.17)	2, 3 ^e , 4
Valve-removal plugs ^b (see 14.6)	NA	BSDVs ^d (see 14.17)	3 ^e , 4
Top connectors (see 14.7)	1, 2, 3 ^e , 4	Chokes (adjustable and positive) (see 14.15)	1, 2, 3 ^e , 4
Crossover connectors (see 14.8)	1, 2, 3 ^e , 4	Casing and Tubing Heads	
Other end connectors ^a (see 14.9)	1, 2, 3, 4	Housings (see 14.14)	1, 2, 3 ^e , 4
Spools (adapter, spacer) (see 14.10)	1, 2, 3 ^e , 4	Adapters (see 14.14)	1, 2, 3 ^e , 4
Weld-neck flanges ^a (see J.1)	1, 2, 3, 4	Other Equipment	
Segmented flanges ^a (see L.1)	1, 2, 3, 4	Actuators ^b (see 14.16)	NA
Nonintegral metal seals ^a (see 10.4.5)	NA	Tree assemblies ^b (see 14.18)	NA
Casing and Tubing Hangers		Packing mechanisms ^b (see 9.1)	NA
Slip-type ^a (see 14.13)	1, 2, 3, 4	Pressure boundary penetrations ^b (see 9.2)	NA
Mandrel-type ^a (see 14.13)	1, 2, 3, 4	Test and gauge ports ^b (see 9.3)	NA
FOOTNOTES ^a Gas testing is not required, so PSL 3G designation is not applicable. ^b There is only one level of requirements for these products, so PSLs are not applicable (NA). ^c PSL 1 is not applicable to SSVs and USVs. ^d PSL 1 and PSL 2 are not applicable to BSDVs. ^e For products eligible for gas testing, PSL 3G designation and marking may apply.			

Table 5—Minimum PSL

Material Class	Rated Working Pressure					
	13.8 MPa (2000 psi)	20.7 MPa (3000 psi)	34.5 MPa (5000 psi)	69.0 MPa (10,000 psi)	103.5 MPa (15,000 psi)	138.0 MPa (20,000 psi)
AA, BB, CC	PSL 1, PSL 2, PSL 3, PSL 4	PSL 1, PSL 2, PSL 3, PSL 4	PSL 1, PSL 2, PSL 3, PSL 4	PSL 2, PSL 3, PSL 4	PSL 2, PSL 3, PSL 4	PSL 3, PSL 4
DD, EE, FF	PSL 1, PSL 2, PSL 3, PSL 4	PSL 1, PSL 2, PSL 3, PSL 4	PSL 1, PSL 2, PSL 3, PSL 4	PSL 2, PSL 3, PSL 4	PSL 3, PSL 4	PSL 3, PSL 4
HH, ZZ	PSL 3, PSL 4	PSL 3, PSL 4	PSL 3, PSL 4	PSL 3, PSL 4	PSL 3, PSL 4	PSL 4
NOTE 1 For RWP/Material Class combinations that may have more than one applicable PSL, only one PSL is marked on products that satisfy the material, welding, quality, and testing requirements for that specific PSL (see 4.3.4.1) NOTE 2 For products eligible for gas testing, PSL 3G may be applied wherever PSL 3 is listed (see Table 35, Note “c”)						

5 Design

5.1 Design Methods

5.1.1 End and Outlet Connectors

End and outlet connectors shall be an integral part of the body or attached by welding that meets the requirements of Section 7.

NOTE 1 Information on design analysis and load capacities of flanges specified in this specification can be found in API 6AF, API 6AF1, and API 6AF2.

Design of 16B and 16BX end and outlet clamp hub connectors used on equipment specified in this specification shall conform to the material strength and dimensional requirements of API 16A.

NOTE 2 Clamps meeting the requirements of API 16A are acceptable for installation on equipment specified in this specification with clamp hub end connectors meeting the requirements of API 16A.

5.1.2 Hangers, Back-pressure Valves, Lock Screws, and Stems

Casing hangers, tubing hangers, back-pressure valves, lock screws, and stems shall be designed to satisfy the manufacturer's documented performance characteristics and service conditions in accordance with 4.3. The manufacturer shall document engineering practices and acceptance criteria on which the design is based.

5.1.3 Bodies, Bonnets, and Other End Connectors

5.1.3.1 General

OECs, bodies, and bonnets (in designs other than those specified in this specification) shall be designed in accordance with one or more of the methods given in 5.1.3.2, 5.1.3.3, and 5.1.3.4.

If stress levels calculated by the methods in 5.1.3.2, 5.1.3.3, and 5.1.3.4 exceed the allowable stresses, other methods identified by the manufacturer shall be used to justify these stresses.

NOTE Fatigue analysis and localized bearing stress values are outside the scope of this specification.

5.1.3.2 API Standard 6X

If used, design calculations for pressure-containing equipment shall conform to the design methodology of API 6X. The use of von Mises equivalent stress shall be permitted.

5.1.3.3 Distortion Energy Theory

If used, design calculations for pressure-containing equipment shall conform to the von Mises yield criterion (also known as the maximum distortion energy theory of failure). Rules for the use and impact of discontinuities and stress concentrations are outside the scope of this method. However, the basic pressure-vessel wall thickness may be sized by combining triaxial stresses based on hydrostatic shell test pressure and limited by the criterion in 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-specified minimum yield strength.

5.1.3.4 Experimental Stress Analysis

If experimental stress analysis is used as an alternative to 5.1.3.2 or 5.1.3.3, it shall conform to ASME BPVC:2004 with 2005 and 2006 addenda, Section VIII, Division 2, Appendix 6.

5.1.3.5 Tapped Holes for Studded Connections Other Than Flanges

The stud thread-anchoring configuration shall be designed to sustain a tensile load equivalent to the load that can be transferred to the stud through a fully engaged nut.

5.1.4 Other Parts

All other pressure-containing parts and all pressure-controlling parts shall be designed to satisfy the manufacturer's documented performance characteristics and the service conditions in 4.3. The manufacturer shall document engineering practices and acceptance criteria on which the design is based.

5.1.5 Equipment-specific Requirements

NOTE Equipment-specific requirements are specified in Section 14.

5.2 Design Tolerances

Unless otherwise specified in the appropriate table or figure, the tolerances in Table 6 shall apply to dimensions included in this specification.

Table 6—Tolerances, Unless Otherwise Stated

SI		USC	
Dimension	Tolerance mm	Dimension	Tolerance in.
x.x	± 0.5	x.xx	± 0.02
x.xx	± 0.13	x.xxx	± 0.005

5.3 Design Documentation

Documentation of designs shall include methods, assumptions, calculations, and design requirements. Design requirements shall include, but not be limited to, those criteria for size, test and operating pressures, material, environmental, and other pertinent requirements on which the design is based. Design documentation media shall be clear, legible, reproducible, and retrievable. Design documentation shall be retained for 5 years after the last unit of that model, size, and rated working pressure is manufactured.

5.4 Design Review and Verification

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

5.5 Design Validation

Manufacturers shall document their design validation procedures and the results of design validation.

Design validation shall be performed in accordance with Annex F when specified by the manufacturer or purchaser.

6 Materials

6.1 General

6.1.1 Applicability and Alloys

Bodies, bonnets, end and outlet connectors, clamp hub end connectors, hangers, and pressure boundary penetrations shall meet the requirements of Section 6. Other Pressure-containing and pressure-controlling parts shall be made of materials that satisfy 6.2.1 and the requirements of Section 4 and Section 5.

Material requirements in Section 6 shall apply to carbon steels, low-alloy steels, and martensitic stainless steels (other than precipitation-hardening types). Other alloy systems (including precipitation-hardening stainless steels) shall satisfy the applicable requirements of Section 4, Section 5, and Section 6.

Age-hardened nickel-based alloys for pressure-containing and pressure-controlling parts that are addressed in API 6ACRA shall conform to API 6ACRA.

NOTE Section 14.13.3 provides material requirements for hangers.

Materials for actuators shall be as specified in 14.16.3.

6.1.2 Material Forming Processes

PSL 1, PSL 2, and PSL 3 bodies, bonnets, end and outlet connectors (including clamp hub end connectors) shall be manufactured from either wrought or cast materials.

PSL 4 bodies, bonnets, end and outlet connectors (including clamp hub end connectors) shall be manufactured from wrought materials.

6.2 Written Specifications

6.2.1 Applicability

All metallic and nonmetallic pressure-containing or pressure-controlling parts shall require a written material specification.

6.2.2 Metallic Requirements

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

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

6.2.3 Nonmetallic Requirements

Nonmetallic pressure-containing or pressure-controlling seals in contact with retained fluids shall have written material specifications. The manufacturer's written specified requirement for nonmetallic materials shall define the following:

- generic base polymer(s) (see ASTM D1418), if applicable;

NOTE Reference to generic base polymer does not apply to graphite material.

- physical property requirements;
- material qualification that shall meet the equipment class requirement;
- storage and age-control requirements.

6.3 Bodies, Bonnets, and End and Outlet Connectors

6.3.1 Materials

6.3.1.1 Application

All bodies, bonnets, and end and outlet connectors shall be fabricated from standard or nonstandard (see 6.3.1.2) materials. Standard material qualification testing shall satisfy the requirements of 6.3.2.

6.3.1.2 Nonstandard Materials

Nonstandard materials for parts shown in Table 7 shall have a specified minimum yield strength at least equal to that of the lowest-strength standard material permitted for that application.

Nonstandard materials shall be materials with properties that do not meet all the requirements of Table 8 for a standard material. Nonstandard material shall conform to the manufacturer's written specification that shall include minimum requirements for:

- tensile strength (see 6.3.2.2);
- yield strength;
- hardness;
- impact strength, as applicable (see 6.3.2.3);
- a minimum of 15 % elongation;
- a minimum of 20 % reduction of area.

Table 7—Standard and Nonstandard Material Applications for Bodies, Bonnets, and End and Outlet Connectors

Part	Material Designations for Pressure Ratings ^a					
	13.8 MPa (2000 psi)	20.7 MPa (3000 psi)	34.5 MPa (5000 psi)	69.0 MPa (10,000 psi)	103.5 MPa (15,000 psi)	138.0 MPa (20,000 psi)
	Body ^b , Bonnet					
	36K, 45K 60K, 75K, NS	36K, 45K 60K, 75K, NS	36K, 45K 60K, 75K, NS	36K, 45K 60K, 75K, NS	45K, 60K 75K, NS	60K, 75K NS
	Integral End Connector					
Flanged Threaded Other ^c	60K, 75K, NS 60K, 75K, NS PMR	60K, 75K, NS 60K, 75K, NS PMR	60K, 75K, NS 60K, 75K, NS PMR	60K, 75K, NS NA PMR	75K, NS NA PMR	75K, NS NA PMR
Weld-neck Blind Threaded Other ^c	Loose Connector					
	45K	45K	45K	60K, 75K, NS	75K, NS	75K, NS
	60K, 75K, NS	60K, 75K, NS	60K, 75K, NS	60K, 75K, NS	75K, NS	75K, NS
	60K, 75K, NS	60K, 75K, NS	60K, 75K, NS	NA	NA	NA
	PMR	PMR	PMR	PMR	PMR	PMR
FOOTNOTES ^a “NS” indicates nonstandard materials as specified in 6.3.1.2. ^b If end connectors are of the material designation indicated, design is in accordance with Section 5 and welding is in accordance with Section 7. ^c As specified by the manufacturer.						

Table 8—Standard Material Property Requirements for Bodies, Bonnets, and End and Outlet Connectors

Material Designation	0.2 % Offset Yield Strength min. MPa (psi)	Tensile Strength min. MPa (psi)	Elongation in 50 mm (2 in.) min. %	Reduction in Area min. %
36K	248 (36,000)	483 (70,000)	21	No requirement
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)	17	35

6.3.2 Material Qualification Testing**6.3.2.1 General**

If minimum tensile and/or impact properties are required for material to be qualified for service, the required tests shall be performed on specimens from a qualification test coupon (QTC) as described in 6.4.

6.3.2.2 Tensile Testing**6.3.2.2.1 Test Method**

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

A minimum of one tensile test shall be performed. The results of the tensile test(s) shall satisfy the applicable requirements of Table 8.

6.3.2.2.2 Retesting

If the results of the tensile test(s) do not satisfy the applicable requirements, two additional tests on tensile specimens removed from the required location within the same QTC with no additional heat-treatment may be performed to qualify the material, and the results of each of these tests shall satisfy the applicable requirements.

6.3.2.3 Impact Testing

6.3.2.3.1 Test Specimens

Impact test of a QTC shall be used to qualify a heat and the bodies, bonnets, and end and outlet connectors produced from that heat and shall conform to the requirements of Table 9.

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

For PSL 4, subsize specimens shall not be used.

Table 9—Charpy V-notch Impact Requirements—10 mm x 10 mm

Temperature		Minimum Average Impact Value, J (ft-lb)			
		Transverse Direction		Longitudinal Direction	
		Wrought or Cast Material, Weld Qualification		Alternate Method for Wrought Materials Only	
Class	Test °C (°F)	PSL 1 and PSL 2	PSL 3 and PSL 4	PSL 1 and PSL 2	PSL 3 and PSL 4
K	−60 (−75)	20 (15)	20 (15)	27 (20)	27 (20)
L	−46 (−50)	20 (15)	20 (15)	27 (20)	27 (20)
N	−46 (−50)	20 (15)	20 (15)	27 (20)	27 (20)
P	−29 (−20)	20 (15)	20 (15)	27 (20)	27 (20)
S	−18 (0)	—	20 (15)	—	27 (20)
T	−18 (0)	—	20 (15)	—	27 (20)
U	−18 (0)	—	20 (15)	—	27 (20)
V	−18 (0)	—	20 (15)	—	27 (20)

Table 10—Adjustment Factors for Subsize Impact Specimens (PSL 1 to PSL 3)

Specimen Dimension	Adjustment Factor	Minimum Average Impact Value	
		Transverse Direction Wrought and Castings J (ft-lb)	Longitudinal Direction Wrought ^a J (ft-lb)
10 mm x 10 mm (full size)	1 (none)	20 (15)	27 (20)
10 mm x 7.5 mm	0.833	17 (13)	23 (17)
10 mm x 6.7 mm	0.780	16 (12)	21 (16)
10 mm x 5.0 mm	0.667	13 (10)	18 (13)
10 mm x 3.3 mm	0.440	9 (7)	12 (9)
10 mm x 2.5 mm	0.333	7 (5)	9 (7)
FOOTNOTE			
^a Castings have no directionality.			

6.3.2.3.2 Test Method

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

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

To qualify material for a temperature rating, impact tests shall be performed at or below the lowest temperature shown in Table 9 for that temperature range.

Three impact specimens shall be tested to qualify a heat of material. Impact properties as determined from these tests shall satisfy the applicable requirements of Table 9 or Table 10. In no case shall an individual impact value fall below two-thirds of that required as a minimum average. No more than one of the three test results shall be below the required minimum average.

NOTE 2 Where no acceptance criteria are shown in Table 9, impact testing is not required.

6.3.2.3.3 Retesting

If a test fails, then a retest of three additional specimens removed from the required location within the same QTC, with no additional heat-treatment, may be made, each of which shall exhibit an impact value equal to or exceeding the required minimum average value of Table 9 or Table 10.

6.3.2.3.4 Specimen Orientation

The values listed in Table 9 and Table 10 shall be the minimum acceptable values for wrought materials tested in the transverse direction, and for castings and weld qualifications.

Wrought materials may be tested in the longitudinal direction instead of the transverse direction and shall meet the requirements of Table 9 and Table 10.

Castings have no directionality; the values of the transverse direction of Table 9 and Table 10 shall apply.

6.3.3 Processing

6.3.3.1 Casting Practices

For PSL 1, all castings used for bodies, bonnets, and end and outlet connectors shall meet the applicable requirements of Section 6 and Section 10. The casting practices shall be qualified to casting specification level (CSL) 2 foundry qualification requirements in API 20A, as a minimum.

For PSL 2 and PSL 3, all castings used for bodies, bonnets, and end and outlet connectors shall meet the applicable requirements of Section 6 and Section 10. The casting practices shall be qualified to CSL 3 foundry qualification requirements in API 20A.

NOTE 1 For PSL 4, this section does not apply as only wrought material is permitted.

NOTE 2 The production sampling in Section 10 for PSL 1 and PSL 2 bodies, bonnets, and end and outlet connectors is intended to monitor control of casting practices.

6.3.3.2 Hot Working Practices

For PSL 1, PSL 2, PSL 3, and PSL 4, all wrought materials shall be formed using hot working practices that produce a wrought structure throughout (see 6.4.3.1.3).

6.3.3.3 Melting Practices

For PSL 1, PSL 2, and PSL 3, the manufacturer shall specify melting practices.

For PSL 4, the melting practice requirements shall be identical to those for PSL 1, PSL 2, and PSL 3 with the addition that the manufacturer shall document the melting practice used for PSL 4 material.

6.3.4 Heat-treating

6.3.4.1 Equipment

All heat-treatment operations shall be performed using equipment qualified in accordance with the requirements specified by the manufacturer. The requirements for the heat-treating furnace survey shall conform to Annex M.

6.3.4.2 Temperature

For PSL 1, PSL 2, and PSL 3, time at temperature and thermal cycles shall conform to the manufacturer's heat-treatment specifications.

For PSL 4, the following shall apply.

- The temperature requirements of PSL 1, PSL 2, and PSL 3 shall apply with the addition that the temperature levels for PSL 4 parts shall be determined by using a heat sink.

NOTE 1 For alloy materials that are processed in accordance with API 6ACRA, temperature levels may be monitored using a contact thermocouple.

- The heat sink shall be made of the same class of material if the parts are made of an alloy of the following classes: carbon steel, alloy steel, stainless steel, titanium-based alloy, nickel-copper alloys, and nickel-based alloys.
- For parts that do not meet one of the preceding classes, the heat sink shall be made from the same alloy as the part. The equivalent round (ER) section of all heat sinks shall be determined in accordance with the methods of 6.4.2. The ER of the heat sink shall be greater than or equal to the largest ER of any single part in a heat-treatment load.

NOTE 2 As an alternative, a production part may serve as the heat sink, provided all the requirements of 6.3.4.2 are satisfied.

The temperature-sensing tip of the thermocouple shall be within the part or heat sink and be no closer than 25 mm (1 in.) to any external or internal surface.

6.3.4.3 Quenching (for Quenched and Tempered Materials)

6.3.4.3.1 Water Quenching

The temperature of the water shall not exceed 38 °C (100 °F) at the start of the quench. For bath-type quenching, the temperature of the water shall not exceed 49 °C (120 °F) at any time during the quench cycle.

6.3.4.3.2 Other Quenching Media

The temperature range of other quenching media, such as oil or polymer, shall meet the manufacturer's written specification.

6.3.5 Chemical Composition

6.3.5.1 General

The manufacturer shall specify the nominal chemical composition, including composition tolerances, of the material. Material composition shall be determined on a heat basis (or a remelt-ingot basis for remelt-grade materials) in accordance with a nationally or internationally recognized standard.

6.3.5.2 Composition Limits—Requirements

Bodies, bonnets, and end and outlet connectors manufactured from carbon, low-alloy, and martensitic stainless steels (other than precipitation-hardening types) shall conform to the compositional limits given in Table 11 and Table 12.