Ballot #5858

Proposed draft includes Addendum 2 highlighted in yellow.

Specification for Marine Drilling Riser Equipment

1 Scope

This specification establishes standards of performance and quality for the design, manufacture, and fabrication of marine drilling riser equipment used in conjunction with a subsea blowout preventer (BOP) stack.

This specification provides the requirements for the following major subsystems in the marine drilling riser system:

— riser tensioner equipment;

— flex/ball joints;

— choke, kill, and auxiliary lines;

— drape hoses and jumper lines for flex/ball joints;

— telescopic joint (slip joint) and tensioner ring;

— riser joints;

— buoyancy equipment;

— riser running equipment;

— special riser system components;

— lower riser adapter;

— riser coupling.

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

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 applies (including any addenda/errata).

API Technical Report 5C3, *Technical Report on Equations and Calculations for Casing, Tubing, and Line Pipe Used As Casing or Tubing; and Performance Properties Tables for Casing and Tubing*

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

API Specification 7K, *Drilling and Well Servicing Equipment*

API Specification 8C, *Drilling and Production Hoisting Equipment (PSL 1 and PSL 2)*

API Specification 9A, *Specification for Wire Rope*

API Recommended Practice 9B, *Application, Care, and Use of Wire Rope for Oil Field Service*

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

API Specification 16C, *Choke and Kill Equipment*

API Specification 16D, *Specification for Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment*

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

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

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

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

AISC 360 [1], *Specification for Structural Steel Buildings—Allowable Stress Design and Plastic Design*, 1989 Edition

ASME B31.3 [2], *Process Piping*

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section V: Nondestructive Examination*, 2010

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section V, Subsection A, Article 6 and Subsection B*, 2010

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section V, Subsection A, Article 7 and Subsection B*, 2010

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section V, Subsection A, Article 9*, 2010

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section VIII: Rules for Construction of Pressure Vessels; Division 1*

ASME *Boiler and Pressure Vessel Code* (*BPVC*), *Section VIII: Rules for Construction of Pressure Vessels; Division 2: Alternative Rules*

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

[1] American Institute of Steel Construction, One East Wacker Drive, Suite 700, Chicago, Illinois 60601, www.aisc.org.
[2] ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASNT Recommended Practice No. SNT-TC-1A [3], *Personnel Qualification and Certification in Nondestructive Testing*

ASTM A370 [4], *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

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

ASTM A770/A770M, *Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications*

ASTM A923, *Standard Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels*

ASTM E562, *Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count*

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 Method for Rockwell Hardness of Metallic Materials*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E94, *Standard Guide for Radiographic Examination*

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 Examination for General Industry*

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

ASTM E388, *Standard Test Method for Wavelength Accuracy and Spectral Bandwidth of Fluorescence Spectrometers*

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

ASTM E562, *Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count*

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*

AWHEM Technical Report TR1201 [5], *Recommendation for Elimination of Lead Filling in Target Flanges*

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

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

[5] Association of Well Head Equipment Manufacturers, 1102 Glouchester Lane, Houston, Texas 77073, www.awhem.org.

AWS D1.1 [6], *Structural Welding Code, Steel*

IEC 61892 [7], *Mobile and fixed offshore units—Electrical installations*

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

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

ISO 6508-1, *Metallic materials – Rockwell hardness test – Part 1: Test method*

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

ISO 11120, *Gas cylinders – Refillable seamless steel tubes of water capacity between 150 l and 3000 l – Design, construction and testing*

NACE [8] MR0175/ISO 15156, *Petroleum, petrochemical, and natural gas industries—Materials for use in H_2S-containing environments in oil and gas production*

NFPA 70 [9], *National Electrical Code*

UL 94 [10], *Standard for Safety: Test for Flammability of Plastic Materials for Parts in Devices and Appliances*

SSPC CS 23.00 [11], *Specification of the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and their Alloys and Composites for the Corrosion Protection of Steel*

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

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

3.1.1
accumulator
Pressure vessel charged with gas over liquid and used to store hydraulic fluid under pressure.

3.1.2
actuator
Mechanism for the remote or automatic operation of a valve or choke.

3.1.3
air can buoyancy
Tension applied to the riser string by the net buoyancy of a chamber created by a closed-top, open-bottom cylinder forming an annulus around the outside of the riser pipe that is filled with air or other low-density fluid.

6 American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.
7 International Electrotechnical Commission, 3, rue de Varembé, 1st Floor, PO Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.
8 NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.
9 National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.
10 Underwriters Laboratories, 333 Pfingsten Road, North Brook, Illinois 60062, www.ul.com.
11 The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

3.1.4
annulus
Space between two pipes, when one pipe is positioned inside the other.

3.1.5
anti-recoil system
Means of limiting the upward acceleration of the riser when a disconnect is made at the riser connector.

3.1.6
auxiliary line
Conduit [excluding choke and kill (C&K) lines] attached to the outside of the riser main tube (e.g. hydraulic supply line, buoyancy control line, mud boost line).

3.1.7
back pressure
Pressure resulting from restriction of fluid flow downstream.

3.1.8
ball joint
Ball and socket assembly allowing rotation between the two halves that may be positioned in the riser string to reduce local bending stresses.

3.1.9
blowout
Uncontrolled flow of well fluids from the wellbore.

3.1.10
blowout preventer
BOP
Equipment installed at the wellhead or wellhead assemblies to contain wellbore fluids either in the annular space between the casing and the tubulars or in an open hole during drilling, completion, testing, or workover operations.

3.1.11
blowout preventer, annular type
Remotely controlled device that can form a seal in the annular space around any object in the wellbore or upon itself.

NOTE Compression of reinforced elastomer packing element by hydraulic pressure effects seal.

3.1.12
bolting
All threaded fasteners including studs, tap end studs, double ended studs, headed bolts, cap screws, screws, and nuts.

3.1.12.1
class 2 bolting
Bolting in the riser's primary load path not exposed to subsea environment or any pressure-containing bolting not intended for wellbore fluid containment.

NOTE See Table 2.

3.1.12.2
class 3 bolting
Subsea bolting in the riser's primary load path or whose failure could result in release of wellbore fluid to the environment.

NOTE Examples include riser coupling bolts, see Table 2.

3.1.12.3
utility bolting
Bolting required for mounting equipment and accessories to the riser equipment not identified as class 2 or class 3 bolting.

NOTE Examples include bolting on lifting eye, wear bushing, nameplate, clamps for tubing, guards, buoyancy supports.

3.1.13
BOP stack
Assembly of well control equipment including BOPs, spools, valves, hydraulic connectors, and nipples that connects to the subsea wellhead.

NOTE Common usage of this term sometimes includes the lower marine riser package (LMRP).

3.1.14
box
Female member of a riser coupling, C&K line stab assembly, or auxiliary line stab assembly.

3.1.15
buoyancy control line
Auxiliary line dedicated to controlling, charging, or discharging air can buoyancy chambers.

3.1.16
buoyancy equipment
Devices added to riser joints to reduce their submerged weight, thereby reducing riser top tension requirements.

NOTE The devices normally used for risers take the form of syntactic foam modules or open-bottom air chambers.

3.1.17
choke and kill line
C&K line
External conduits arranged around the riser pipe and used for circulation of fluids into and out of the wellbore to control well pressure.

3.1.18
collapse pressure
External pressure at which a structural member's original shape is permanently altered.

3.1.19
control pod
Assembly of subsea valves and regulators that operates BOP equipment when activated.

3.1.20
coupling
Mechanical means for joining two sections of riser pipe in end-to-end engagement.

3.1.21
dehydrogenation heat treatment
DHT
Activity carried out to diffuse hydrogen and minimize the risk of hydrogen cold cracking in completed or partially completed weld joints prior to the weld joint cooling to ambient temperature.

3.1.22
diverter
Device attached to the wellhead or marine riser to close the vertical flow path and direct well flow away from the drill floor and rig.

3.1.23
drape hose
Flexible line connecting a choke, kill, auxiliary, or other line on the riser to the appropriate piping on the rig structure.

NOTE 1 A U-shaped bend in this line allows for relative movement between the vessel and the outer barrel of the telescopic joint as the vessel moves.

NOTE 2 This is sometimes referred to as a “moonpool line.”

3.1.24
drilling fluid
Water- or oil-based fluid with suspension of clays or solids circulated down the drill pipe into the well and back up to the rig for purposes including containment of formation pressure, the removal of cuttings, bit lubrication and cooling, treating the wall of the well, and providing a source for well data.

NOTE This is also known as “mud.”

3.1.25
factory acceptance testing
Testing by a manufacturer of a particular product to validate its conformance to the specified performance requirements and ratings.

3.1.26
fleet angle
Angle between the vertical axis and a riser tensioner line (or hydraulic cylinder rod for direct-acting tensioners) at the point where the line (or rod) connects to the tension ring.

3.1.27
flex joint
Steel and elastomer assembly allowing rotation between the two halves that may be positioned in the riser string to reduce local bending stresses.

3.1.28
full-length riser joint
Joint of typical length for a particular drilling vessel’s riser storage racks and riser handling capabilities or for a particular riser purchase.

3.1.29

handling tool
running tool
Device that joins to the upper end of a riser joint to permit the lifting and lowering of the joint and the assembled riser string in the derrick by the elevators.

3.1.30
heat treatment (heat treating)
Specified, timed sequence of controlled heating and cooling of materials for the purpose of changing physical or mechanical properties.

3.1.31
hydraulic connector
Mechanical connector that is activated hydraulically and connects the BOP stack to the wellhead or the LMRP to the lower BOP stack.

3.1.32
hydraulic line
Auxiliary line from the vessel to the subsea BOP stack that supplies control system operating fluid to the LMRP and the BOP stack.

3.1.33
instrumented riser joint
Riser joint equipped with sensors for monitoring parameters such as tension in the riser pipe wall, riser angular offset, annulus fluid temperature and pressure, etc.

3.1.34
jumper line
Flexible section of choke, kill, or auxiliary line that provides a continuous flow around a flex/ball joint while accommodating the angular motion at the flex/ball joint.

3.1.35
keel joint
Riser joint designed to withstand contact between the riser and bottom of the moonpool.

3.1.36
landing joint
Riser joint temporarily attached above the telescopic joint used to land the BOP stack on the wellhead.

3.1.37
load sharing
Riser joint design where rated load is distributed between the main tube and one or more of the external lines.

3.1.38
local peak stress
Highest stress in the region or component under consideration

NOTE The basic characteristic of a peak stress is that it causes no significant distortion and is principally objectionable as a possible initiation site for a fatigue crack. These stresses are highly localized and occur at geometric discontinuities.

3.1.39

lower marine riser package
LMRP
Upper section of a two-section subsea BOP stack generally including a hydraulic connector; annular BOP; ball/flex joint; riser adapter; jumper lines for the choke, kill, and auxiliary lines; and subsea control pods.

NOTE This interfaces between the lower subsea BOP stack and the drilling riser.

3.1.40
non-load sharing
Riser joint design where the rated load is carried by the main tube only.

3.1.41
main tube
riser pipe
Pipe that forms the principal conduit of the riser joint.

NOTE The riser main tube is the conduit for guiding the drill string and containing the return fluid flow from the well.

3.1.42
major weld repair
Weld whose depth is greater than 25 % of the original wall thickness or 25.4 mm (1 in.), whichever is less.

3.1.43
makeup tool
Device used to engage and/or preload coupling members.

3.1.44
marine drilling riser
Tubular conduit serving as an extension of the wellbore from the equipment on the wellhead at the seafloor to a floating drilling rig.

3.1.45
maximum allowable working pressure
MAWP
Maximum internal pressure that the equipment is designed to contain or control.

3.1.46
maximum compression pressure
MCP
Maximum pressure that a tensioner achieves when fully retracted for wire line tensioners or when fully extended for direct-acting tensioners.

3.1.47
maximum supply pressure
MSP
Highest pressure that can be supplied to the tensioners.

3.1.48
module
Individual, serialized piece of buoyancy.

3.1.49

mud boost line
Auxiliary line that provides supplementary fluid supply from the surface and injects it into the riser near the LMRP to assist in the circulation of drill cuttings up the marine riser.

3.1.50
other end connection
OEC
Connection that is not specified in an API specification or standard.

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

3.1.51
pin
Male member of a riser coupling or a choke, kill, or auxiliary line stab assembly.

3.1.52
postweld heat treatment
PWHT
Any heat treatment subsequent to welding, including stress relief.

3.1.53
preload
Compressive bearing load developed between connections at their interface.

NOTE This is accomplished by elastic deformation during makeup.

3.1.54
pressure-containing component
Component whose failure to function as intended would cause a release of pressurized fluid to the environment.

3.1.55
primary-load-carrying component
Component whose failure would compromise the structural integrity of the marine drilling riser system.

NOTE Examples are components that carry all or a major part of the tension in the riser.

3.1.56
protector, box or pin
Cap or cover used to protect the box or pin from damage during storage and handling.

3.1.57
pup joint
Riser joint whose length is shorter than a standard-length riser joint.

3.1.58
rated load
Maximum applied loading condition used for design, analysis, and operation of the equipment.

3.1.59
rated working pressure
Maximum internal pressure equipment is designed to contain and/or control.

3.1.60

reference stress
Stress at the reference section used for determination of SAF.

3.1.61
relevant indication
Any surface indication (liquid penetration or magnetic particle examination) with a major dimension greater than 1.6 mm (0.062 in.).

NOTE Inherent indication not associated with surface rupture are considered nonrelevant indications.

3.1.62
riser adapter
Crossover between riser and flex joint, ball joint, or LMRP.

3.1.63
riser annulus
Space around the pipe (drill pipe, casing, or tubing) suspended in a riser; its outer boundary is the internal surface of the riser pipe.

3.1.64
riser connector
LMRP connector
Hydraulically operated connector that joins the LMRP to the top of the BOP stack.

3.1.65
riser disconnect
Operation of unlatching the riser connector to separate the riser and LMRP from the BOP stack.

3.1.66
riser fill-up valve joint
Special riser joint having a valve that allows the riser annulus to be opened to the sea.

3.1.67
riser joint
Section of riser main tube having ends fitted with a box and pin and including choke, kill, and (optional) auxiliary lines and their support brackets.

3.1.68
riser spider
Device that supports the riser string on the uppermost coupling support shoulder during deployment and retrieval.

3.1.69
riser string
Deployed assembly of riser joints.

3.1.70
riser tensioner
Means for providing and maintaining top tension on the deployed riser string to prevent buckling.

3.1.71

riser tensioner ring
Structural interface between the riser string and the riser tensioners.

3.1.72
stabilized (pressure testing)
State in which the initial pressure decline rate has decreased to within the manufacturer's specified rate.

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

3.1.73
stress amplification factor
SAF
Ratio of the incremental change of local peak stress (maximum cyclic principal stress) to the corresponding incremental change of the reference stress used for fatigue analysis.

3.1.74
stress load ratio
SLR
Ratio of the incremental change of local peak stress (maximum cyclic principal stress) to the corresponding incremental change in the global load (tension/compression or bending) used for fatigue analysis.

3.1.75
support brackets
Brackets positioned at intervals along the riser joint that provide intermediate radial and lateral support from the riser main tube to the choke, kill, and auxiliary lines.

3.1.76
syntactic foam
Typically a composite material of hollow spherical fillers in a matrix or binder used to build buoyancy modules.

3.1.77
telescopic joint
slip joint
Riser joint having an inner barrel and an outer barrel with sealing means between the two barrels.

NOTE The inner barrel moves within the outer barrel to compensate for the change in the length of the riser string as the vessel moves.

3.1.78
telescopic joint packer
Means of sealing the annular space between the inner and outer barrels of the telescopic joint.

3.1.79
terminal fitting
Connection between a rigid choke, kill, or auxiliary line on a riser string and its drape hose, affecting a nominal 180° turn in flow direction.

3.1.80
thrust collar
Device for transmitting the buoyancy force of a buoyancy module to the riser joint.

3.1.81

type certification testing
Testing by a manufacturer of a representative specimen (or prototype) of a product that qualifies the design and, therefore, validates the integrity of other products of the same design and similar size, dimensions, materials, and manufacture.

3.1.82
submerged weight
Weight minus the buoyancy effects of water.

3.2 Abbreviations and Symbols

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

APV	air pressure vessel
BOP	blowout preventer
C&K	choke and kill
CEM	contract equipment manufacturer
CRA	corrosion-resistant alloy
DAC	distance amplitude curve
DHT	dehydrogenation heat treatment
DSS/SDSS	duplex stainless steel/super duplex stainless steel
EA	tension stiffness
EI	bending stiffness
EOS	equation of state
ER	equivalent round
HRC	Rockwell hardness scale C
HVOF	high-velocity oxygenated fuel
ITP	inspection test plan
LMRP	lower marine riser package
LP	liquid penetrant
MAWP	maximum allowable working pressure
MCP	maximum compression pressure
MP	magnetic particle
MPD	managed pressure drilling

MPS	manufacturing procedure specification
MSP	maximum supply pressure
MTL	maximum tension limit
MTO	metal turnover
NDE	nondestructive examination
OEC	other end connection
PQR	procedure qualification record
PQT	procedure qualification trial
PWHT	postweld heat treatment
QTC	qualification test coupon
RH	relative humidity
SAF	stress amplification factor
SLR	stress load ratio
TSA	thermal sprayed aluminum
TSC	thermal sprayed coating
t	weld thickness
WPS	welding procedure specification

4 Design

4.1 General

These design standards shall apply to all riser system components that are in the primary load path during operation, running, and retrieval, including but not limited to riser couplings, riser main tube, riser adapters, riser external lines when used for load sharing, riser tensioner rings, telescopic joints, flex/ball joints, and special riser joints. See Annex B for a discussion of the components in a marine drilling riser system.

NOTE Additional component-specific requirements are found in Sections 7 through 18.

4.2 Service Classifications

The riser manufacturer shall provide the following design information for each riser model.

— Main tube description (outside diameter, wall thickness, corrosion allowance, and material).

— C&K and auxiliary line description (outside diameters, wall thickness, corrosion allowance, and material).

— Rated load of riser components, with non-load-sharing or load-sharing designation.

— When applicable, buoyancy depth rating and thrust loads.

— Coupling description (manufacturer, model, coupling rated load).

— Rated working pressures of main tube, C&K, and auxiliary lines (under zero tension).

— Minimum and maximum temperatures for various riser lines/components.

NOTE Procedures for determining design loads are detailed in API 16Q. Guidelines for care and operation are also given in API 16Q.

4.3 Size and Coupling Model

Riser systems shall be described by the size of the main tube and the manufacturer's coupling model designation. Riser pipe outer diameter, wall thickness, corrosion allowance, and material designations for which the riser system is designed shall be documented. The description shall also include the characteristics of C&K and auxiliary lines (diameters, wall thicknesses, corrosion allowances, and material designations for each).

4.4 Rated Load

The purchaser shall specify the minimum rated load or the minimum performance requirements of the riser system components.

The manufacturer shall establish and document the rated load for each riser component based on the minimum rated load or minimum performance requirements specified by the purchaser.

The rated load shall correspond to the total combined load that may be applied to the component. The total combined load includes the axial tension, bending loads, pressure separation loads, and any applicable preloads applied to the component.

NOTE 1 The rated load for non-load-sharing risers can be specified either as an axisymmetric tension of magnitude or it may be considered to be any combination of tension and bending moment as per Equation (1). For load-sharing riser designs, the bending moment relation deviates from Equation (1).

$$T+\frac{McA}{I}=T+\frac{M\,32t\left(D-t\right)^{2}}{D^{4}-\left(D-2t\right)^{4}}=T+T_{\mathrm{EQ}}=T_{\mathrm{DES}} \tag{1}$$

where

T is the tension;

M is the bending moment;

A is the main tube cross-sectional area;

c is the mean radius of main tube;

I is the moment of inertia of main tube;

D is the outside diameter of main tube;

t is the wall thickness of main tube.

T_{DES} is the axisymmetric tensile load;

T_{EQ} is the equivalent tension.

Internal pressure, external pressure, and temperature shall be included in the component's rated load.

Additional sources of applied load as described below may significantly affect the riser equipment design and shall be included in the design calculations.

— The manufacturer shall document the loads induced by choke, kill, and auxiliary lines for which the riser has been designed.

NOTE 2 Loads can be induced on the joint from pressure in the lines, from deflections imposed on the lines, and also from differential temperatures in the lines.

— If the riser joints provide support for buoyancy, then the manufacturer shall document the buoyancy thrust loads for which the riser has been designed.

— The manufacturer shall document the riser handling loads for which the riser is designed and how these loads are applied.

The riser system shall be designed to support the rated load and any applicable preloads, while keeping the maximum cross-sectional stresses within specified allowable limits. All components shall meet the stress requirements of Annex C unless otherwise specified in Sections 7 through 18. The manufacturer shall document the procedures used and the results.

NOTE 3 If finite element stress analysis is used, see Annex D.

NOTE 4 The load rating of a riser joint may be less than the coupling rating.

Choke, kill, and riser auxiliary lines shall meet the requirements of this specification, Section 9.

NOTE 5 The moment capacity of the assembled component may have limiting factors other than the main tube stresses; for example, a riser joint may be limited by the tensile stress in choke, kill, or auxiliary lines produced by moment in the joint. As a result, the moment/tension relationship above may not accurately apply beyond a specific maximum combination of loads, as moment may have a disproportionate effect on the riser external lines.

4.5 Pressure Ratings

The manufacturer shall document the rated differential pressure for the riser system component and the tension conditions for which they apply.

4.6 Temperature Criteria

The minimum design temperature for the choke, kill, auxiliary lines, and main tube shall be 0 °C (32 °F) unless the purchaser specifies a lower temperature.

The maximum temperature for design varies for the different lines. The maximum design temperature for the main tube and the C&K lines shall be 82 °C (180 °F) unless the purchaser specifies a higher temperature. The maximum design temperature for all auxiliary lines shall be 57 °C (135 °F) unless the purchaser specifies a higher temperature (see Table 1).

Table 1—Design Temperatures for Various Line Types

Type of Line	Minimum Fluid Temperature	Maximum Fluid Temperature
Main tube	0 °C (32 °F)	82 °C (180 °F)
Choke and kill line	0 °C (32 °F)	82 °C (180 °F)
All auxiliary lines	0 °C (32 °F)	57 °C (135 °F)

4.7 Design of Structures and Lifting Attachments

Lifting attachments and structures (e.g. padeyes, lift points, baskets, etc.) shall be designed to meet the requirements of AISC 360 or other nationally or internationally recognized standard. The AISC 360 increase in allowable stresses for short-term loads shall not be used.

Drilling riser equipment that requires lifting with the rig cranes during the normal course of operations shall be fitted with suitable lifting attachments. The design load for the lifting attachments shall be 2.0 times the static sling load in the direction of the sling plus 10 % of the static sling load applied perpendicular to the face of the attachment at the center of the hole for the shackle pin (parallel to the shackle pin).

4.8 Design Documentation

For each riser system size, design, and service classification, the manufacturer shall retain the following documentation for a minimum of 10 years after the manufacture of the last unit of that size, design, and service classification:

a) service classification, design bases, and stress amplification factors (SAFs) or stress load ratios (SLRs) used;

b) design loads (tensile, bending, and others);

c) finite element analysis performed; and

d) results of tests performed.

5 Materials and Welding Requirements

5.1 General

The material requirements in this specification are not intended to overrule material requirements for equipment covered and manufactured in accordance with other API specifications.

Primary-load-carrying components and/or pressure-containing components shall conform to the material and welding requirements specified by this section. In the case of a conflict between this section and specific equipment requirements elsewhere in this specification, the specific equipment requirements shall apply.

Parts other than primary-load-carrying or pressure-containing components shall be made of materials that satisfy the design requirements of the equipment manufacturer.

Material and welding designed for sour conditions shall meet the applicable requirements of NACE MR0175/ISO 15156.

Material and welding of components designed for use in sour service conditions shall meet the requirements of NACE MR0175/ISO 15156 without the use of the permitted exclusion written for drilling riser systems.

NOTE 1 Typically drilling riser main tube, riser coupling, auxiliary lines, ball or flex joints, and telescopic joints (materials and welding) need not conform to NACE MR0175/ISO 15156, because wellbore fluids are diverted through the C&K lines at the seafloor BOP stack.

NOTE 2 Composite materials are outside the scope of this document.

5.2 Materials Selection

Material selection for primary-load-carrying components and pressure-containing components should include consideration for the type of loading, fatigue and fracture mechanics considerations, temperature range, corrosive conditions, strength requirements, and consequences of failure. These considerations shall be included as part of the design review documentation.

The metallic materials that can be exposed to wellbore fluids in the C&K lines shall meet the requirements for sour service defined in NACE MR0175/ISO 15156.

NOTE 1 Care should be exercised in the selection of materials for applications requiring high strength, corrosion resistance, and resistance to hydrogen embrittlement.

NOTE 2 Some materials have demonstrated a susceptibility to hydrogen embrittlement when exposed to cathodic protection in seawater. Materials that have shown this susceptibility include low-alloy steels, martensitic stainless steels, and more highly alloyed steels having actual yield strengths over 135,000 psi (930.8 MPa) or hardness levels above 34 Rockwell C.

Material selection for nonmetallic (e.g. elastomers and thermoplastics) materials shall include consideration for the type of loading, temperature range, explosive decompression resistance (if appropriate), environmental resistance, strength and ductility requirements, and consequences of failure. These considerations shall be included as part of the design review documentation.

5.3 Written Specifications

All materials (including nonmetallic) shall conform to a written specification. The written specification shall be a nationally or internationally recognized standard, or the manufacturer's document.

Specifications for metallic components used for primary-load-carrying components or pressure-containing components shall, at the minimum contain requirements for the following:

— material chemical composition limits and tolerances;

— forming practices—forging, etc.;

— heat treatment procedures including cycle time and temperature with tolerances, heat-treating equipment, and cooling media;

— nondestructive examination (NDE) requirements;

— mechanical property requirements including yield strength, tensile strength, elongation, reduction of area, hardness range, and impact toughness properties.

Specifications for nonmetallic components used for primary-load-carrying components or pressure-containing components shall define the following:

— material type—base material/polymer;

— service temperature range;

— tensile strength, elongation, and elastic modulus;

— acceptable hardness range—shore, in accordance with ASTM D2240;

— density, compression set, and fluid compatibility;

— fiber reinforcement—type, composition, and properties.

5.4 Metallic Materials

5.4.1 Steels

5.4.1.1 General

Non-primary-load-carrying and non-pressure-containing component materials shall be addressed by the manufacturer written specifications.

All primary-load-carrying and pressure-containing materials shall meet the requirements of 5.4, 5.5, and 5.6. Castings shall not be used for primary-load-carrying components unless otherwise allowed by equipment-specific sections.

Primary-load-carrying and pressure-containing materials shall be tested for chemical composition, tensile properties, impact properties, and hardness, unless explicitly excluded in this section or by the equipment-specific sections. The mechanical properties for these components shall be established by testing from a qualification test coupon (QTC) in accordance with 5.6 of this specification, in its final heat treatment condition.

5.4.1.2 Carbon and Low-alloy Steels

5.4.1.2.1 Chemical Composition

Materials shall conform to the chemical composition specified in the written specification. This specification shall include limits and tolerances on the elements carbon, manganese, phosphorous, sulfur, silicon, and any other elements added intentionally. Residual elements shall meet the requirements of the written specification. Chemical composition shall be determined on a heat basis in accordance with the written specification.

5.4.1.2.2 Mechanical Properties

Materials shall meet the mechanical properties specified in the manufacturer's written specification.

— *Impact Testing*.

Charpy V-notch impact tests shall be conducted in accordance with ASTM A370, ASTM E23, or equivalent industry standard, using one set of three specimens removed from the QTC in a location as specified by API 16A or equivalent industry recognized specification. Standard size (10 mm × 10 mm) Charpy V-notch specimens shall be used whenever practical. Impact energy requirements may be reduced by a factor of 0.883 and 0.667 for $^{3}/_{4}$ size and $^{1}/_{2}$ size specimens, respectively.

When full-size impact specimens are not practical due to size constraints, the subsize specimen shall be tested and meet the criteria per methods defined by ASTM A370.

Impact testing shall be conducted at temperature of −20 °C (−4 °F) or lower, and no higher than minimum design temperature.

Specimens shall be tested in parallel or transverse to the grain orientation. Specimens tested with orientation transverse to the major grain flow shall exhibit 20 J (15 ft-lb) minimum average value and 14 J (10 ft-lb) for single minimum of a set of three specimens (e.g. transverse on a hollow core or solid forging and radial on a rolled ring). Specimens tested with orientation parallel to major grain flow shall exhibit 27 J (20 ft-lb) minimum average value and 20 J (15 ft-lb) for single minimum of a set of three specimens. The location of the specimen in the QTC shall be in accordance with API 16A, with exception of main tube, which shall conform to API 5L.

— *Hardness*.

Materials shall meet the hardness requirements specified in the manufacturer's written specification

The hardness of components and the QTC shall be determined in accordance with ASTM E10 or ASTM E18 or equivalent recognized standard. A minimum of one hardness test shall be performed on the QTC after the heat treatment cycle [exclusive of postweld heat treatments (PWHTs)]. Conversion of hardness values between test methods shall be in accordance with ASTM E140. The hardness of the QTC and the parts shall conform with the range given by the written specification.

— *Tensile Properties*.

The tensile properties of the materials for all primary-load-carrying and pressure-containing equipment shall be in conformance with the requirements of the written specification chosen for the parts by the manufacturer/purchaser as provided for by 5.3. The material shall meet the requirements for yield strength, ultimate strength, elongation, and when appropriate the reduction of area as required by the design.

Wrought carbon and low-alloy steel such as forgings and bar used for pressure-containing applications shall exhibit a minimum of 35 % reduction of area (excluding plate) and a minimum of 18 % elongation.

The main tube shall meet the requirements of API 5L for PSL 2. Test specimens and test methods shall be in accordance with ASTM A370 or equivalent. Specimen orientation and location shall be in accordance with API 16A or equivalent industry standard. As-heat-treated dimensions shall be used for determining the component thickness.

5.4.1.3 Stainless Steels

5.4.1.3.1 Chemical Composition

All stainless steel materials shall conform to the chemical composition specified in the written specification. This specification shall include limits and tolerances on the elements relevant to the particular grade of stainless steel, and any other elements added intentionally. Residual elements shall meet the requirements of the written specification. Chemical composition shall be determined on a heat basis in accordance with the written specification.

Ferritic-austenitic stainless steel grades shall meet the minimum requirements for pitting-resistance equivalent number (PREN) as specified by NACE MR0175.

5.4.1.3.2 Mechanical Properties

All materials shall meet the minimum mechanical properties specified in the manufacturer's written specification.

The manufacturer shall ensure stainless steels are not adversely affected by deleterious phases that may hinder toughness and corrosion resistance.

— *Impact Testing*.

When required, Charpy V-notch impact tests shall be conducted in accordance with ASTM A370, ASTM E23, or equivalent using specimens removed from the QTC. Standard size (10 mm × 10 mm) Charpy V-notch specimens shall be used whenever practical. Impact energy requirements may be reduced by a factor of 0.883 and 0.667 for $^{3}/_{4}$ size and $^{1}/_{2}$ size specimens, respectively. One set of three test specimens shall be removed from the QTC at an orientation and location as specified in 5.4.1.2.2.

Ferritic-austenitic grades shall be impact tested and meet the requirements specified by ASTM A923 Method B for deleterious phases.

Impact testing of austenitic stainless steels is not required.

— *Hardness*.

The hardness of components and the QTC shall be determined in accordance with ASTM E10 or ASTM E18 or equivalent recognized standard. A minimum of one hardness test shall be performed on the QTC after the final heat treatment cycle.

All precipitation hardening and martensitic materials shall meet the hardness requirements specified in the manufacturer's written specification. Hardness testing is not required for ferritic-austenitic or austenitic materials.

Materials intended for sour service environment shall follow applicable limits specified by NACE MR0175.

5.4.1.3.3 Tensile Properties

The tensile properties of the materials for all primary-load-carrying and pressure-containing equipment shall be in conformance with the requirements of the written specification chosen for the parts by the manufacturer/purchaser as provided for by 5.3. The material shall meet the requirements for yield strength, ultimate strength, elongation, and when appropriate the reduction of area as required by the design.

5.4.1.3.4 Microstructural Requirements for Ferritic-austenitic Stainless Steel

Ferritic-austenitic stainless steels shall be inspected for ferrite content by ASTM E562 point count method. The microstructure of the material shall exhibit a ferrite content of 35 % to 65 %, inclusive, after heat treatment.

The microstructure of weld heat-affected zones and ferritic-austenitic weld metal (when ferritic-austenitic weld metal is used) shall have between 30 % and 70 % ferrite.

5.4.2 Nickel-based Alloys

Nickel-based alloys in raw material form (excluding welding consumables) shall conform to API 6ACRA and the equipment manufacturer's written specifications.

Nickel-based alloys not covered in API 6ACRA shall conform to manufacturer's written specifications and NACE MR0175.

Any nickel-based alloy intended for use in sour service shall conform to the requirements of NACE MR0175.

5.5 Material Applications

5.5.1 Main Tube

Riser main tube shall be manufactured per API 5L (PSL 2) requirements and may be longitudinally seam welded or seamless. Spiral-welded pipe and electric-welded pipe shall not be used.

5.5.2 Auxiliary Piping

Only seamless pipe shall be used for hydraulic applications.

5.5.3 Bolting for Marine Drilling Riser Equipment

For class 3 and class 2 bolting, the following requirements shall apply.

— Manufacturers shall have a documented procedure for the qualification of bolting manufacturers, which follows the requirements of API 20E and API 20F.

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

— Bolting exposed to wellbore fluids shall meet the requirements of NACE MR0175/ISO 15156.

— Manufacturers shall have documented specifications that include the thread form and dimensions of studs, nuts, and bolts.

— When headed, bolting shall be created through the hot upset, closed die forging process.

— Bolting manufactured from proprietary materials shall conform to the manufacturer's written specification and the requirements of API 20E or API 20F with the exception that the material shall meet manufacturer's specified chemical composition and mechanical properties (per Table 2).

Riser coupling bolting shall be considered class 3 bolting regardless of location in the riser string.

Bolting above the tension ring excluding riser coupling bolts in the primary load path shall be considered class 2.

Bolting below the tension ring in the primary load path shall be considered class 3.

For bolting purposes, the tension ring shall be considered subsea equipment. Primary-load-path bolting on the tension ring shall be class 3.

Table 2—Bolting Requirements

Bolting Type	Material	Requirement Source
Class 3	Alloy steel and carbon steel Stainless steel and corrosion-resistant alloy (CRA)	API 20E BSL-3 API 20F BSL-3
Class 2	Alloy steel and carbon steel Stainless steel and CRA	API 20E BSL-2 API 20F BSL-2
Utility	Alloy steel and carbon steel	Manufacturer's specification

	Stainless steel and CRA	Manufacturer's specification

Utility bolting shall conform to the manufacturer's written specification.

NOTE 1 When plating or coating is specified, refer to 5.8.2.

NOTE 2 For bolting class, see bolting definition in 3.1.12.

5.5.4 Cathodically Protected Steels

Bolting in direct electrical contact with cathodically protected equipment (including components coated with thermally sprayed aluminum) shall be of materials that have shown to have low susceptibility to hydrogen embrittlement.

NOTE Bolting may be coated with various materials for lubricity, corrosion protection, and/or environment isolation.

Regardless of application, coatings shall not alter the bolting design and/or material selection unless agreed to by the purchaser. All coatings applied by electrochemical or autocatalytic means shall have a quality assurance procedure that includes adequate thermal bake-out to increase resistance to cracking caused by hydrogen embrittlement (e.g. see ASTM B850).

5.6 Qualification Test Coupons (QTCs)

5.6.1 General

Mechanical testing to determine the material properties shall be performed on specimens from an acceptable QTC as defined below.

5.6.2 Main Tube (API 5L)

For the main tube, multiple QTCs shall be taken per the requirements of API 5L.

NOTE Additional QTCs may be required per the manufacturer's written specification.

5.6.3 Forgings and Wrought Products

For forgings, extrusions, and wrought products, the QTC shall consist of prolongations, sacrificial forgings, or separately forged test coupons. The separately forged QTC shall be from the same heat as the production parts it represents and shall exhibit hot working ratios that are equal to or less than that used on the production parts. The size of the QTC shall be based on the equivalent round (ER) method as outlined in API 16A. The ER of the QTC shall be equal to or greater than the dimensions of the part it qualifies, but need not exceed 127 mm (5 in.).

The QTC should be heat treated with the production parts it represents whenever practical and shall accompany the parts throughout all heat treat cycles. The QTC shall be furnished in the same heat treat condition as the parts it represents. When the QTC is not heat treated with the parts, the austenitizing and/or tempering temperature of the QTC shall be within 14 °C (25 °F) of those used for the parts. For parts that are quenched and tempered, the QTC shall be quenched in the same media used to quench the production parts. "Production-type" furnaces shall be used. Cycle time for the QTC at the qualifying temperature shall not exceed that for the part.

5.6.4 Castings

QTCs for castings shall conform to API 16A.

5.7 Welding

5.7.1 Primary-load-carrying Weldments and Pressure-containing Weldments

All weld procedures and welders or welding operators shall be qualified in accordance with API 16A, except NACE MR0175 requirements are only applicable to weldments and weld procedure qualification intended for sour service environment. Other recognized industry standards may be used for weld procedure qualification when approved by the purchaser. All welding procedures shall be qualified to meet the same minimum mechanical property requirements as the base material used for the design. Additional essential welding variables shall be by agreement between the purchaser and manufacturer.

Weld procedure qualification and welding practices should be supplemented with requirements necessary for the prevention of hydrogen delayed cracking of welds between alloys with high hardenability.

For corrosion-resistant or hard-facing overlays, the API 16A requirements shall apply.

Butter welds, as defined in ASME *BPVC*, Section IX, shall be approved by the purchaser. Butter weld joints and joining welds shall require procedure qualification records (PQRs) for the buttering weld process and for the joining weld process. A welding procedure specification (WPS) shall be required for the entire completed weldment joint.

Transition welds shall be approved by the purchaser. Each of the two weldments at either extremity of a transition joint shall require a separate WPS and PQR to complete the entire weldment transition joint.

All fabrication welding procedure qualifications, where the base metal requires impact testing, shall measure the notch toughness of the weld metal and heat-affected zone. For procedure qualification tests joining dissimilar materials, both heat-affected zones shall be tested.

Preheating of assemblies or parts, when required, shall be performed to manufacturer's written procedures. If required, these procedures shall address postweld temperature maintenance [dehydrogenation heat treatment (DHT)] to prevent delayed cracking.

NOTE The controlled cooling rate of the weldment after welding, the maintenance of the preheat, and the interpass temperature prior to the PWHT may be shown in the WPS or manufacturing written procedure.

The storage, care, and control of welding consumables shall be defined in the quality assurance procedures that control the manufacturer's welding operations.

5.7.2 Structural Welding Procedure and Welder Performance

Structural weld procedures and welder/operator performance shall be qualified in accordance with the requirements of AWS D1.1, ASME *BPVC*, Section IX, or other recognized industry structural welding specification.

All welding procedures shall be qualified to meet the same minimum mechanical property requirements as the base material used for the design. When impact and/or hardness testing is required by design, the specimens shall be taken from the welded coupon in accordance with the requirements of API 16A.

NOTE Tensile strength may be allowed to be lower as prescribed in ASME *BPVC*, Section IX.

5.7.3 Lifting Devices

Except as amended or superseded by other requirements in the equipment-specific Sections 7 through 18, weld procedure qualifications, welder and welder operator qualifications, and welding processes for lifting devices shall be in accordance with the requirements in ASME *BPVC*, Section IX, AWS D1.1, or other equivalent industry standards.

5.7.4 Noncritical Welding

Welding of noncritical components shall be in accordance with manufacturer's written procedures/specifications or manufacturer-approved written procedures/specifications.

Noncritical welding shall not be allowed on the following: sour service applications, pressure-containing, hoisting equipment, primary-load-carrying members, and/or lifting devices.

5.7.5 Repair of Welds

Welding shall be considered as a repair if performed after PWHT; or if no PWHT is required, after final NDE of the weldment.

NOTE In-process weld repair prior to PWHT (if applicable) is not addressed by this paragraph.

NDE of weld defect repairs shall be identical to that of the original weld.

All major repair of welds to pressure-containing members, where failure would result in release of wellbore fluid to the environment, and to primary-load-carrying members performed subsequent to original PWHT shall be mapped.

Surface examination shall be performed on all excavations for weld repairs, with the method and acceptance criteria as specified in 6.5.2.2.

Total PWHT time at temperature after the repair(s) shall not exceed the maximum time qualified and recorded on the WPS. If a weld is to be repaired after PWHT, both the original and the repair WPS shall have additional PWHT time to ensure that the total cumulative time at temperature does not exceed the time qualified. All PWHT cycles shall be recorded on a furnace chart or digital file.

5.7.6 Repair Welding of Base Metal

5.7.6.1 General

There shall be adequate access to evaluate, remove, and inspect the nonconforming condition causing the need for the repair. The nonconforming condition causing the need for repair shall be removed and evaluated by NDE prior to the repair.

The WPS and the available access for repair shall be such as to ensure complete fusion of the weld with the base material.

The repair welds on pressure-containing and primary-load-carrying components shall conform to all NDE requirements and acceptance criteria for the components.

Total PWHT time at temperature after the repair(s) shall not exceed the maximum time qualified and recorded on the WPS.

5.7.6.2 Repair Welding Requirements for Wrought Products

All repair welding shall be performed in accordance with the manufacturer's WPSs and inspected to manufacturer's written specifications. WPSs shall be documented and shall be supplied at the purchaser's request.

Prior to any repair, the manufacturer shall document the following criteria for permitted repairs:

— defect type,

— defect size limits,

— definition of major/minor repairs.

All excavations, prior to repair and the subsequent weld repair, shall meet the quality control requirements specified in Section 6.

For major repair welds, the manufacturer shall also produce a weld map of the area to be repaired and the repair sequence. Documentation of repairs shall be maintained in accordance with requirements of Section 6.

5.7.6.3 Riser Main Tube

Wrought tubular products shall not be repair welded.

5.7.7 PWHT

The WPS used for qualifying a repair shall reflect the actual sequence of weld repair and PWHT performed on the repaired item. The WPS shall be qualified to perform the total number of PWHT hours to the base material and to the original weld metal.

5.8 Metallic Coatings

5.8.1 Metallic Coatings Applied by Thermal Spray or Spray and Fused Process

Application of thermal spray and spray and fused processes shall be performed by using vendors and procedures approved by the equipment manufacturer.

The procedures to be approved shall as minimum address the following variables:

— finished thickness of the overlay or hard-facing material;

— type of base metal and qualified thickness range;

— type of filler metal (classification if applicable), particle size, and powder feed rate;

— position;

— preheat, PWHT, and PWHT after fusing (when applicable);

— gas feed rate, plasma/feed gas composition, multiple or single layers, torch to work piece, surface preparation, spray torch, fusing temperature range (when applicable); and

— base metal properties after final PWHT and qualification of final PWHT.

NOTE Variables listed above may be addressed as ranges. Alternatively to the requirements of 5.8.1, if a weld procedure qualification is desired by the equipment manufacturer, more detail can be found in ASME *BPVC*, Section IX under Oxyfuel Gas Welding. For more detail on thermal spray aluminum process, see Annex E.

5.8.2 Metallic Coatings Applied by Plating Process

Application of metallic coatings by plating shall be performed by using vendors and procedures approved by the equipment manufacturer.

The procedures to be approved shall as minimum address the following variables:

— type of plating process and plating material;

— thickness requirements of plated material;

— base metal properties and material's susceptibility to hydrogen embrittlement (relevant to plating process);

— dehydrogenation process (hydrogen bake-out) maximum time allowed between parts being plated and parts being baked, bake-out temperature, minimum bake-out time at temperature; and

— testing and NDE for base metal and plating, as per applicable industry standards.

The procedures to be approved should address the following:

— pre-plating requirements such as visual inspection, surface finish, residual magnetism, suitable cleaning methods;

— plating solution essential variables such as concentration, pH, specific gravity, maximum number of metal turnovers (MTOs);

— health and safety measures.

When hydrogen bake-out is required for the plated material, the bake-out shall occur within 3 hours of the plating process, but preferably within 1 hour.

6 Quality Control Requirements

6.1 General

Section 6 specifies quality control requirements and shall apply to primary-load-carrying components and/or pressure-containing components within the scope of this specification. The main tube shall meet the requirements of API 5L, PSL 2. Other tubular components (i.e. mud boost line) manufactured from carbon and low-alloy steel shall follow API 5CT for eddy current and/or flux leakage testing methodology and acceptance criteria. Tubular components (i.e. hydraulic lines) manufactured from duplex, super duplex, and stainless steel shall be per manufacturer's specification.

Quality control requirements for non-primary-load-carrying components and/or non-pressure-containing components within the scope of this specification shall be performed and documented in accordance with the manufacturer's written specifications.

6.2 Measuring and Testing Equipment

6.2.1 General

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

6.2.2 Pressure-measuring Devices

Test pressure-measuring devices shall be either pressure gauges or pressure transducers and shall be accurate to at least ±1.0 % of full-scale range.

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

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

Intervals shall be established for calibrations based on repeatability and degree of usage. Calibration intervals shall be a maximum of three months until recorded calibration history can be established by the equipment manufacturer and new longer intervals (three months maximum increment) established.

6.3 Quality Control Personnel Qualifications

6.3.1 NDE Personnel

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

6.3.2 Visual Examination Personnel

Personnel performing visual examinations shall have an annual eye examination in accordance with ASNT SNT-TC-1A or ISO 9712.

6.3.3 Welding Inspectors

Personnel performing visual inspection of welding operations and completed welds shall be qualified and certified to one or more of the following:

— AWS Senior Certified Welding Inspector (SCWI);

— AWS Certified Welding Inspector (CWI);

— AWS Certified Associate Welding Inspector (CAWI);

— CSWIP Certified Visual Welding Inspectors (Level 1);

— CSWIP Certified Welding Inspectors (Level 2);

— CSWIP Certified Senior Welding Inspectors (Level 3);

— welding inspector certified by the manufacturer’s documented training program.

The manufacturer shall have written procedures:

— defining the roles, responsibilities, authority, and accountability of a welding inspector;

— defining essential welding variables and equipment monitoring;

— defining welding, weld NDE, and PWHT audits;

— defining the in-house welding inspector certification program, if used, including training syllabus, instructor qualification requirements, length of certification, and renewal requirements.

6.3.4 Other Personnel

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

6.4 Quality Control Requirements for Equipment and Parts

6.4.1 Quality Control Instructions

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

NOTE This requirement is not applicable to hardness testing.

6.4.2 Visual Examination

6.4.2.1 Sampling

Each part shall be visually examined.

6.4.2.2 Procedure

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

6.4.2.3 Acceptance Criteria

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

6.4.3 Surface NDE

6.4.3.1 Surface NDE of Ferromagnetic Materials

All accessible surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by either magnetic particle (MP) or liquid penetrant (LP) methods.

6.4.3.2 Surface NDE of Nonferromagnetic Materials

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

6.4.3.3 Surface NDE of Overlay Cladding

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

6.4.3.4 Procedures

6.4.3.4.1 General

MP examination shall be in accordance with procedures specified in ASTM E709. Prods shall not be permitted on surfaces or sealing surfaces.

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

6.4.3.4.2 Acceptance Criteria for Surfaces Other Than Pressure-contact (Metal-to-metal) Sealing Surfaces

Acceptance criteria shall be:

— no relevant indications interpreted as a crack,

— no relevant indication with a major dimension equal to or greater than 5 mm ($^3/_{16}$ in.),

— no more than 10 relevant indications in any continuous 40 cm^2 (6 in.^{2}) area,

— four or more relevant indications in a line separated by less than 1.6 mm ($^1/_{16}$ in.) (edge to edge) are unacceptable.

6.4.3.4.3 Acceptance Criteria for Pressure Contact (Metal-to-Metal) Sealing Surfaces

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

6.4.4 Volumetric NDE

The following requirements shall apply.

a) *Sampling*.

As far as practical, the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after final heat treatment and prior to machining operations that limit effective interpretation of the results of the examination.

For quench-and-tempered products, the volumetric inspection shall be performed after final heat treatment exclusive of retempering to reduce hardness.

b) *Ultrasonic Examination*.

1) Test Method.

Hot-worked parts: Ultrasonic examination of hot-worked parts shall be performed in accordance with the flat-bottom hole procedures specified in ASTM A388 (except immersion method may be used) and ASTM E428.

Additionally, rings and hollow forgings that have an axial length greater than 2 in. with an OD to ID ratio of less than 2 to 1 shall be inspected with an angle beam inspection in accordance with ASTM A388/A388M.

Calibration: Distance amplitude curve (DAC) shall be based on 1.6 mm ($^1/_{16}$ in.) flat-bottom hole for metal thicknesses through 38 mm (1$^1/_2$ in.), on 3.2 mm ($^1/_8$ in.) flat-bottom hole for metal thicknesses from 38 mm (1$^1/_2$ in.) through 150 mm (6 in.), and on 6.4 mm ($^1/_4$ in.) flat-bottom hole for metal thicknesses exceeding 150 mm (6 in.).

2) Acceptance Criteria.

The following acceptance criteria shall apply:

— no single indications exceeding reference DAC;

— no multiple indications exceeding 50 % of reference DAC.

Multiple indications shall be defined as two or more indications (each exceeding 50 % of the reference DAC) within 13 mm (1/2 in.) of each other in any direction.

c) *Radiographic Examination*.

1) Test Method.

Radiographic examination of hot-worked parts shall be performed in accordance with methods specified in 6.5.

2) Acceptance Criteria.

The following acceptance criteria shall apply to hot-worked parts:

— no cracks, laps, or bursts;

— no group of indications in a line that have an aggregate length greater than "*t*" in a length of 12*t*;

— no elongated indications with length greater than stated in Table 3.

Table 3—Inclusion Criteria

Thickness, *t*		**Inclusion Length**	
mm	(in.)	mm	(in.)
<19	< 0.76	6.4	0.25
19 ≤ *t* ≤ 57	0.76 ≤ *t* ≤ 2.25	0.33 × *t*	0.33 × *t*
> 57	> 2.25	19.0	0.75

6.5 NDE of Fabrication and Repair of Weldments

6.5.1 General

If examination is required, essential welding variables and equipment shall be monitored during welding. The entire accessible weld, plus at least 13 mm (1/2 in.) or surrounding base metal, shall be examined.

NDE shall be carried out after final PWHT.

6.5.2 NDE of Fabrication Welding

6.5.2.1 Visual Examination

All fabrication welds shall be visually examined in accordance with ASME *BPVC* (2010), Section V, Subsection A, Article 9. Undercuts shall not reduce the thickness in the affected area to below the design thickness and shall be ground to blend smoothly with the surrounding material.

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

6.5.2.2 Surface NDE

6.5.2.2.1 General

All primary-load-carrying and pressure-containing welds and attachment welds to main load-bearing and pressure-containing components shall be examined.

6.5.2.2.2 Method

Ferromagnetic materials shall be examined by the MP method in accordance with ASME *BPVC* (2010), Section V, Subsection A, Article 7 and Subsection B, Article 25 or ASTM E709, or the LP method in accordance with ASME *BPVC* (2010), Section V, Subsection A, Article 6 and Subsection B, Article 24 or ASTM E165. MP inspection of machined surfaces shall be by the wet fluorescent method; other surfaces shall be examined by a wet method or dry method.

Nonferromagnetic materials shall be examined by the LP method in accordance with ASME *BPVC* (2010), Section V, Subsection A, Article 6 and Subsection B, Article 24 or ASTM E165.

If the use of prods cannot be avoided, all prod burn marks shall be removed by grinding and the affected areas shall be reexamined by the LP method.

6.5.2.2.3 Surface Acceptance Criteria

The surface acceptance criteria shall be:

— no relevant linear indications with a major dimension equal to or greater than 5 mm ($^{3}/_{16}$ in.);

— no rounded indications with a major dimension greater than 3 mm ($^{1}/_{8}$ in.), for welds whose depth is 17 mm ($^{5}/_{8}$ in.) or less;

— no rounded indications with a major dimension greater than 5 mm ($^{3}/_{16}$ in.), for welds whose depth is greater than 17 mm ($^{5}/_{8}$ in.);

— no more than three relevant indications in a line separated by less than 2 mm ($^{1}/_{16}$ in.) edge to edge.

6.5.2.2.4 Volumetric NDE

6.5.2.2.4.1 General

One hundred percent of full-penetration pressure-containing welds and full-penetration welds in the primary load path shall be examined by either radiography or ultrasonic methods after all welding, PWHT, and machining operations.

6.5.2.2.4.2 Radiography

Radiographic examinations shall be performed in accordance with procedures specified in ASTM E94, to a minimum equivalent sensitivity of 2 %.

NOTE Both X-ray and gamma ray radiation sources are acceptable within the inherent thickness range limitation of each. Real-time imaging and recording/enhancement methods may be used when the manufacturer has documented proof that the methods result in a minimum equivalent sensitivity of 2 %. Wire-type image quality indicators are acceptable for use per ASTM E747.

Acceptance criteria specify that no type of crack, zone of incomplete fusion, or penetration shall be allowed. No elongated slag inclusion shall be allowed that has a length equal to or greater than shown in Table 3.

In addition, there shall be no group of slag inclusions in a line having an aggregate length greater than the weld thickness (t) in any total weld length $12t$, except when the distance between successive inclusions exceeds six times the length of the longest inclusion.

No rounded indications in excess of those specified in ASME *BPVC*, Section VIII, Division 1, Appendix 1 shall be permitted.

6.5.2.2.4.3 Ultrasonic

Ultrasonic examinations shall be performed in accordance with procedures specified in ASME *BPVC*, Section V, Article 4.

No linear indications interpreted as cracks, incomplete joint penetration, or incomplete fusion shall be allowed. No slag, porosity, or other indications shall be allowed with amplitudes exceeding the reference level whose length exceeds the values shown in Table 3.

6.5.2.2.4.4 Weld Hardness Testing

All pressure-containing and primary-load-path welds shall be hardness tested. Hardness testing shall be performed in accordance with one of the following:

— Vickers method (ASTM E384 or ISO 6507-1, *Metallic materials—Vickers hardness test—Part 1: Test method*);

— Brinell method (ASTM E10 or ISO 6506-1, *Metallic materials—Brinell hardness test—Part 1: Test method*);

— Rockwell method (ASTM E18 or ISO 6508-1, *Metallic materials—Rockwell hardness test—Part 1: Test method*).

At least one hardness test shall be performed in both the weld and in the adjacent unaffected base metal after all heat treatment and machining operations. Hardness values shall meet the requirements of the manufacturer's written specification.

Locations deemed inaccessible by the manufacturer for hardness testing shall be identified and recorded.

6.6 Equipment Traceability

All assemblies as defined in Section 1 shall be serialized with a unique number that allows the assembly and all major components to be traced back through the manufacturing process to the raw material heat certification documents.

Utility fasteners and pipe fittings shall be exempt from traceability requirements provided they are marked in accordance with recognized industry standards.

6.7 Requirements for Quality Control Records

6.7.1 General

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

6.7.2 NACE Records Requirements

Records required to demonstrate conformance of equipment to NACE requirements shall be in addition to records described in other sections of this standard, unless the records required by this standard also satisfy the NACE MR0175/ISO 15156 requirements.

6.7.3 Records Control

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

Records required by this standard shall be retained by the manufacturer for a minimum of 10 years following the date of manufacture as marked on the equipment associated with the records.

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

6.7.4 Records Maintained by the Manufacturer

The manufacturer shall retain all documents and records as required in Section 4 through Section 6 and as required by the equipment-specific sections.

For primary-load-carrying and pressure-containing parts or components covered in 6.1, the following records shall be retained:

— weld PQR,

— welder qualification record,

— material test records,

— NDE personnel qualification records,

— NDE records.

For non-primary-load-carrying and non-pressure-containing parts or components covered in 6.1, records shall be retained per manufacturer documentation requirements.

6.8 Manufacturing Data Book

A data book containing information as stated in Annex F shall be furnished upon product delivery unless otherwise specified by the purchaser.

7 Riser Tensioner Equipment

7.1 General

Required stroke, maximum tension, pressure, and tension variation with stroke shall determine performance requirements for riser tensioners.

NOTE 1 Dynamic effects of gas and liquid flow are outside the scope of this section.

Riser tensioning systems on dynamically positioned vessels shall be equipped with anti-recoil systems to protect the riser and vessel following emergency riser disconnects.

NOTE 2 Specifications for anti-recoil systems are generally custom designed for the specific tensioner system and are beyond the scope of this document.

NOTE 3 Figure G.2 shows a typical wire rope tensioning system.

7.2 Pressure

The tensioner system safety relief valve's set pressure shall not exceed the maximum allowable working pressure (MAWP).

The maximum compression pressure (MCP) shall be limited to no more than 93 % of the MAWP to accommodate for safety relief valve tolerances.

The maximum supply pressure (MSP) shall be less than or equal to MCP minus the potential increase in pressure that can be caused by real gas compression due to changes in stroke, per Figure 1. Given the actual tensioner stroke position, the tensioner pressure shall be limited so that the pressure achieved when fully compressed shall not exceed MCP.

NOTE Pressure settings above MSP are allowed depending on the actual stroke of the tensioners provided that the 100 % performance curve is not exceeded.

7.3 Service Ratings

7.3.1 Tension Capacities

7.3.1.1 Rated Tension

Tensioners shall be rated at the 75 % stroke position for compression-loaded tensioners and 25 % stroke position for tension-loaded tensioners (see Figure 1).

NOTE Ideally during operation, riser tensioners are set at the mid-stroke (50 % stroke) to allow for equal stroking either side of the mid-point as the vessel heaves. In reality, achieving mid-stroke position is difficult due to the following:

— riser geometry might not position the tension ring exactly where a mid-stroke position can be obtained,

— increased tension with increased mud weights results in additional riser stretch,

— tidal changes at the well site can change the stroke setting.

The above factors along with the potential for drift-off make it desirable to miss the mid-stroke setting to the high side should a miss occur. The rated tension shall not exceed MCP at any stroke.

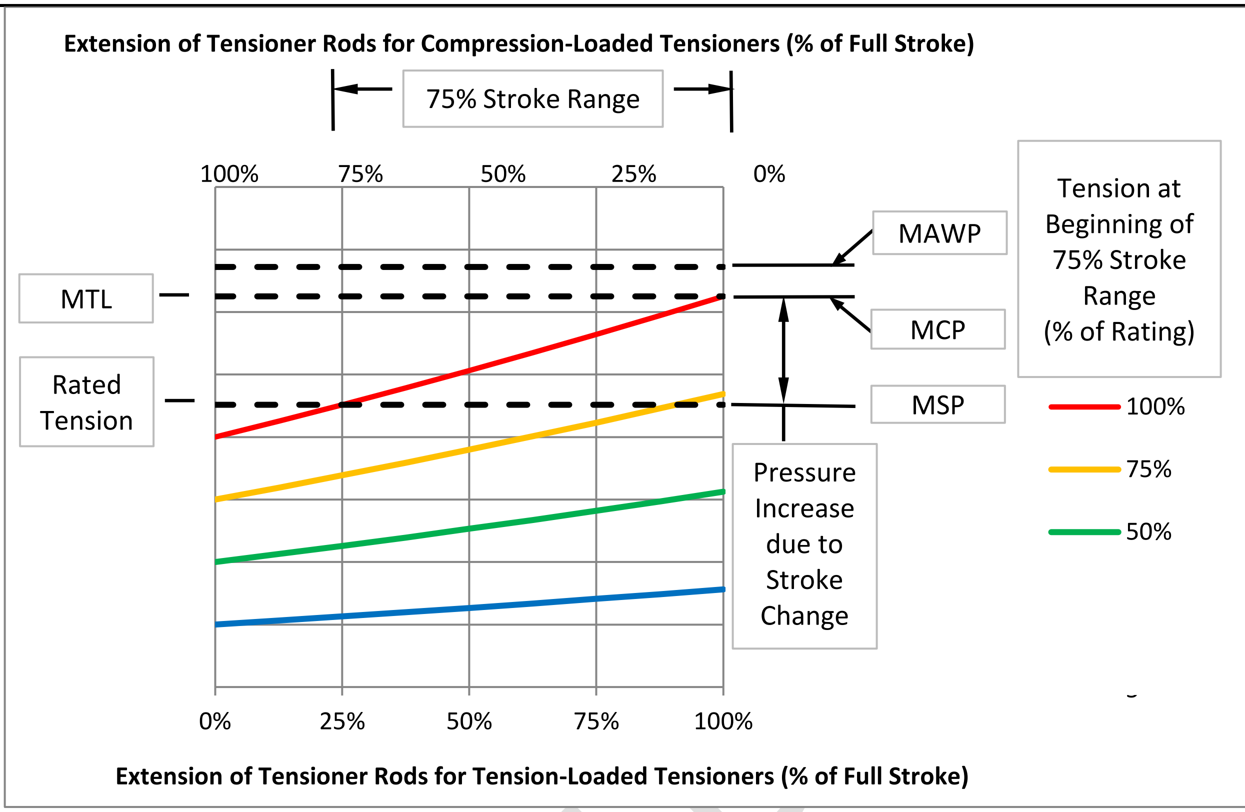

Figure 1—Rated Tension and MTL to MSP, MCP, and MAWP (for Illustration Only)

7.3.1.2 Maximum Tension Limit (MTL)

The MTL shall be calculated using the MCP.

7.3.1.3 Tension Rating Calculations

7.3.1.3.1 Wire Rope Tensioners

7.3.1.3.1.1 Compression Loaded

A marine riser tensioner that utilizes wire lines and sheaves shall be rated according to the tension produced in the wire line at the last sheave at the base of the tensioner. For the most often used "rod end up" orientation, the rated tension and MTL shall be calculated by multiplying the pressure by the effective piston area, then subtracting the maximum corresponding rod side pressure multiplied by the effective rod side area, the weight of the piston rod assembly, rod end attachments, and wire line wrapped around the tensioner, and then dividing by the number of parts of line used.

NOTE For other rod orientations, the effects of the weight of the moving components and wire rope are typically calculated relative to the orientation.

7.3.1.3.1.2 Tension Loaded

A marine riser tensioner that utilizes wire lines and sheaves shall be rated according to the tension produced in the wire line at the last sheave at the base of the tensioner. For a "rod down" orientation in which the cylinder is mounted to the rig and the rod and rod end sheaves move, the rated tension and MTL shall be calculated by multiplying the pressure by the effective rod area, then subtracting the maximum corresponding piston side pressure multiplied by the effective piston side area, the weight of the piston rod assembly, rod end attachments, and wire line wrapped around the tensioner, and then dividing by the number of parts of line used.

NOTE For other rod orientations, the effects of the weight of the moving components and wire rope are typically calculated relative to the orientation.

7.3.1.3.2 Direct-acting Tensioners

7.3.1.3.2.1 Compression Loaded

The rated tension and MTL shall be calculated by multiplying the pressure by the effective piston side area, then subtracting the maximum corresponding rod side pressure multiplied by the effective rod area, the weight of the piston/rod assembly, and rod end attachments.

7.3.1.3.2.2 Tension Loaded

The rated tension and MTL shall be calculated by multiplying the pressure by the effective rod side area, then subtracting the maximum corresponding piston side pressure multiplied by the effective piston area, the weight of the piston/rod assembly, and rod end attachments.

NOTE See Table G.1 for example calculations.

7.3.2 Rated Stroke

The full range of stroke, including stroke that is used for end cushioning, that can be accommodated by the tensioner cylinder shall determine the rated stroke.

7.4 Tension and Pressure vs Stroke

7.4.1 Tensioner Performance Curves

The manufacturer shall provide plots of tension vs stroke for the full stroke range of the tensioner. At a minimum, curves shall be provided that correspond to 25 %, 50 %, 75 %, and 100 % of rated tension as shown in Figure 1.

NOTE Figure 1 shows an example plot. Annex G shows example calculations.

The calculations shall include compression and expansion characteristics of real gas using one of the real gas methods defined below:

1) NIST (National Institute of Standards and Technology) data,
2) Benedict–Webb–Rubin equation of state (EOS),
3) van der Waals EOS,
4) polytropic constant table per Annex H,
5) an alternate polytropic constant if justified and documented through testing.

Adiabatic behavior shall be assumed for Methods 1) through 3). Since Method 5 is time dependent, the minimum applicable duration shall be stated.

7.4.2 Allowable Tension Variation due to Gas Volume Change

NOTE The tension variation with stroke, exclusive of mechanical friction and hydraulic inefficiencies, is directly related to the total working air pressure vessel volume connected to the tensioners. Fewer APVs provide larger tension variation as the vessel heaves.

The total tension variation caused by volume change, for the 100 % rated tension curve (highest curve in Figure 1) at minimum rated temperature, shall be limited to no more than a 40 % reduction from the MTL over the full range of tensioner stroke unless otherwise specified by the purchaser.

7.5 Design Standards

7.5.1 Pressure Vessels

Pressure vessels shall be designed, fabricated, and tested in accordance with ASME *BPVC*, Section VIII, Division 1 or Division 2; ISO 11120; or other nationally or internationally recognized standard. Alloy or carbon steel vessels shall include 0.063-in. minimum corrosion allowance. Each vessel shall be equipped with a shut-off valve, drain valve, and pressure-relief device.

7.5.2 Cylinders

Cylinders shall be designed, fabricated, and tested to meet the strength requirements of ASME *BPVC*, Section VIII, Division 1 or Division 2, or other nationally or internationally recognized standards. Any associated nonpressure boundary components such as solid rods, rams, or like elements shall be designed in accordance with AISC or other nationally or internationally recognized standards.

7.5.3 Piping

All piping shall be designed in accordance with ASME B31.3 or other nationally or internationally recognized standard.

For interconnect piping that is outside the tensioner manufacturer's scope of supply, the tensioner manufacturer shall provide recommended pipe size and maximum equivalent length to prevent excessive hydraulic and pneumatic inefficiencies during operation.

7.5.4 Wire Rope

All wire rope used in marine riser tensioners shall conform to API 9A. The rope shall be sized to have a minimum design safety factor of 3.0 on breaking strength. The design safety factor shall be determined by dividing the wire rope breaking strength by the MTL.

7.5.5 Sheaves

Sheave diameters shall be determined in accordance with recommendations given in API 9B. The sheave diameter factor shall meet or exceed "Condition B." Otherwise, the sheaves shall conform to API 8C.

7.5.6 Electrical Wiring

Electrical equipment and wiring shall conform to API 500, API 505, or other national or international recognized standards such as NFPA 70, *National Electrical Code*, Class I, Division 2 or IEC 61892.

7.5.7 Other Structural and Mechanical Elements

All other structural and mechanical elements shall be designed in accordance with AISC or other nationally or internationally recognized standard. Design loads of the tensioner structural parts shall be based on the tension produced at MAWP, plus the weight of the device and its contents. The tensioner structural parts shall be designed according to AISC or other nationally or internationally recognized standard. A fatigue analysis shall be performed and documented for the tensioner structural parts.

7.5.8 Tensioner Foundations

The manufacturer shall provide the mounting and installation information to designer/purchasers, including design load, orientation, alignment, allowable fleet angle, and minimum clearances.

7.6 Operational Controls

The tensioner system shall, as a minimum, include equipment to control and monitor the tension level.

7.7 Temperature Considerations

7.7.1 Structural Design Consideration

The manufacturer shall clearly state the appropriate service temperature range claimed for all tensioner components.

NOTE Cited design codes may not address extreme low-temperature service.

7.7.2 Fluids and Elastomers

Working fluids and elastomers also affect system reliability and performance and shall be considered when establishing the overall service temperature rating.

7.8 Fluids

The tensioner manufacturer shall specify the hydraulic fluid suitable for the tensioner. Any alternative fluid shall be approved by the manufacturer.

NOTE Important considerations are:

— viscosity (with temperature relation),

— pH value,

— corrosion properties,

— lubricity value,

— ignition characteristics,

— operating temperature range,

— foaming characteristics,

— color so as to permit ready detection of leaks,

— material compatibility,

— cleanliness.

7.9 Rod Materials and Coatings

Rods shall be made from a corrosion-resistant material or have a corrosion-resistant coating.

NOTE 1 Typically, rod material or coatings are selected to provide suitable corrosion resistance, hardness, wear, seal compatibility, and durability.

NOTE 2 Advanced corrosion-resistant coatings are now widely available in addition to the traditional industrial hard chrome over steel. These may include laser clad alloys, high-velocity oxygenated fuel (HVOF) compounds, or ceramics. When advanced corrosion-resistant coatings are used, careful selection of appropriate seal and bearing materials are required to ensure adequate wear and life results.

NOTE 3 Ceramic-coated rods may be subject to corrosion in the underlying base material if using a water-glycol hydraulic fluid. In the presence of some materials and design configurations, some fluids may act as an electrolyte and thus produce an electrical potential across the rod.

7.10 Failure Control Provisions

The riser tensioner system shall incorporate provisions to prevent structural failure of the riser tensioning equipment resulting from a sudden loss of pressure, from a failure of the tensioner ropes, or from any other sudden loss of tension in the principal load carrying components. The manufacturer shall demonstrate the effectiveness of the system by test or analyses.

7.11 Marking

The manufacturer shall provide on a nameplate or otherwise affix to each tensioner the following information:

— name of manufacturer,

— unique serial number,

— tension rating,

— operating ambient temperature range (minimum and maximum),

— API 16F.

7.12 Materials

Materials shall conform to the requirements of Section 5, except castings shall be allowed for primary-load-carrying and pressure-containing components where a single failure of a component does not lead to a system failure. Castings shall have volumetric NDE performed in accordance with API 8C.

NOTE Examples of tensioner components where castings might be used are shackles, sheaves, pipe fittings, valves, and wire sockets for connecting tensioners to the tension ring.

7.13 Quality Control

Quality control shall conform to the requirements of Section 6.

8 Flex/Ball Joints

8.1 Service Classification

8.1.1 Tensile and Compressive Capacity

The tensile load capacity rating for flex/ball joints is the same as defined in Section 4.

NOTE Upper flex/ball joints installed above the telescopic joints are not normally subjected to the same severity of loading as riser couplings. Service loads may vary from tensile to compressive.

For flex/ball joints designed for installation above the telescopic joint, manufacturer shall specify both tensile and compressive design load limits.

8.1.2 Rated Working Pressure

The manufacturer shall specify the applicable pressure rating.

NOTE Internal pressure ratings for upper flex and ball joints are commonly 300 psi or 500 psi. Lower and intermediate flex and ball joint ratings commonly range from 600 psi to 6000 psi.

8.1.3 Combined Loading

The manufacturer shall specify the combined tensile/pressure design load limits.

NOTE The flex/ball joint is subjected to simultaneous tensile loads, pressure differentials, and angular rotations. The tensile capacity of the unit is seldom applicable over its full operation pressure range.

8.1.4 Flex Angle

Flex and ball joints shall be capable of flexing to the specified maximum flex angle in any plane passing through the longitudinal axis.

NOTE The flex angle limit for upper flex and ball joints is commonly ±15° for upper flex joints, ±10° for lower flex joints, and ±20° for intermediate flex joints.

The manufacturer shall specify the full range of the flex angle limits.

8.1.5 Load/Deflection Curve

The manufacturer shall provide the bending load/deflection curve for the full range of flex angles suitable for riser analysis to the purchaser.

8.2 Design

8.2.1 Structural and Pressure Members

Design criteria for structural and pressure members shall conform to the guidelines established in Section 4 of this document and stress requirements of Annex C.

8.2.2 Flex Joints

NOTE Flex joints for drilling risers use a laminated structure of elastomer and metal.

A design certification report or series of reports shall be prepared to qualify each flex joint design. This report shall include:

— summary of design requirements;

— applicable specifications and references;

— description of design;

— bill of material with material properties;

— fluid compatibility data;

— stress analysis of all loaded components including the flex elements;

— failure modes (e.g. yielding, buckling, stability, external collapse, mechanical failure);

— qualification test report that includes test criteria and results.

8.2.3 Ball Joints

A pressure-balanced ball joint shall require a hydraulic fluid bearing between the ball and socket when service loads are applied. The manufacturer shall furnish recommended balancing pressure settings as a function of riser tension, water depth, and mud weight.

8.3 Materials

Materials shall conform to the requirements of Section 5.

8.4 Dimensions

8.4.1 Bore Size

The manufacturer shall provide calculated drift capability (length and diameter) relative to flex angle.

8.4.2 Outer Diameter

The manufacturer shall specify the maximum OD of the flex or ball joint.

8.5 Testing

8.5.1 Design Type Certification Testing

For type certification of a design, the supplier shall demonstrate that the flex joint or ball joint is designed in accordance with a basis developed and supported by results from actual full-scale testing. The flex or ball joint shall be cycled to ±50 % of the specified maximum flex angle for 100,000 cycles in one plane of flexure without visible deterioration of the flex elements or structural and pressure members. The joint shall be pressure tested to verify pressure integrity at full rated working pressure following the cyclic flexure test.

For type certification of each design, the design shall be verified.

8.5.2 Factory Acceptance Testing

Each new flex joint and ball joint shall be subjected to hydrostatic testing at 1.5 times rated working pressure. In addition, each ball joint balancing chamber hydraulic circuit shall be pressure tested at 1.5 times the maximum operating pressure.

8.6 Marking

The manufacturer shall provide on a nameplate or otherwise affix to each flex joint or ball joint the following information:

— name of manufacturer,

— a unique serial number,

— tensile load rating,

— compressive load rating,

— rated working pressure,

— maximum flex angle,

— API 16F.

9 Choke, Kill, and Auxiliary Lines

9.1 Design—Choke, Kill, and Auxiliary Lines

9.1.1 Service Conditions

9.1.1.1 C&K Lines

API 16C service conditions shall be applied.

9.1.1.2 Auxiliary Lines

Auxiliary lines shall be designed for service classifications (see 4.2) specified by this specification.

NOTE Mud boost lines need not conform to NACE MR0175/ISO 15156 unless specified by the purchaser.

9.1.2 Design Method

9.1.2.1 C&K Lines

API 16C design methods for rigid piping shall be applied.

Pin and box end connections shall be designed using the methodology presented in Annex C of this specification. External loads resulting from all riser design loads shall be included in the design evaluation.

9.1.2.2 Auxiliary Lines

ASME B31.3 or ASME *BPVC*, Section VIII, Division 2 design methods for pipe wall thickness shall be used for rigid auxiliary lines.

Pin and box end connections shall be designed using the methodology presented in Annex C of this specification. External loads resulting from all riser design loads shall be included in the design evaluation.

9.1.3 Performance Requirements

9.1.3.1 C&K Lines

API 16C performance requirements shall be applied. Load capability shall include external loads resulting from all riser design loads.

Analysis shall account for joint tension, joint flexure in bending, thermal expansion of both main tube and choke, kill, and auxiliary lines, and applications from zero pressure to full rated working pressure on the combination of the external lines and main tube.

The manufacturer shall document the load combinations considered in the design of the C&K lines.

Minimum wall thickness corrosion/erosion allowance shall be 1.3 mm (0.05 in.), applied to the internal surfaces. The external surface shall be suitably protected from external corrosion.

For pipe bends, the minimum bending allowance shall be specified by the manufacturer's bending specification. This allowance shall be applied to the wall thickness for the external surface.

C&K lines should be as straight as possible to reduce the potential for erosion during operations.

— Pipe bends should use long radii ($R/d \geq 10$ where R is the pipe bend radius at centerline and d is the nominal ID of the pipe).

— Block ells and tees should be targeted or have fluid cushions installed in all expected flow directions.

— Short radius ($R/d < 10$) pipe bends/turns of an angle equal to 60° or greater should be equipped with a target, increased wall thickness, or a fluid cushion in all expected flow directions.

Targets shall not be lead filled. Targets shall have a minimum thickness of 1.0 times the end connection ID or be ≥ closest corresponding thickness dimension "T" from API 6A for "Type 6BX Blind and Test Flanges." The increased wall thickness method shall utilize a wall thickness ≥ 1.5 times the local nominal pipe wall thickness. Fluid cushions shall have an ID ≥ the end connection ID and a depth ≥ 1.0 times the end connection ID.

NOTE Reference AWHEM TR1201 for targets and fluid cushion examples.

When the surrounding geometries do not allow the inclusion of these erosion control methods, then the risks of erosion shall be addressed as specified per Section 19 of this document.

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 inlets end connection.

9.1.3.2 Auxiliary Lines

The performance requirements of this specification shall be applied. Load capability shall include external loads resulting from all riser design loads.

Analysis shall account for joint tension, joint flexure in bending, thermal expansion of both main tube and choke, kill, and auxiliary lines, and applications from zero pressure to full rated working pressure on the combination of the external lines and main tube.

The manufacturer shall document the load combinations considered in the design of the auxiliary lines.

Minimum wall thickness corrosion/erosion allowance shall be 1.3 mm (0.05 in.), applied to the internal surfaces. The external surface shall be suitably protected from external corrosion.

NOTE This may be reduced to zero for CRAs in nonerosive service, such as hydraulic conduit lines.

The minimum bending allowance shall be specified by the manufacturer's bending specification. This allowance shall be applied to the wall thickness for the external surface.

9.2 Testing of Choke, Kill, and Auxiliary Lines

9.2.1 Hydrostatic Proof Testing

Hydrostatic proof testing shall be in accordance with API 16C for all lines. The hydrostatic proof test pressure shall be 1.5 times rated working pressure. Proof test is normally conducted prior to the installation of the choke, kill, and auxiliary lines into the finished riser joint assembly; the riser joint and choke, kill, and auxiliary lines are not required by this specification to withstand proof test pressure as an assembly.

9.2.2 Design Validation—Nonmetallic Seals for C&K Lines

Nonmetallic seals for C&K lines shall require design validation in accordance with API 16C.

9.2.3 Design Validation—Nonmetallic Seals for Auxiliary Lines

NOTE Nonmetallic seals for auxiliary lines may be design validated by hydrostatic proof testing.

Nonmetallic seals for auxiliary lines designed for exposure to sour environments shall require design validation in accordance with API 16C.

9.3 Materials—Choke, Kill, and Auxiliary Lines

9.3.1 C&K Lines

Metallic and nonmetallic materials shall be in accordance with API 16C.

9.3.2 Auxiliary Lines

Metallic and nonmetallic materials shall be in accordance with Section 5. Auxiliary lines designed for exposure to sour environments shall conform to NACE MR0175/ISO 15156.

9.4 Welding and Quality Process Control—Choke, Kill, and Auxiliary Lines

9.4.1 C&K Lines

Welding and quality process control shall be in accordance with API 16C.

9.4.2 Auxiliary Lines

Welding and quality process control shall be in accordance to Sections 5 and 6, respectively.

10 Drape Hoses and Jumper Lines

10.1 Service Classification

10.1.1 Drape Hoses

Drape hoses at the telescopic joint shall be classified according to internal pressure and relative movement between the riser and the drilling vessel. The internal pressure rating of the lines shall be at least as high as that of the lines to which they connect. The drape hoses shall be long enough to accommodate the design stroke of the telescoping joint and any rotation that may occur between the drilling vessel and the telescoping joint.

10.1.2 Jumper Lines

Jumper lines around the flex or ball joint shall be classified for internal pressure and relative movement between the riser and the BOP stack. The internal pressure rating of the lines shall be at least as high as that of the lines to which they connect. The jumper lines shall accommodate the design rotation of the flex or ball joint and any relative displacements this rotation may induce between the ends of the jumper.

10.2 Design

The design of all drape hoses and jumper sections of riser C&K lines shall be in accordance with API 16C.

The design of all drape hoses and jumper sections of riser mud booster lines shall be in accordance with API 7K.

The design of all drape hoses and jumper sections of riser hydraulic lines shall be in accordance with API 16D.

The design of drape hoses and jumper sections of auxiliary lines not covered above shall be in accordance with API 7K.

10.3 Process Control

Process control shall be in accordance with the applicable document identified in 10.2.

10.4 Quality Control

Quality control shall be in accordance with the applicable document identified in 10.2.

11 Telescopic Joint (Slip Joint)

11.1 Service Classification

11.1.1 General

The four loading conditions for telescopic joint load classification shall be:

— supporting the riser with the tensioners;

— supporting the riser from the top end of the telescopic joint (with the handling tool or the spider) with the inner barrel collapsed and locked;

— supporting the riser with the top end of the telescopic joint with the inner barrel stroked out;

— maximum internal pressure rating (minimum rated component).

11.1.2 Load Capacity

Load capacity of the telescopic joint shall be based on stress magnitude in the weakest load-carrying element when subjected to design load. Allowable stress limits enumerated in Annex C of this specification shall apply to all load-carrying elements of the telescopic joint when the riser system is in service with design load applied.

NOTE Telescopic joint may have independent load ratings for:

a) tension in service, no pressure on C&K and auxiliary lines;

b) tension in service, pressure on C&K and auxiliary lines;

c) collapsed and locked (pinned); and

d) fully extended, supporting load on inner barrel shoe at maximum wear allowance.

Maximum wear allowance for the inner barrel shoe shall be listed in the telescopic joint's operations and maintenance manual.

11.1.3 Stress Amplification Factor (SAF)

SAF or SLR (see Annex I) shall be calculated for the tension in service load case [see Case a) in 11.1.2, Note] in the critical sections to be used in a fatigue analysis.

11.2 Design

A method shall be provided for easily locking the telescopic joint in the closed position to facilitate handling. The packing elements that affect a dynamic seal between the inner and outer barrel shall be designed to allow for replacement while the telescopic joint is in the field.

NOTE 1 The packers may be energized to allow control of sealing with zero visible leakage.

NOTE 2 A lubrication and cooling arrangement may be provided on the upper side of the packer system.

The packer system shall be designed to hold the rated bore pressure with zero leakage while experiencing continuous relative movement induced by the vessel motion. A primary and secondary packer shall be provided, with the primary packer replaceable while the telescopic joint is hanging from the spider.

NOTE 3 The telescopic joint may be designed to integrate with a riser tension ring. Design method for tension ring is addressed in Section 15.

If integral choke, kill, and auxiliary lines on the marine riser terminate at the telescopic joint, provisions shall be made for terminal fittings connected to drape hoses that allow for relative motion between the riser and the vessel. For C&K lines, the terminal fittings shall be designed for erosion resistance.

11.3 Testing

11.3.1 Prototype Testing

The following components shall be prototype tested to a minimum load of 1.25 times the rated load capacity of the component per 11.1.2:

— inner and outer barrel locking mechanism,

— packer housing, and

— other end connections (OECs) in tensile load path excluding those defined in Section 16.

The equipment shall be loaded in essentially the same manner as in actual service.

The test load, equal to 1.25 times the rated load, shall be applied for a period not less than 5 minutes.

A function test of the locking mechanism per 11.3.4 shall be performed after the completion of the prototype load test.

All primary-load-carrying components shall be inspected in accordance with Section 6 after the prototype load test.

11.3.2 Type Certification Testing—Packer Design

11.3.2.1 General

Telescopic joint packer designs shall be subjected to type certification testing. Such testing shall be performed to ensure the capacity of the design to meet the intended service requirements. Specimens used for type certification testing shall be of the same materials and physical dimensions and tolerances as production units.

NOTE Test fixtures that accurately simulate the geometric constraints and sealing surface may be used.

The following tests shall apply.

11.3.2.2 Hydrostatic Test

Internal bore pressure tests shall be conducted at 25 psi, 50 psi, 100 psi, 200 psi, and telescopic joint rated bore pressure. Each test shall demonstrate the pressure retention capability relative to the minimum actuation pressure of the telescoping joint packer system by holding test pressure without visible leakage for a period of not less than 15 minutes. All tests shall be conducted with water.

11.3.2.3 Reciprocation Test

The packer system shall be subjected to an inner barrel reciprocation test. There shall be no visible leakage for 100 cycles of 10 ft single amplitude strokes (10 ft in one direction and reverse for a total of 20 ft of total travel per cycle); maximum cycle time is 25 seconds (1 ft/sec minimum speed average). Separate tests shall be conducted at bore pressures of 25 psi, 50 psi, 100 psi, 200 psi, and telescopic joint rated bore pressure.

NOTE The inner barrel may be lubricated with water.

11.3.2.4 Wear Test—Normal Operation

The packer system shall be subjected to a reciprocating inner barrel wear test. With the packer system energized sufficiently to seal 25 psi bore pressure, the inner barrel shall be reciprocated for 50,000 cycles of 2 ft stroke (2 ft minimum in one direction and reverse for a total of 4 ft minimum of total travel per cycle); maximum time per cycle is 10 seconds. A minimum of 5 cycles/min shall be completed.

NOTE The inner barrel may be lubricated with water.

The test shall not consume more than 10 % of the available sealing element determined by before and after measurement as established by the manufacturer. After the test is completed, the packer system shall satisfy the hydrostatic test requirements as described in 11.3.2.2.

11.3.3 Production Hydrostatic Pressure Test

Pressure-containing systems shall be pressure tested to 1.5 times the maximum rated pressure of that system. The test shall have a hold period of not less than 3 minutes after stabilization with no visible leaks. The pressure test shall be repeated with a hold period of not less than 15 minutes after stabilization with no visible leaks.

11.3.4 Production Functional Test

The locking mechanism shall have a functional test performed to ensure proper operation of the components per manufacturer's written specification.

11.3.5 Design Type Certification Testing—Rotating Telescopic Joint Tensioner Bearing

Tensioner bearings located on the telescopic joint shall be tested in accordance with 15.4.3.

11.4 Materials

Materials shall meet the requirements of Section 5.

11.5 Quality Control

The quality control requirements of Section 6 shall apply to all primary-load-carrying components and/or pressure-containing equipment and components.

11.6 Dimensions

Telescopic joint minimum ID shall be no smaller than the ID of the drilling riser to which it attaches.

11.7 Process Control

Dimensional and weight tolerances for the inner barrel pipe shall conform to API 5L. The sealing surface of the inner barrel shall have a minimum surface finish of standard pipe in accordance with API 5L free from scale and corrosion.

11.8 Marking

The manufacturer shall provide on a nameplate or otherwise affix to each telescopic joint the following information:

— name of manufacturer,

— part number,

— a unique serial number,

— API 16F.

12 Riser Joints

12.1 Service Classification

The riser joint service classification shall be the maximum static tensile capacity for rated load capacity and shall be determined by the weakest structural element (see Annex C). In most instances, the weakest element will be the riser pipe between the riser pin and box couplings. The maximum static tensile capacity of the riser pipe shall be based upon the minimum manufactured wall thickness less a corrosion/erosion allowance of 1.27 mm (0.050 in.) or as otherwise stipulated by the purchaser.

12.2 Design

The riser joint design shall incorporate the following features.

a) The riser joint design shall provide a means for connecting individual riser joints as well as sealing internal pressure in the riser bore and all attaching external lines (choke, kill, and auxiliary line piping).

b) All external lines shall meet the requirements of Section 9 of this specification. Support brackets for these lines shall be designed and axially spaced to provide sufficient support for the external lines under the full range of service loads.

NOTE 1 The elastic stability of the external lines being tested outside of the riser joint assembly is significantly different than the stability of these lines being tested installed in the riser joint.

c) The riser joint design shall provide a means to handle the joint both in the vertical and horizontal positions.

d) The riser joint design shall provide a load shoulder to interface with the riser spider and be of sufficient strength to carry the maximum anticipated hangoff weight of the complete riser string during BOP stack deployment and retrieval.

e) The riser joint shall be designed to withstand the maximum anticipated uplift from buoyancy modules specifically designed for the riser joint.

f) The riser joint shall have a maximum external envelope to permit deployment and retrieval through the rig rotary table (less rotary bushing) and diverter housing.

g) The riser joint design shall minimize exposed external square shoulders that may obstruct deployment and retrieval of the riser.

h) Stresses shall not exceed allowable limits set forth in Annex C for any load combination of allowed tension, bending moment, internal or external pressure, or thermal expansion of any of the parts of the assembled components.

NOTE 2 Under certain conditions, the support from the external auxiliary lines and C&K lines may be considered in the riser joint static tensile capacity load rating.

i) Riser pup joints shall be similar to standard riser joints except for length and shall meet the same design requirements specified for standard length riser joints.

j) The design requirements and qualifications of specifications for marine drilling riser couplings shall conform to Section 16.

12.3 SAF/SLR

The procedure in Annex I shall be used for determining the SAF or SLR using the load cases as described below.

— L_1 = Nominal preload plus 0.2 × rated load.

— L_2 = Nominal preload plus 0.4 × rated load.

— L_3 = Nominal preload plus 0.6 × rated load.

— L_4 = Nominal preload plus 0.8 × rated load.

— L_5 = Nominal preload plus 1.0 × rated load

— L_6 = Minimum preload plus 0.2 × rated load.

— L_7 = Minimum preload plus 0.4 × rated load.

— L_8 = Minimum preload plus 0.6 × rated load.

— L_9 = Minimum preload plus 0.8 × rated load.

— L_{10} = Minimum preload plus 1.0 × rated load.

If SAF/SLR varies with load or preload, this variation shall be documented.

12.4 Pressure Ratings

The primary riser pipe and riser coupling seal shall be rated to the maximum service conditions considering the maximum anticipated water depth, drilling mud weight, and managed pressure drilling (MPD) effects.

The collapse pressure for the main tube shall be calculated per API 5C3 and shall be provided to the purchaser for pipe axial loads equivalent to riser tensions from zero to the rated load of riser joint in increments of no more than 20 %.

The C&K line assemblies shall be consistent with the pressure rating of the BOPs and flow rate capacity as expected and specified by the purchaser.

12.5 Drift Testing

NOTE Drifting of riser is not required unless mandated by the purchaser.

If required, the drift requirements shall be clearly documented in the purchase agreement by purchaser and shall specify the following:

— riser components to be drift tested,

— percentage of components to be drift tested,

— minimum drift diameter,

— minimum drift length,

— required markings,

— type and location.

12.6 Materials and Welding

Materials and welding shall meet the requirements of Section 5.

12.7 Dimensions

The purchaser shall specify the minimum ID of the riser joint.

The minimum ID of the riser joint shall not be less than the minimum bore of the BOP stack, unless otherwise agreed to with the purchaser.

The riser pipe nominal outside diameter and wall thickness shall be specified by the manufacturer unless otherwise agreed to with the purchaser.

The overall length of a standard riser joint and pup joints shall be specified by the purchaser.

12.8 Process Control

The manufacturer shall be responsible for maintaining documentation to ensure conformance of the riser joint design to this specification.

Additionally, raw material traceability to heat number, including the chemical physical and mechanical properties of load-bearing and pressure-containing components, shall be maintained through the complete manufacturing cycle.

12.9 Quality Control

Quality control shall conform to the requirements of Section 6.

12.10 Marking

The riser joint shall be permanently marked using a low-stress method. Marking shall correspond to a data sheet for the joint. The data sheet shall include as a minimum the manufacturer’s name and part number, a unique serial number, the maximum load ratings, the as-built assembled weight excluding buoyancy and protectors, and indication of conformance to API 16F.

The marking on the riser joint shall include the following information:

— name of manufacturer,

— part number,

— a unique serial number,

— maximum load rating,

— API 16F.

13 Buoyancy Equipment

13.1 General

Design of riser buoyancy equipment shall conform to the requirements of this specification.

NOTE Buoyancy is generally provided by the use of syntactic foam modules. Alternatively, air cans provide buoyant lift in some applications.

13.2 Syntactic Foam Modules

13.2.1 Service Classification

Syntactic foam buoyancy equipment shall be classified according to its rated service depth, which is the maximum depth in seawater at which it will provide buoyancy within design limits. The manufacturer shall type certify the service depth rating for each syntactic foam composition by hydrostatic testing as described in 13.2.6.6.

13.2.2 Design

The purchaser shall specify the net lift per joint to be provided by the equipment. The buoyancy calculation shall be based on the weight in seawater of the riser and all its metal accessories, as shown in the following example.

— Riser joint weight in air = 11,250 lb.

— Riser joint weight in seawater = 0.87 × 11,250 = 9,788 lb.

— Desired buoyancy to lift = 95 % (defined by purchaser).

— Net lift per joint= 0.95 × 9,788 = 9,298 lb.

NOTE This is nominal buoyancy; tolerances on buoyancy are defined in 13.2.6.4. The above calculation is based on a standard carbon steel riser and a nominal seawater density SG = 1.025. Other seawater densities and/or riser material will require alternate calculation formulas.

The design and construction of the modules shall meet the purchaser's specified requirements of riser handling, storage, and maximum riser deflection (under dynamic conditions) based on parameters of the stacking arrangements (i.e. cordwood vs vertical, battens/no battens, etc.). The material shall be strong enough to permit riser joints with buoyancy to be safely stacked without damaging the modules and without affecting performance. The manufacturer shall state the maximum height to which joints can be stacked without damage under conditions specified by the purchaser. These conditions shall be documented.

The length of the buoyancy equipment shall be such that sufficient clearance is provided for riser couplings and for supporting the riser on the spider during riser deployment and retrieval. The buoyancy equipment shall allow for adequate clearance for external lines and their support clamps.

Thrust collars shall be provided for the transfer of longitudinal forces into the riser pipe or connectors. The downward longitudinal force shall be assumed to be at least twice the full dry weight load (to account for impact loads), and the upward force shall be the total net buoyancy force.

The syntactic foam modules shall be attached to the riser with material of sufficient strength to hold the modules securely in place. The design shall be such that the attachment means is not exposed to damage in normal handling. 316SS or other comparable corrosion-resistant material shall be used for attachment hardware.

13.2.3 Material

The exterior of syntactic foam shall resist impact and abrasion encountered in normal handling.

The manufacturer shall meet the following requirements from UL 94 for material classed HBF (horizontal burning foamed).

— No specimen shall have a burning rate that exceeds 40 mm/min over a 100-mm span.

— A specimen shall cease to burn before flaming or glowing reaches the 125-mm gauge mark.

NOTE See UL 94 for test procedures.

13.2.4 Dimensions

The internal radius of the modules shall conform to the outer radius of the riser pipe without binding or excessive looseness. The purchaser shall specify any special shape requirements.

NOTE Flexure lugs or elastomeric spacers may be located on the inner radius of each module to provide clearance and prevent transfer of bending forces between riser and buoyancy equipment.

13.2.5 Process Control

The manufacturer shall establish a process and records system that identifies the process variables associated with the manufacture of each individual buoyancy module.

Complete records shall be kept of the manufacturing process and made available to the purchaser. At minimum, the records shall include the following:

— module serial number and date of molding,

— quality control data of the molding material,

— quality control data of the curing process,

— dimensional measurements,

— hydrostatic testing,

— finished weight in air and seawater buoyancy,

— all data points, calculated averages, or buoyancy loss shall be reflected to two decimal points i.e. 4.00 % using standard rounding methodologies.

13.2.6 Inspection and Testing

13.2.6.1 General

Testing of core sections or coupons shall not be acceptable for either qualification or conformance testing.

13.2.6.2 Quality Assurance Plan

Buoyancy modules shall be dimensionally and mechanically inspected to ensure conformance to drawings and specifications at no less than the following intervals:

— “first article” of the first part molded,

— “mold approval” on the first part from each mold,

— “random sampling” of at least 5 % of production from each mold.

13.2.6.3 Module Documentation

A production/inspection data sheet, containing the following information as a minimum, shall be prepared for each module.

a) Serial number and date of molding.

b) Service depth rating.

c) Measured dry weight.

d) Calculated submerged weight in seawater (SG = 1.025).

e) Displaced volume of water.

f) Specified foam density.

g) Actual foam density.

h) Net buoyancy in fresh and seawater (SG = 1.025).

i) All critical dimensions.

j) Flatness/straightness.

k) Serial number of mold used to produce the module.

l) Flammability rating.

NOTE Items d), e), g), and h) are to be provided on the basis of a 5 % random sample of modules produced from each mold.

13.2.6.4 Buoyancy Verification

Tolerance limits on net lift shall be:

— any individual module: ±5 % from design, and

— average of all modules of the same depth rating: ±2 % from design.

NOTE For smaller quantities, only the individual module tolerance is applicable (average of modules requirement is not applicable).

Smaller quantities shall be defined as the lesser of 450 ft of cumulative riser footage, or 50 modules, of same depth rating buoyancy.

Net lift for a module shall be the lift provided by the module calculated using the measured weight of the module, the water weight of the attachment hardware, the average volume of the type of module at approximately atmospheric pressure, and the density of seawater with a specific gravity of 1.025. The manufacturer shall document the details of the calculation method and data used for the net lift calculations.

For riser analysis the following shall be considered.

— Take into account mounting hardware and stop collars, either with the module weight and volume used, or accounted for separately.

— Temperature effects and seawater specific gravity differences for specific geographic locations separately.

— Buoyancy loss caused by pressure effects, water ingress, etc., separately. Hydrostatic sampling of modules provides data for making appropriate allowances in the analysis.

13.2.6.5 Hydrostatic Testing Requirements

13.2.6.5.1 General

Three levels of hydrostatic testing shall be required.

13.2.6.5.2 Type Certification Testing

These tests shall provide assurance that the syntactic foam does not absorb water at an excessive rate while under pressure. The manufacturer shall perform tests or produce records of prior tests that confirm that the material is qualified for rated service depth.

The qualification test material shall be the same nominal density (specific weight) as the material to be used for production parts.

Crush strength shall be at least 1.25 times the hydrostatic pressure at service depth.

A minimum of two modules for each test (crush strength and buoyancy loss) shall be tested. The modules submitted for testing shall not have been subjected to prior pressure testing.

Testing shall follow the procedure given in 13.2.6.6. The test pressure shall correspond to the service depth rating of the modules. The test duration shall be 96 hours.

Acceptance criteria shall be based on the results of the 96-hour tests with the last 72 hours of data extrapolated over a 12-month period.

i) The total buoyancy loss of a module shall not exceed

— 4 % for buoyancy rated to a depth of 6000 ft or shallower,

— 5 % for buoyancy rated to a depth greater than 6000 ft.

ii) Compression of material at service depth shall not cause more than 1.50 % loss of net volume.

Mechanical damage shall not exceed manufacturer's written specification.

13.2.6.5.3 Initial Production Testing

One complete set of first production modules for each depth rating produced by the supplier shall be tested. The tests shall follow the procedures given in 13.2.6.6.

Acceptance criteria shall be based on the results of a 24-hour test with the last 20 hours of data extrapolated over a 12-month period.

i) The total buoyancy loss of a module shall not exceed

— 4 % for buoyancy rated to a depth of 6000 ft or shallower,

— 5 % for buoyancy rated to a depth greater than 6000 ft.

ii) The modules shall not have any visual defects that exceed those allowed by the manufacturer's written specification.

iii) The modules shall be dimensionally correct and provide the required amount of buoyancy within the tolerances of the manufacturer's written specification.

NOTE These modules, if they pass the test, may be considered as part of the production order.

13.2.6.5.4 Production Sample Testing

Actual production shall be subject to sample conformance testing. The manufacturer or an independent testing facility shall test at least 5.0 % of the modules (one out of a batch of 20 consecutive serial numbers of a given geometry and depth rating) at hydrostatic pressure corresponding to the rated service depth.

The tests shall follow the procedures given in 13.2.6.6 with the exception that the test duration shall be 24 hours.

Acceptance criteria shall be as follows.

i) Manufacturer shall have written criteria for inspection and acceptance of buoyancy subjected to hydrostatic pressure test.

ii) The total buoyancy loss of a module shall not exceed

— 5 % based on the results of the 24-hr tests with the last 20 hours of data extrapolated over a 12-month period for buoyancy of a depth rating deeper than 6000 ft,

— 4 % based on the results of the 24-hr tests with the last 20 hours of data extrapolated over a 12-month period for buoyancy of a depth rating of 6000 ft or shallower.

iii) If the sample module, selected by a method agreed to by the customer and the manufacturer, fails the above acceptance criteria for conformance testing, the following procedure shall be followed.

If the sample module fails the test, the supplier shall proceed with testing of two additional modules from the same batch. If both of these modules pass the test, then the entire batch shall be regarded as acceptable. If one or both of these test modules fail the test, then the entire batch shall be quarantined.

NOTE 1 The supplier, at their discretion, may elect to test each individual module remaining in the batch.

Only modules that pass the acceptance criteria shall be deemed as acceptable.

NOTE 2 Modules not passing the acceptance criteria may, at the customer's discretion, be rerated for another depth rating, or accepted as is with the test failure noted.

13.2.6.6 Hydrostatic Test Procedure

The following procedures shall be followed.

a) Weigh and record the weight of each module in air.

b) Immerse in fresh water and verify the module submerged weight. Calculate and record actual density. Correction for actual buoyancy in seawater shall be recorded.

c) Seal hyperbaric chamber and gradually increase test pressure until maximum test pressure is attained. The pressure ramp rate for the hydrostatic crush test only shall not be more than 5 bars/min. Check and record buoyancy loss during this period.

d) Maintain test pressure continuously for the specified test duration. Record changes in buoyancy and temperature at intervals of no less than 5 minutes during this period.

e) Depressurize the chamber.

f) Remove modules from chamber. Weigh and record results. Inspect for mechanical damage.

g) Extrapolate the total buoyancy loss data over a 12-month period from the results obtained.

h) Buoyancy loss shall be represented in percentage terms to two decimal points i.e. 4.00 % using standard rounding methodologies. The extrapolation method employed shall be recorded in the manufacturer’s data books.

NOTE Total buoyancy loss includes initial compressive losses resulting from the bulk modulus and the losses caused by water ingress and damage.

13.2.7 Markings

Syntactic foam buoyancy modules shall be pigmented or painted a highly visible color.

Each module shall have, as a minimum, the following information shall be printed indelibly on its surface:

— manufacturer,

— module serial number (see 13.2.5),

— service depth rating,

— API 16F.

Serial numbers shall be located in a minimum of three places on each module: the outer surface, the inner surface, and the end of the module.

Each module shall be identified with a color code for each depth rating as agreed by manufacturer and purchaser.

13.2.8 Data Sheet

A data sheet shall be provided for each module. The data sheet shall include, as a minimum, the module's serial number, volume, air weight, calculated net lift in seawater, and average water absorption vs time for the batch.

13.2.9 Packaging

The manufacturer shall supply packaging that will ensure damage free shipment and storage.

14 Riser Running and Handling Equipment

14.1 General

Handling tools for the riser and the diverter, if used to support the riser and the BOP stack, shall be designed for hoisting and lowering the riser system through the riser spider and rotary table and be designed and rated in accordance with 14.3.

Riser hangoff spiders shall be rated to support the riser system and BOP stack at the drill floor level. The riser spider and gimbal/shock absorber, if applicable, shall be designed and rated in accordance with 14.3.

Testing of the riser handling tools, riser spider, and gimbal/shock absorber shall follow the requirements of 14.4.

14.2 Coverage

This section shall apply to the following riser running and handling equipment, including but not limited to:

— manual riser running tools;

— hydraulic riser running tools;

— riser spiders;

— riser gimbals;

— equipment used to lift, run, retrieve, or support the riser string and BOP stack.

14.3 Design

14.3.1 Loading

Equipment in 14.2 shall be designed for the following loads:

— maximum rated static load capacity,

— angular capacity of gimbal,

— bending loads (during handling),

— loads due to pressure.

The gimbal assembly pivoting stiffness as a function of compressive load shall be documented by the manufacturer. Load capacity at maximum angular capacity shall be reported considering strength requirements per 14.3.2 and riser coupling lift off from landing shoulder.

14.3.2 Strength Analysis

14.3.2.1 General

The equipment design analysis shall address yielding, buckling, deflection, and rupture as possible modes of failure.

Finite element analysis, in conjunction with closed form analytical solutions, may be used. All forces that may govern the design shall be taken into account. For each cross section to be considered, the most unfavorable combination, position, and direction of forces shall be used.

14.3.2.2 Allowable Stress

Stress allowables shall be determined per Annex C. The design safety factor shall be as stated in 14.3.2.3.

14.3.2.3 Design Safety Factor

The design safety factor, SF_D, shall equal 2.25.

The design safety factor is intended as a design criterion and shall not under any circumstances be construed as allowing loads on the equipment in excess of the load rating.

14.3.2.4 Contact Stresses and Geometric Discontinuities (Secondary Stresses)

For areas with contact stresses and geometric discontinuities, the primary membrane stress through the section shall meet the requirements of 14.3.2.2. The rated load capacity with design safety factor shall be analyzed per 14.3.2.6 when the primary membrane stresses exceed the limits in 14.3.2.2.

For areas where secondary stresses exceed the allowables of 14.3.2.2, the requirements of 14.3.2.5 shall apply.

14.3.2.5 Ultimate Strength (Plastic) Analysis

The lower bound true stress–true strain curve, with strain hardening and change in geometry, shall be used for determining the local strain limit and shakedown of the high-stress region. The curve shall be based on the specified minimum yield stress. The material model for this type of analysis shall be defined by either or both of the following:

— the yield surface defining when plastic strains are generated shall be modelled using von Mises plasticity,

— the kinematic hardening model defining how the yield surface changes for plastic strains.

The load shall be increased incrementally in the finite element analysis model of the structure until the model fails to converge or the deformation is large enough such that the structure no longer serves its purpose per the functional requirements. This shall be the lower bound load. The rated load shall be the lower bound load divided by the safety factor in 14.3.2.3.

NOTE The use of the method in this section requires local strains to be analyzed for the test load with the addition of a few cycles of the rated load to determine if shakedown occurs, i.e. no progressive distortion or stress ratcheting.

14.3.2.6 Limit Analysis (Elastic Perfectly Plastic Analysis) (Alternate Method)

The finite element model shall be loaded until the lower bound collapse load is identified by failure of the numerical solution to converge. The nonlinear analysis shall be conducted with a material model that defines yielding using a bilinear von Mises plasticity. For this method, stresses less than the yield strength shall have a slope equal to the elastic modulus of the material; above yield the slope shall be as near zero as numerically practical.

NOTE 1 The lower bound collapse load, per the above paragraph, is the limit load. The rated load using this method is the limit load divided by the safety factor in 14.3.2.3.

NOTE 2 The results of the limit analysis may be used to justify primary membrane stresses exceeding the stress allowables in 14.3.2.2, but not secondary stresses.

The rated load determined using the method in 14.3.2.5 shall be greater than the rated load determined using the limit analysis method.

14.3.2.7 Bolted Connections

Bolts subject to the primary load shall meet the requirements of Equation (5) **or** (6):

a) for calculation-based analysis or when FEA results show joint separation (i.e. when the contact pressure between the bolted components ≤ 0).

$$\frac{2.25 \times \text{rated load}}{A_{\text{bolt}}} \leq S_{\text{y}} \quad (5)$$

b) when FEA results show that a joint does not separate (i.e. the contact pressure between the bolted components > 0).

$$\frac{\text{Preload + (joint stiffness constant} \times 1.5 \times \text{rated load)}}{A_{\text{bolt}}} \leq 0.83 S_{\text{y}} \quad (6)$$

where

A_{bolt} is the minimum cross section of the bolt being considered.

Equation (6) considers the effective joint stiffness, i.e. bolt stiffness plus the clamped components stiffness. Both Equations (5) and (6) consider only the membrane stresses through the bolt section and do not account for secondary and bending effects.

14.3.2.8 Pressure-containing Components

Pressure-containing components shall be designed using the design methodology and stress allowables described in Annex C. The design safety factor shall be per Annex C.

14.3.3 Design Verification

The design shall be verified using an independent source outside of the design process.

14.4 Testing

14.4.1 Prototype Testing

Prototype testing shall be performed to validate the strength analyses specified in 14.3.2. The component rated load shall be applied to verify any assumptions made in the analysis of the component.

NOTE The prototype testing has two primary objectives: to verify any assumptions made about preloading, separation behavior, friction coefficients, structural material response, and boundary conditions and to substantiate the analytical stress predictions.

Strain measurements shall be determined as near as physically possible to at least five of the highly stressed locations and five locations away from stress concentrations as predicted by the methods in 14.3.2. The measurements shall correlate to the design methodology used to within manufacturer's acceptance criteria.

14.4.2 Production Testing

14.4.2.1 Proof Load Test

To ensure conformity with specified requirements, the production unit shall be tested to a minimum load of 1.5 times the rated load capacity of the component.

NOTE Gimbals need only be loaded in the axial direction.

The equipment shall be mounted in a test fixture capable of loading the equipment in the same manner as in actual service and with the same areas of contact on the load-bearing surfaces.

The test load, equal to 1.5 times the rated load, shall be applied for a period not less than 5 minutes.

All primary-load-carrying components shall be inspected in accordance with Section 6 after the production load test.

14.4.2.2 Pressure Test

Pressure-containing systems shall be pressure tested to 1.5 times the maximum rated pressure of that system for a period not less than 5 minutes after stabilization with no detectable leaks. The pressure test shall be performed after the production load test and inspection in accordance with Section 6.

14.4.2.3 Functional Test

Functional test shall be performed to ensure proper operation of the components. The function test shall be performed after the completion of the production load test and after the completion of the pressure test including inspection in accordance with Section 6.

14.5 Materials

14.5.1 General

The material requirements for all primary-load-carrying components and/or pressure-containing equipment and components shall conform to Section 5, unless specified below.

14.5.2 Chemical Composition

The maximum mass fraction of sulfur and phosphorous shall each be 0.025, expressed as a percentage.

14.5.3 Mechanical Properties

Impact and tensile properties shall apply as follows:

a) *Impact Properties*.

Subsize test pieces of width less than 5 mm as defined in ASTM A370 shall not be used. Material is not required to be impact tested at or below 6 mm thickness.

For materials of a specified minimum yield strength of at least 310 MPa (45 ksi), the average impact toughness shall be 42 J (31 ft-lb) at −20 °C (−4 °F) with no individual value less than 32 J (24 ft-lb).

For materials with a minimum specified yield strength of less than 310 MPa (45 ksi), the average impact toughness shall be 27 J (20 ft-lb) at −20 °C (−4 °F) with no individual value less than 20 J (15 ft-lb).

For design temperatures below −20 °C (−4 °F) (e.g. arctic service), the following supplementary impact toughness requirements shall apply.

— The maximum impact test temperature for materials used in primary-load-carrying components with a required minimum operating temperature below −20 °C (−4 °F) shall be specified by the purchaser.

— Impact testing shall be performed in accordance with Section 6 and ASTM A370. The minimum average Charpy impact energy of three full-size test pieces, tested at the specified (or lower) temperature, shall be 27 J (20 ft-lb) with no individual value less than 20 J (15 ft-lb).

— Each primary-load-carrying component shall be marked "LTT" to indicate that low-temperature testing has been performed using low-stress, hard die-stamps near the load rating identification. Each primary-load-carrying component shall also be marked to show the actual design and test temperature in degrees Celsius.

b) *Tensile Properties*.

Components shall be fabricated from materials meeting the applicable requirements for ductility specified in the Table 4.

Where the design requires through-thickness properties (typically required for plate and rolled shapes), the material shall be tested for reduction of area in the through-thickness direction in accordance with ASTM A770. The minimum shall be 25 %.

Table 4—Elongation Properties

Yield Strength		**Elongation, minimum %**	
MPa	ksi	$L_0 = 4d$	$L_0 = 5d$
Less than 310	Less than 45	23	20
310 to 517	45 to 75	20	18
Over 517 to 758	Over 75 to 110	17	15
Over 758	Over 110	14	12
Where L_0 is the gauge length and d is the diameter.			

14.6 Quality Control

The quality control requirements of Section 6 shall apply to all primary-load-carrying components and/or pressure-containing equipment and components.

14.7 Dimensions

Verification of dimensions shall be carried out on a sample basis as defined and documented by the manufacturer.

All main load-bearing and pressure-sealing threads shall be gauged to the requirements of the relevant thread specification(s).

The manufacturer shall specify the maximum diameter of riser string component that can pass through the spider with the dogs or jaws retracted.

The verification of external interface dimensions shall be carried out on each components and/or assembly as relevant.

14.8 Marking

Components designed to Section 14 shall be marked using permanent low-stress, metal impression stampings with the following information:

— name of manufacturer,

— part number,

— unique serial number,

— maximum load rating,

— API 16F.

15 Tensioner Rings

15.1 General

15.1.1 General

A tensioner ring shall be incorporated to allow attachment of the purchaser-specific number of riser tensioning lines. The tensioner ring shall be of either the fixed or swiveling type as specified by the purchaser. Purchaser shall specify the maximum individual load ratings of the tensioning lines. For dynamically positioned and turret-moored vessels, the tensioner ring shall be designed to permit the ring to rotate while design tensile load is applied to the telescopic joint outer barrel.

NOTE Tensioner rings or riser support rings may be integrated into the telescopic joint in order to apply varying tension into the riser string during operational procedures.

15.1.2 Nonrotating Tensioner Rings

Nonrotating tensioner rings shall be designed per the requirements of this specification

A design certification report or series of reports shall be prepared to qualify each tensioner ring joint design. This report shall include:

— description of design, attachment to the telescopic joint, and storage of the tensioner ring when not connected to the telescopic joint;

— proper lubrication type and frequency of lubrication;

— the effects of bending and deflection; and

— the effects of asymmetric loading on the structural integrity in the event of the failure of at least one tensioner or a larger number as specified by the purchaser.

15.1.3 Rotating Tensioner Rings

For dynamically positioned and turret-moored vessel systems, the tensioner ring shall rotate through a rotating mechanism either integral to the tension ring or to the telescoping joint.

NOTE The rotating mechanism inherently has a degree of rotational friction.

A design certification report or series of reports shall be prepared to qualify each tensioner ring joint design. This report shall include:

— description of design, attachment to the telescopic joint, and storage of the tensioner ring when not connected to the telescopic joint;

— summary of frictional performance as a function of tension load and of any rotational operating parameters, e.g. hydraulic pressure;

— proper lubrication type and frequency of lubrication;

— the effects of bending and deflection on the rotational characteristics; and

— the effects of asymmetric loading on the structural integrity in the event of the failure of at least one tensioner or a larger number as specified by the purchaser.

15.2 Service Classification

The tensioner ring service classification shall be the maximum static tensile capacity for the rated load capacity of the riser system, tensioner system, or as otherwise stipulated by the purchaser.

The tensioner ring service classification shall designate if the design is rotating or nonrotating.

15.3 Design

15.3.1 Strength Analysis

The equipment design analysis shall address yielding, buckling, deflection, and rupture as possible modes of failure.

Finite element analysis, in conjunction with closed form analytical solutions, may be used. All forces that may govern the design shall be taken into account. For each cross section to be considered, the most unfavorable combination, position, and direction of forces shall be used.

15.3.2 Design Safety Factor

The design safety factor, SF_D, shall be per Annex C.

15.3.3 Allowable Stress

Linearized stresses and associated stress allowables shall be determined per Annex C. The design safety factor shall be as stated in 15.3.2.

15.3.4 Pressure-containing Components

Pressure-containing components shall be designed using the design methodology and stress allowables described in Annex C. The design safety factor shall be per Annex C.

15.4 Tension Ring or Hands Free Gooseneck – Secondary Locking

15.4.1 General

A mechanical secondary lock shall be installed to prevent the unintended release from the storage and operating position(s).

15.4.2 Design

The secondary lock system shall be designed to maintain engagement even if the primary unlock function is engaged. The lock system design shall account for other loads that may arise in rated operating conditions, such as back-driving.

Examples of secondary lock(s) may include:

- Hitch pins,
- Secondary bolts.

A discrete remote function to actuate the secondary lock is permissible provided that this remote function is not required to keep the lock engaged.

15.4.3 Prototype Testing

A prototype test shall validate the ability of the secondary lock mechanism to maintain the primary locks in the locked position even if the primary unlock function is engaged. This test load shall be 1.25 times the design load. Testing of the secondary lock in a fixture is permissible.

15.4.4 Production Testing

Production testing of the full ring assembly shall include a function test of the secondary unlock design load.

15.5 Testing

15.5.1 Production Testing

15.5.1.1 General

To ensure conformity with specified requirements, the design of the padeyes or direct-acting tensioner attachment points shall be validated using test of production products to a minimum load of 1.25 times the rated load capacity in the axial direction of the component.

The equipment shall be mounted in a test fixture capable of loading the equipment in essentially the same manner as in actual service and with essentially the same areas of contact on the load-bearing surfaces.

NOTE 1 Padeyes may be tested using opposing pairs or may be tested altogether.

The test load, equal to 1.25 times the rated load, shall be applied for a period not less than 5 minutes.

All primary-load-carrying components shall be inspected in accordance with Section 6 as appropriate after the production load test.

NOTE 2 If the tensioner attachments (padeyes) are directly welded to the outer barrel the production test may be applied to the section of outer barrel prior to welding the section into the overall telescopic joint weld assembly.

15.5.1.2 Pressure Test

Pressure-containing systems shall be pressure tested to 1.5 times the maximum rated pressure of that system. The test shall have a hold period of not less than 3 minutes after stabilization with no visible leaks. The pressure test shall be repeated with a hold period of not less than 15 minutes after stabilization with no visible leaks.

15.5.1.3 Functional Test

Functional test shall be performed to ensure proper operation of the components per manufacturer's written specification. The function test shall be performed after the completion of the production load test.

15.5.2 Prototype Testing

To ensure conformity with specified requirements, the locking mechanism used to attach the tension ring to the riser string component or diverter housing shall be prototype tested to a minimum load of 1.25 times the rated load capacity of the component.

The equipment shall be mounted in a test fixture capable of loading the equipment in essentially the same manner as in actual service and with essentially the same areas of contact on the load-bearing surfaces. A single locking mechanism may be tested in lieu of the entire assembly.

The test load, equal to 1.25 times the rated load, shall be applied for a period not less than 5 minutes.

All primary-load-carrying components shall be inspected in accordance with Section 6 as appropriate after the production load test.

15.5.3 Design Type Certification Testing—Rotating Tensioner Rings

For type certification of a rotating tensioner ring design, a scaled model or full-scale ring shall be tested. The amount of torque needed to initiate rotation (breakaway) and running torque shall be measured for at least four axial tension loads in equal increments up to the maximum tension rating of the swivel. Tests shall be run at each tension load in increasing order and then repeated in decreasing order (it is not necessary to repeat the test at the highest tension) using the following procedure.

— At each tension load increment level, rotate the ring under test load through 360° (or maximum design range) at 2° to 4° per minute in increments of at least 90°. Peak and average torque shall be documented at each increment of rotation. The data shall also be summarized as peak and average torque for each load level over the entire range of rotation.

— At each load increment, rotate the ring under test load 10° in less than 30 seconds and document breakaway and running torque under the load considered.

— If scaled model testing is used in place of full-scale testing, the manufacturer shall demonstrate that the extrapolated stresses and torques do not under-predict the full-scale values.

15.6 Materials

Materials shall meet the requirements of Section 5.

15.7 Quality Control

The quality control requirements of Section 6 shall apply to all primary-load-carrying components and/or pressure-containing equipment and components.

15.8 Dimensions

Verification of dimensions shall be carried out on a sample basis as defined and documented by the manufacturer.

All main load-bearing and pressure-sealing threads shall be gauged to the requirements of the relevant thread specification(s).

The manufacturer shall specify the maximum diameter of riser string component that can pass through the spider with the dogs or jaws retracted.

The verification of external interface dimensions shall be carried out on each components and/or assembly as relevant.

15.9 Marking

Components designed to Section 15 shall be marked using permanent low-stress, metal impression stampings with the following information:

— name of manufacturer,

— part number,

— unique serial number,

— maximum load rating,

— API 16F,

— individual rated load of each padeye shall be marked on the padeye.

16 Riser Coupling

16.1 General

The design, rating, manufacturing, and testing of marine drilling riser couplings shall follow the requirements of this section.

Coupling capacity shall be rated in accordance to 16.2.3 to enable the grouping of coupling models according to their maximum stresses developed under specific levels of loading, regardless of manufacturer or method of makeup.

16.2 Service Classification

16.2.1 General

The coupling manufacturer shall provide design information for each coupling size and model that defines load capacity rating and load-sharing or non-load-sharing designation. These data shall be based on rated load (defined in 16.2.3) and verified by testing (specified in 16.5).

16.2.2 Size

Riser couplings shall be categorized by size of the riser main tube. Riser pipe outer diameter and wall thickness (or wall thickness range) for which the coupling is designed shall be documented. The categorization shall include the characteristics of C&K and auxiliary lines (diameters, wall thicknesses, and grades of steel for each).

16.2.3 Rated Load

The rated loads listed shall provide a means of general classification of coupling models based on stress magnitude caused by applied load. To qualify for a particular rated load, neither calculated nor measured stresses in a coupling shall exceed the allowable stress limits of the coupling material when subjected to the rated load (see Annex C for the allowable material stresses).

The rated loads shall be as follows:

— 0.50 million pounds,

— 1.00 million pounds,

— 1.25 million pounds,

— 1.50 million pounds,

— 2.00 million pounds,

— 2.50 million pounds,

— 3.00 million pounds,

— 3.50 million pounds,

— 4.00 million pounds,

— 4.50 million pounds,

— 5.00 million pounds.

NOTE The rated load or rated working pressure of the coupling may be greater than that of an assembled riser joint.

16.2.4 Rated Working Pressure

Riser couplings shall be designed to provide a pressure seal between joints. The manufacturer shall document the rated internal working pressure for each riser coupling.

16.2.5 Running and Retrieval Rated Load

The manufacturer shall document the riser handling loads for which the coupling is designed and how these loads are applied.

NOTE Temporary loads are induced by suspending the riser from the handling tool and/or spider.

16.3 Design Loads

Additional sources of applied load that are not included in the rated load may significantly affect the coupling design and shall be included in design calculations. These additional loads are described below.

— *Loads Induced by C&K and Auxiliary Lines*.

The manufacturer shall document those loads induced by choke, kill, and auxiliary lines for which the coupling has been designed.

NOTE Riser couplings typically provide support for C&K and auxiliary lines. This support constrains the lines to approximate the curvature of the riser pipe. Loads can be induced on the coupling from pressure in the lines, imposed deflections on the lines, and the weight of the lines. Another possible source of loads is differential temperatures in the lines.

— *Loads Induced by Buoyancy*.

The manufacturer shall document the buoyancy thrust loads for which the coupling has been designed.

NOTE Riser couplings may provide support for buoyancy, which induces loads on the couplings.

16.4 Design Analysis

16.4.1 Stress Analysis

The design of a riser coupling for static loading shall require that it support the design load and preload, if any, while keeping the maximum cross-sectional stresses within specified allowable limits. For all riser coupling components except bolts, stress levels shall be kept below the values provided in Annex C of this specification.

For load-carrying bolts in bolted-flange couplings, the manufacturer shall document the design allowable stress levels in the bolts. Acceptance criteria for these bolt stresses shall be based on recognized codes and standards.

Design of riser couplings for static loading (Annex C) and determination of the stress amplification factor shall require detailed knowledge of the stress distribution in the coupling. A finite element analysis of the riser coupling shall be performed and documented. The analysis shall provide accurate or conservative peak stresses and shall include any deleterious effects of loss of preload from wear, friction, and manufacturing tolerances. See Annex D for suggestions for the analysis.

The following shall be documented and included in the analysis:

— grid size,

— boundary conditions,

— preload losses,

— software and version.

Finite element analysis shall be verified by strain gauge test of prototype in accordance with 16.5.

16.4.2 SAF/SLR

The procedure in Annex I shall be used for determining the SAF and or SLR using the load cases as described below.

— L_1 = Nominal preload plus 0.2 × rated load.

— L_2 = Nominal preload plus 0.4 × rated load.

— L_3 = Nominal preload plus 0.6 × rated load.

— L_4 = Nominal preload plus 0.8 × rated load.

— L_5 = Nominal preload plus 1.0 × rated load

— L_6 = Minimum preload plus 0.2 × rated load.

— L_7 = Minimum preload plus 0.4 × rated load.

— L_8 = Minimum preload plus 0.6 × rated load.

— L_9 = Minimum preload plus 0.8 × rated load.

— L_{10} = Minimum preload plus 1.0 × rated load.

The SAF/SLR for the pin and for the box of the coupling shall be calculated. If SAF/SLR varies with load or preload, this variation shall be documented.

16.4.3 Design Documentation

For each size, model, and service classification, the following documentation shall be retained by the manufacturer for a period of at least 10 years after the manufacture of the last unit of that size, model, and service classification:

— design loads (tensile, bending, loads from auxiliary lines, and others) as defined in this section;

— finite element analysis performed in accordance with 16.4.1;

— results of tests performed in accordance with 16.5;

— results of SAF/SLR and peak stress calculations in accordance with 16.4.2.

16.5 Testing

16.5.1 General

Three types of full-scale design qualification tests shall be performed:

— a tensile load test to establish the rated load of the coupling design,

— a makeup test to demonstrate the ability of the coupling to be correctly made up in the field and the repeatability of proper makeup, and

— an internal pressure test to check pressure integrity and seal effectiveness.

These tests shall be performed on a full-scale coupling specimen(s) to qualify the design of each coupling model.

To assure validity of the test results, the testing machine shall be qualified and calibrated and so documented.

The test coupling for all verification and qualification tests shall be built to standard dimensions and manufacturing tolerances and have standard finishes, coatings, and materials. These tests and those described in 16.5.2 shall be for design evaluation only; they are not intended for in-service readiness testing.

NOTE Optional performance tests listed in Annex J may also be included. A cyclic load or fatigue test may be performed to verify fatigue calculations and to check that no areas of stress concentration were overlooked in the design analysis.

Cyclic testing to failure yields a data point to aid in predicting fatigue life. Other optional performance testing may be included to substantiate serviceability.

16.5.2 Design Qualification Tests

16.5.2.1 Load Rating Test

Tensile load shall be applied to qualify the coupling design for a rated load as defined in 16.2.3.

NOTE Normal design qualification tests may be performed simultaneously with the verification testing per 16.5.3.

16.5.2.2 Makeup Test

The manufacturer's standard makeup tools shall be used to apply preload to the coupling. Strain measurements from selected points on the coupling, performed in accordance with 16.5.3, should corroborate the values used in the analysis performed per 16.4.1. Measured preload stresses shall meet or exceed the minimum required preload stresses over at least 10 successive makeup sequences.

16.5.2.3 Internal Pressure Test

Internal water pressure equal to the coupling rated working pressure shall be applied with no structural failure or leaks.

16.5.3 Verification Test

After completion of the design studies, a prototype (or multiple prototypes) of the riser coupling shall be tested to verify the stress analysis.

The testing shall have two primary objectives:

— to verify any assumptions that were made about preloading, separation behavior, and friction coefficients;

— to substantiate the analytical stress predictions.

Strain measurement data shall be used to measure preload stresses as they relate to makeup load or displacement.

The coupling design load shall be applied to verify any assumption made in the analysis regarding separation.

Strain measurements shall be taken as near as physically possible to at least five of the most highly stressed regions as predicted by the finite element analyses performed in accordance with 16.4.1 and in five locations away from stress concentrations. All strain measurements and the associated loading conditions shall be recorded in a manner that they may be retained as part of the coupling design documentation. The measurements shall correlate to the design methodology used within manufacturer's acceptance criteria.

NOTE It is often difficult to acquire sufficient strain data to totally correlate with the analytical results. High-stress areas may be inaccessible and are sometimes so small that a strain measurement gives an average rather than the peak value. The testing may serve to verify the pattern of strain in regions surrounding the critical points.

16.6 Material

16.6.1 Mechanical Properties

All materials shall meet the minimum and maximum mechanical properties per Section 5 except as noted in this section.

Mechanical testing shall be performed per 5.4 after all heat treatment for mechanical properties.

16.6.2 Impact Testing

Mechanical testing shall be performed per ASTM A370, ASTM E23, or equivalent after all heat treatment for mechanical properties and shall use representative test coupons. Notch impact tests shall be performed with the test specimens oriented longitudinal or transverse to the grain orientation of the parent metal.

Materials for components that are in the load path, including weldments, shall meet the following minimum Charpy V-notch impact values for longitudinal oriented specimens.

— Average for three specimens: 31 ft-lb @ −20 °C (−4 °F).

— Minimum single value: 24 ft-lb @ −20 °C (−4 °F).

Materials for components that are in the load path, including weldments, shall meet the following minimum Charpy V-notch impact values for transverse oriented specimens.

— Average for three specimens: 23 ft-lb @ −20 °C (−4 °F).

— Minimum single value: 18 ft-lb @ −20 °C (−4 °F).

16.6.3 Test Specimens

16.6.3.1 General

Test specimens shall be taken from a qualified test coupon (QTC) as defined by API 6A, PSL3.

16.6.3.2 Tensile and Impact Testing

Tensile and impact test specimens shall be removed from the same QTC after the final QTC heat treatment cycle.

Tensile and impact specimens shall be removed from the QTC so that their longitudinal centerline axis is wholly within the center core ¼ T envelope for a solid QTC or within ¼ in. of the mid-thickness of the thickest section of a hollow QTC.

When a sacrificial production part is used as a QTC, the impact and tensile test specimens shall be removed from the ¼ T location of the thickest section in that part.

16.6.3.3 Hardness Testing

The following steps apply to hardness testing.

— A minimum of two Brinell hardness tests shall be performed on the QTC after the final heat treatment cycle.

— Hardness testing shall be performed in accordance with procedures specified in ASTM A370.

— The hardness of the QTC shall meet the manufacturer’s written specification.

16.7 Welding

Welding and weld procedure qualification shall conform to the requirements of Section 5.

16.8 Quality Control

Quality control shall conform to the requirements of Section 6.

16.9 Marking

All riser couplings manufactured in accordance with this specification shall be marked on an appropriate external surface using a low-stress method with the information listed below. Metal impression stamp shall be used in low-stressed area on both box and pin ends.

The following information shall be required:

— manufacturer's name,

— part number,

— unique serial number,

— API 16F.

17 Special Riser System Components

17.1 General

NOTE Special riser system components may be required in some applications as necessitated by water depth, rig configuration, well-control requirements, riser system configuration, environmental considerations, and/or operator or regulatory authority specifications.

17.2 Service Classification

Service classification for load capacity shall be determined by the weakest component in the assembly and shall include the riser couplings, any riser pipe, and any special load-carrying bodies.

17.3 Design

All special riser system components, such as riser fill-up valve joint, riser circulation joint, riser crossover joint, landing or hangoff joint, shall meet the requirements defined in Section 12 of this specification. Water depth limitations (if applicable) of any component shall be documented.

NOTE Crossover riser joints are sometimes used to extend an existing riser string. The crossover joint may be constructed from components manufactured by different manufacturers and differing load ratings. In the event that the crossover joint is composed of components of differing load classifications, then the combined joint carries the classification of the lowest rating of the components.

The crossover joint shall be analyzed in accordance with the same methodology used to qualify riser joints from Section 12. If the load path of the combined joint results in a change in that path, such as auxiliary line position (bolt circle) or angular position, then a proof test shall be required to confirm assumptions of stress levels, stress concentrations, and resultant load classification. Proof test shall account for assumptions of bending stresses and load path eccentricity. Particular attention shall be given to bent auxiliary lines and their effect on fatigue life due to tensile load, pressure load, and local bending.

The riser fill-up valve joint shall include a valve that allows rapid filling of the drilling riser with seawater to reduce the chance of riser collapse in the event that pressure in the riser drops significantly below the external seawater pressure. If auxiliary lines are re-routed due to a change in line position (bolt circle and/or angular deviations), then additional analysis and proof testing shall be required as described for crossover joints.

If keel joints are required in a riser string to reduce or mitigate damage to the riser system in the event that lateral deflection of the riser string brings it into contact with the rig structure, then both horizontal and vertical points of impact with the rig structure shall be analyzed. Analysis shall be performed to determine the effect of this temporary reaction on the riser string as a whole. Manufacturers of keel joints shall determine impact tolerance (load capacity) and after-action inspection and repair procedures. This information shall be provided to the riser system owner/operator.

Other specialty joints not specifically listed shall be designed and documented in accordance with Section 12.

17.4 Testing

The manufacturer shall perform a functional operating test. Documentation shall be furnished to ensure compatibility with the other parts of the drilling riser system.

17.5 Quality Control

Quality control shall conform to the requirements of Section 6.

18 Lower Riser Adapter

18.1 General

The lower riser adapter shall be designed in accordance with Section 12.

Kickouts shall be designed and tested in accordance with Section 9.

NOTE The lower riser adapter is typically the bottom interface of the marine drilling riser with the LMRP. The lower riser adapter usually includes a box or pin looking up; stabs with kickouts for choke, kill, and auxiliary line interface with jumper lines; and a bottom flange or hub for connecting to the lower flex/ball joint.

18.2 Marking

Marking shall be in accordance with 12.10.

18.3 Quality Control

Quality control shall conform to the requirements of Section 6.

19 Operation and Maintenance Manuals

19.1 General

The manufacturer shall provide, at purchaser request, operation and maintenance manuals that shall include, but not be limited to, the following items in this section.

19.2 Equipment Description

The following shall be included:

— written description of the system and each major component;

— drawings of the system and each major component (photographs may be included);

— applicable schematic drawings (hydraulic, pneumatic, and/or electrical as necessary).

19.3 Functional Description

A written explanation of the method of operation and physical function of the system and each major component shall be included.

19.4 Instructions for Equipment Usage

The following shall be included:

— riser choke, kill, and joint pickup and handling;

— coupling makeup and breakout;

— pressure testing of choke, kill, and auxiliary lines;

— riser joint storage and racking;

— compatible packer fluids for telescopic joint.

19.5 Maintenance Instructions

The following shall be included:

— graphic chronological schedule of routine maintenance tasks;

— sample maintenance forms or check lists as necessary;

— log sheets for recording cumulative use of each riser joint and telescopic joint;

— storage instructions and replacement schedule for rubber goods and other consumables;

— specified fluids, lubricants, tools, etc., required to operate and maintain the equipment;

— procedure for fatigue crack inspections;

— procedure for checking the wall thickness;

— drawing(s) showing critical dimensions and limits for in-service interface and sealing of mating parts.

— an inspection interval for erosion on C&K components, as defined in 9.1.3.1, at locations where inclusion of erosion control methods is not possible.

19.6 Warnings and Cautions

Significant hazards (including misconnections, oversights, exceeding design limits, etc.) shall be identified.

Annex A
(informative)

Use of API Monogram by Licensees

A.1 Scope

The API Monogram® is a registered certification mark owned by the American Petroleum Institute (API) and authorized for licensing by the API Board of Directors. Through the API Monogram Program, API licenses product manufacturers to apply the API Monogram to new products which comply with product specifications and have been manufactured under a quality management system that meets the requirements of API Specification Q1. API maintains a complete, searchable list of all Monogram licensees on the API Composite List website (http://compositelist.api.org).

The application of the API Monogram and license number on products constitutes a representation and warranty by the licensee to API and to purchasers of the products that, as of the date indicated, the products were manufactured under a quality management system conforming to the requirements of API Specification Q1 and that the product conforms in every detail with the applicable standard(s) or product specification(s). API Monogram Program licenses are issued only after on-site audits have verified that an organization has implemented and continually maintained a quality management system that meets the requirements of API Specification Q1 and that the resulting products satisfy the requirements of the applicable API product specification(s) and/or standard(s). Although any manufacturer may claim that its products meet API product requirements without monogramming them, only manufacturers with a license from API can apply the API Monogram to their products.

Together with the requirements of the API Monogram license agreement, this annex establishes the requirements for those organizations who wish to voluntarily obtain an API license to provide API monogrammed products that satisfy the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program requirements.

For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, NW, Washington, DC 20005 at Certification@api.org.

A.2 Normative References

For Licensees under the Monogram Program, the latest version of this document shall be used. The requirements identified therein are mandatory.

A.3 Terms and Definitions

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

A.3.1
API monogrammable product
Product that has been newly manufactured by an API Licensee utilizing a fully implemented API Specification Q1 compliant quality management system and that meets all the API-specified requirements of the applicable API product specification(s) and/or standard(s).

A.3.2
API product specification
Prescribed set of rules, conditions, or requirements attributed to a specified product that address the definition of terms; classification of components; delineation of procedures; specified dimensions; manufacturing criteria;

material requirements, performance testing, design of activities; and the measurement of quality and quantity with respect to materials; products, processes, services, and/or practices.

A.3.3
API-specified requirements
Requirements, including performance and Licensee-specified requirements, set forth in API Specification Q1 and the applicable API product specification(s) and/or standard(s).

NOTE Licensee-specified requirements include those activities necessary to satisfy API-specified requirements.

A.3.4
design package
Records and documents required to provide evidence that the applicable product has been designed in accordance with API Specification Q1 and the requirements of the applicable product specification(s) and/or standard(s).

A.3.5
licensee
Organization that has successfully completed the application and audit process, and has been issued a license by API to use the API Monogram Mark.

A.4 Quality Management System Requirements

An organization applying the API Monogram to products shall develop, maintain, and operate at all times a quality management system conforming to API Specification Q1.

A.5 Control of the Application and Removal of the API Monogram

Each licensee shall control the application and removal of the API Monogram in accordance with the following:

a) Products that do not conform to API specified requirements shall not bear the API Monogram.

b) Each licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by this annex and any applicable API product specification(s) and/or standard(s). The marking procedure shall:

   1) define the authority responsible for application and removal of the API Monogram and license number;

   2) define the method(s) used to apply the Monogram and license number;

   3) identify the location on the product where the API Monogram and license number are to be applied;

   4) require the application of the date of manufacture of the product in conjunction with the use of the API Monogram and license number;

   5) require that the date of manufacture, at a minimum, be two digits representing the month and two digits representing the year (e.g. 05-12 for May 2012) unless otherwise stipulated in the applicable API product specification(s) or standard(s); and

   6) define the application of all other required API product specification(s) and/or standard(s) marking requirements.

c) Only an API licensee shall apply the API Monogram and its designated license number to API monogrammable products.

d) The API Monogram and license number, when issued, are site-specific and subsequently the API Monogram shall only be applied at that site specific licensed facility location.
e) The API Monogram may be applied at any time appropriate during the production process but shall be removed in accordance with the licensee's API Monogram marking procedure if the product is subsequently found to be out of conformance with any of the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program.

For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. Requirements for alternative API Monogram marking are detailed in the, *API Alternative Marking Agreement (AMA)*, which is available on the API Monogram Program website at: http://www.api.org/products-and-services/api-monogram-and-apiqr/documents#tab_certification-documents

A.6 Design Package Requirements

Each licensee and/or applicant for licensing shall maintain a current design package for all of the applicable products that fall under the scope of each Monogram license. The design package information shall provide objective evidence that the product design meets the requirements of the applicable and most current API product specification(s) and/or standard(s). The design package(s) shall be made available during API audits of the facility.

In specific instances, the exclusion of design activities is allowed under the Monogram Program, as detailed in Advisory # 6, available on the API Monogram Program website at http://www.api.org/products-and-services/api-monogram-and-apiqr#tab_advisories.

A.7 Manufacturing Capability

The API Monogram Program is designed to identify facilities that have demonstrated the ability to manufacture equipment that conforms to API specifications and/or standards. API may refuse initial licensing or suspend current licensing based on a facility's level of manufacturing capability. If API determines that additional review is warranted, API may perform additional audits (at the organization's expense) of any primary subcontractors to ensure their compliance with applicable specifications.

Facilities with capabilities that are limited to the processes or activities defined below do not meet the manufacturing capability requirements to produce new products, and therefore, shall not be licensed or be the basis for licensing under the API Monogram Program:

— Capabilities that are limited to performing final inspection and testing of the product, except for testing agencies as specified in API Specification 14A and/or API Specification 6AV1

— Buying, selling and/or distributing finished products and materials;

— Design and development activities;

— Tearing-down and/or re-assembling of products/components; and,

— Repairing or remanufacturing of existing, used, worn or damaged products.

In all instances where requirements for manufacturing or manufacturing facilities are explicitly identified within the API product specification, those requirements shall take precedence over this advisory.

A.8 Product Marking Requirements

A.8.1 General

These marking requirements shall apply only to those API Licensees wishing to mark applicable products in conjunction with the requirements of the API Monogram Program.

A.8.2 Product Specification Identification

Manufacturers shall mark products as specified by the applicable API specifications or standards. Marking shall include reference to the applicable API specification and/or standard. Unless otherwise specified, reference to the API specifications and/or standards shall be, as a minimum, "API [Document Number]" (e.g. API 6A, or API 600). Unless otherwise specified, when space allows, the marking may include use of "Spec" or "Std", as applicable (e.g. API Spec 6A or API Std 600).

A.8.3 Units

Products shall be marked with units as specified in the API specification and/or standard. If not specified, equipment shall be marked with U.S. customary (USC) units. Use of dual units [USC units and metric (SI) units] may be acceptable, if such units are allowed by the applicable product specification and/or standard.

A.8.4 Nameplates

Nameplates, when applicable, shall be made of a corrosion-resistant material unless otherwise specified by the API specification and/or standard. Nameplate shall be located as specified by the API specification and/or standard. If the location is not specified, then the licensee shall develop and maintain a procedure detailing the location to which the nameplate shall be applied. Nameplates may be attached at any time during the manufacturing process.

The API Monogram and license number shall be marked on the nameplate, in addition to the other product marking requirements specified by the applicable product specification and/or standard.

A.8.5 License Number

The API Monogram license number shall not be used unless it is marked in conjunction with the API Monogram. The license number shall be used in close proximity to the API Monogram.

A.9 API Monogram Program: Nonconformance Reporting

API solicits information on products that are found to be nonconforming with API specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification and/or standard deficiencies or nonconformities against API specified requirements. Customers are requested to report to API all problems with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at http://ncr.api.org/ncr.aspx.

Annex B
(informative)

Components of a Marine Drilling Riser System

B.1 Marine Drilling Riser System—General

The marine drilling riser system connects the subsea BOP stack to the drilling vessel (see Figure B.1). It is a continuation of the wellbore from the seabed to the surface.

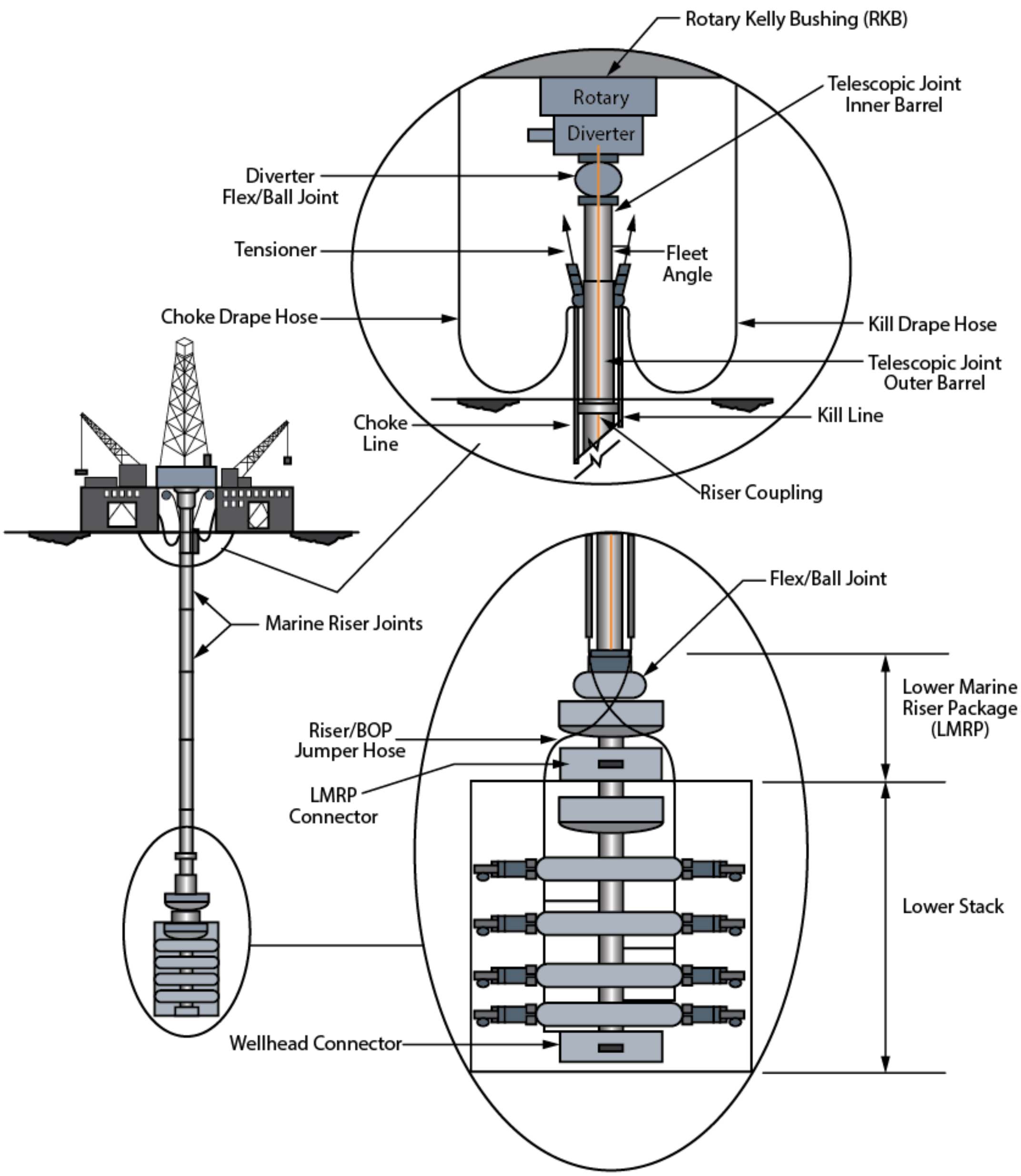

Figure B.1—Marine Drilling Riser System and Associated Equipment

B.2 Functions of Marine Drilling Riser System

The primary functions of the marine riser system are the following.

— Provide for fluid communication between the drilling vessel and the BOP stack and the well:

  — through the main bore during drilling operations;

  — through the C&K lines when the BOP stack is being used to control the well;

  — through the auxiliary lines such as hydraulic fluid supply and mud boost lines.

— Guide tools into the well.

— Serve as a running and retrieving string for the BOP stack.

B.3 System Dimensions

Basic dimensions and interchangeability are fundamental to the design of a marine drilling riser. Riser system component integration and standard riser equipment running procedures require that selected dimensions be examined for compatibility. Those of a basic nature include:

— minimum inside diameter of all components that make up the riser string to allow passage of all bits, casing hangers, wear bushings, and any other equipment that may be run down to the BOP/wellhead;

— maximum outside diameter of all components in the riser string to allow passage through the rotary table and/or diverter housing.

Other basic dimensions to consider include telescopic joint/riser tensioner stroke requirements along with the interface between the handling spider and rotary table. The component manufacturers shall provide these and other basic dimensions requested by the purchaser.

B.4 Tensioner Equipment

Tensioners are used to apply tension at or near the top of the marine drilling riser to prevent the riser from buckling and to support it in a near vertical position. The tensioners are normally located on the drilling vessel near the periphery of the drilling floor. They provide axial tension to the riser while compensating for vessel motion induced by wind, waves, and current. The tensioners generally maintain this tension through the energy transferred from a bank of high-pressure air vessels connected to the hydraulic cylinders of the tensioners.

B.5 Riser Spider

The riser spider is used to support the riser while it is being run or retrieved. When in use, the riser spider is typically located on the drilling rig floor. For deepwater applications, it may be necessary to cushion impact loads on the riser coupling support plates and also to provide a way to isolate the riser from the roll and the pitch motion of the vessel. For such applications, a gimballing and/or shock-absorbing spider may be used. A gimballing and/or shock-absorbing riser spider may consist of a standard riser spider resting on a structure that utilizes either hydraulic or pneumatic accumulators and pistons or elastomeric bearings to provide shock absorption and gimballing.

B.6 Subsea Diverter

The top of the riser system interfaces with the subsea diverter. The diverter system is not considered to be part of the marine drilling riser system. API 64 addresses diverter system equipment.

B.7 Flex/Ball Joint

Flex/ball joints permit relative angular displacement of the riser elements without excessive bending stresses. Typically, a flex/ball joint is positioned between the surface diverter and the telescopic joint and another is positioned below the lower riser adapter in the LMRP (see B.12). Occasionally an intermediate flex joint is used just below the telescopic joint. These lower flexible joints transmit axial riser tension loads. The upper flex/ball joint permits the riser to accommodate roll, pitch, and offset of the vessel.

B.8 Telescopic Joint and Tensioner Ring

Typically, the outer barrel of the telescopic joint connects to the uppermost riser joint and the inner barrel connects to the flex/ball joint at the base of the subsea diverter. The basic function of the telescopic joint, also called the slip joint, is to continuously adapt the riser length to compensate for the horizontal and vertical displacement of the vessel. The telescopic joint has a packer that seals between the inner and outer barrel to prevent fluid leakage from the riser.

The telescopic joint serves to transmit the flow of drilling mud as it returns from the well. It typically has terminal fittings for connecting the choke, kill, and auxiliary line drape hoses to the rigid lines on the riser. A riser tensioner ring is typically attached to or incorporated in the upper portion of the telescopic joint outer barrel. Its function is to transmit the support load from the riser tensioner lines to the outer barrel of the telescopic joint. In some cases, it permits rotation of the vessel around the riser.

Nonrotating tension rings may be attached as follows:

— padeyes directly welded to the outer barrel of the telescopic joint,

— through removable flanged and bolted halves,

— solid section with padeyes installed permanently but not welded to the outer barrel.

A reaction or thrust ring may be attached to the telescopic joint.

For nonrotating tension rings, doubler barrels or increased wall thicknesses of the outer barrels in the local region of the thrust reaction are recommended.

B.9 Riser Joints

A riser joint is typically an assembly of riser pipe, coupling box and pin, C&K lines, auxiliary lines, choke/kill/auxiliary line support brackets, and other devices for guidance and/or supporting buoyancy modules. Riser couplings provide a means of quickly connecting and disconnecting riser joints. Riser couplings also provide a landing/support shoulder to transmit the weight of the deployed string to the riser spider while the riser is being deployed or retrieved. The couplings also provide support points for choke, kill, and auxiliary lines and load reaction points for buoyancy devices.

B.10 Choke, Kill, and Auxiliary Lines

C&K lines run the entire length of the riser and terminate at the BOP. The lines are an integral part of a riser joint and are equipped with stab-in connectors. They are used for well control and for periodic pressure testing of the BOP stack. Where relative motions occur between elements of the riser system, flexible bypass lines are used to maintain continuity of the C&K lines. Such relative motions may occur between the outer barrel of the telescopic joint and the vessel and across any flex/ball joints in the riser string. Auxiliary lines can serve a variety of purposes, including drilling fluid circulation (e.g. “mud boost line”), hydraulic fluid supply for BOP control functions, and air injection and piloting for air can riser flotation.

B.11 Lower Riser Adapter

The lower riser adapter connects the lowermost riser joint to the flex/ball joint on the LMRP. The upper end is a standard riser coupling box or pin and may contain kickouts for the choke, kill, and/or auxiliary lines to facilitate the connection of the bypass lines around the lower flex joint. It may also have provisions for mounting an internal wear bushing.

B.12 LMRP

The LMRP is the assembly located at the bottom of the drilling riser. Typical components, from top to bottom, are:

— lower riser adapter;

— flex/ball joint bypass lines for choke, kill, and auxiliary lines;

— lower flex/ball joint; and

— hydraulic connector (riser connector) for mating the riser to the BOP stack.

The LMRP also accommodates the subsea control pods of the BOP stack control system. The LMRP permits the riser and BOP control pods to be tripped separately from the BOP stack. It commonly will also contain at least one annular BOP.

B.13 Buoyancy Equipment

Buoyancy is added to the marine drilling riser for the purpose of offsetting all or part of the riser weight in seawater, thereby reducing the load on the riser tensioning system/hook load capacity and facilitating drilling in deeper water. Two types of buoyancy equipment have been employed: syntactic foam modules (see 13.2) and air can systems.

An air can is typically an inverted container open to the water at its lower end. An air can is charged with air or other suitable buoyant fluid that displaces a specified volume of water to provide the desired buoyancy.

An air can system may be adjustable, variable, or fixed. The adjustable type permits presetting the air or buoyant fluid volume prior to deploying the riser. The variable type allows injection or removal of buoyant fluid after deployment of the riser. The fixed type does not allow adjustment of buoyancy.

An air can is open at the bottom and centralized around the riser pipe so that water directly interfaces with the air inside. Thus, the maximum differential pressure across the wall of the can is equal to a water head of one can length, regardless of the water depth at which the joint is operating.

Since the pressure differential on the air can structure is a function of can length, not water depth, the buoyant air can system is suitable for deepwater service. Each air can joint may be equipped with a buoyancy control line to independently control buoyancy.

B.14 Riser Pup Joints

Pup joints are riser joints that are shorter than full-length riser joints and are used to establish a deployed riser length within a desired tolerance to accommodate different water depths.

B.15 Riser Handling Tools

A riser-handling tool is used in conjunction with the drawworks and derrick overhead equipment to deploy and retrieve the riser and BOP stack.

B.16 Special Marine Drilling Riser Components

Special marine drilling riser components include the following.

— *Riser Fill-up Valve Joint*—The riser fill-up valve joint provides a means for external water to enter the riser. Its principal purpose is to prevent riser collapse in deep water if pressure in the riser drops significantly below the external seawater pressure.

— *Mud Discharge Valve Joint*—The mud discharge or dump valve joint is a device used to control riser pressure (and hence wellbore pressure) by establishing direct communication between the riser bore and the sea.

— *Instrumented Riser Joints*—Instrumented riser joints can be used to measure and monitor parameters such as riser tension and bending stresses; external water pressure and temperature; drilling fluid density, flow rate, temperature and pressure; tool joint location; and riser angle.

— *Riser Crossovers*—Riser crossovers are special purpose adapter joints that may be used to connect riser joints of different designs. Riser crossovers have one end that mates with the bottom end of one type riser joint and one end that mates with the top end of another type riser joint.

— *Secondary Disconnect Equipment*—Secondary disconnect equipment provides a means of quickly disconnecting the marine drilling riser from the BOP stack when a primary disconnect fails.

— *Riser Circulation Joint*—A riser circulation joint is intended to facilitate pressure control in a deepwater riser if pressurized gas enters at the bottom of the riser. The riser circulation joint shall permit closure of the riser annulus at a location below the telescopic joint. It shall also permit the circulation of the riser annulus fluids by pumping down the mud boost line and discharge of return flow through a choke. The closure system shall meet the requirements of API 16A, and its control system shall meet the requirements of API 16D.

B.17 Riser Couplings

Coupling designs may or may not require coupling preload. Coupling design types include, but are not limited to, the types defined in this section.

— *Breech-block Coupling*—A coupling that is engaged by partial rotation of one member into an interlock with another.

— *Collet-type Coupling*—A coupling having a slotted cylindrical element joining mating coupling members.

— *Dog-type Coupling*—A coupling having dogs that act as wedges mechanically driven between the box and pin for engagement.

— *Flange-type Coupling*—A coupling having two flanges joined by bolts.

— *Threaded Coupling*—A coupling having matching threaded members to form engagement.

Annex C
(normative)

Design for Static Loading

C.1 General

The design of a riser component for static loading requires that it support the preload and the design load while keeping the maximum cross-sectional stresses within allowable limits as specified in this section. Load peak stresses are not considered for static loading, but are of primary concern for evaluating fatigue life as discussed in Annex I.

The following paragraphs define the stress types and stress categories that are pertinent to riser components. A thorough understanding of these stresses is necessary to properly design riser components. Traditional stress analysis methods and or numerical methods such as finite element analysis should be used to determine these stresses.

The three principal stresses should be calculated at all critical locations in the riser components. At locations with axisymmetric geometry such as plain pipe, the principal stresses will usually be in the axial, hoop, and radial directions. For nonaxisymmetric geometry, the directions may be different. Stresses shall be linearized, separated into membrane and bending components, categorized, and converted to von Mises effective stresses before they can be compared to the allowable stresses. The following paragraphs describe this procedure in detail.

C.2 Allowable Stresses

For all components except coupling bolts and auxiliary, choke, and kill lines (see Section 9), linearized stresses shall be less than or equal to the allowable stresses as defined below.

Linearized primary membrane stresses caused by the rated load shall not exceed the maximum allowable stress, $\sigma_{allow,m}$, as calculated by Equation (C.1).

$$\sigma_{\text{allow,m}} = \frac{\sigma_{\text{ys}}}{\text{SF}_{\text{D}}} \tag{C.1}$$

Linearized primary membrane plus primary bending stresses caused by the rated load shall not exceed the maximum allowable stress, $\sigma_{allow,m+b}$, as calculated by Equation (C.2).

$$\sigma_{\text{allow,m+b}} = \frac{1.5 \times \sigma_{\text{ys}}}{\text{SF}_{\text{D}}} \tag{C.2}$$

Linearized membrane plus bending secondary stresses caused by the rated load shall not exceed the maximum allowable stress, $\sigma_{allow,s}$, as calculated by Equation (C.3).

$$\sigma_{\text{allow,s}} = \frac{3.0 \times \sigma_{\text{ys}}}{\text{SF}_{\text{D}}} \tag{C.3}$$

where

σ_{ys} is the material minimum yield strength per ASTM A370.

The design safety factor, SF_D, shall equal 1.5 unless otherwise stated by component section within this specification.

Linearized local membrane stress allowables shall be as defined in ASME *BPVC*, Section VIII, Division 2.

For bolts in the primary load path, the manufacturer shall establish the allowable stress levels for membrane stresses and bending stresses in the bolts.

NOTE 1 Bolt stresses, pure shear stresses, and bearing stresses are compared directly with their respective allowables.

NOTE 2 Bearing and contact stresses caused by the rated load are allowed to exceed the yield strength of the material provided that the shear and tensile stresses in the vicinity of the bearing load are within acceptable limits.

For purposes of design calculations involving shear, the ratio of yield strength in shear to yield strength in tension shall be 0.6. The design safety factor shall equal 1.5 unless otherwise stated by component section within this specification.

C.3 Stress Categories

C.3.1 General

The following categories are used to classify stresses. The categories are based on the response of the loaded component if the material yield strength were exceeded.

C.3.2 Primary Stress

The basic characteristic of a primary stress is that it is not self-limiting, and failure, or at least gross distortion, can occur from one application of the loading. Primary stress is stress caused by the application of mechanical pressure, forces, and moments. Primary stress includes both membrane and bending stress and is assumed to be linearly distributed across the wall section. Local primary stress can redistribute, to stiffer portions of the section under load, as it does in a threaded connector. Thermal stresses are not primary stresses.

C.3.3 Primary Membrane Stress

Membrane stress distributed in a way such that load redistribution cannot occur, and loading beyond the yield strength can proceed to failure. General primary membrane stress intensity is caused only by mechanical loads and excludes effects due to discontinuities and areas of stress concentration.

C.3.4 Primary Bending Stress

The components of primary bending stress shall be calculated from the linear primary stress component distributions that have the same net bending moment as the actual stress component distribution. Primary bending stress components are defined as being proportional to the distance from the centroid of a solid section and exclude discontinuities and stress concentrations.

C.3.5 Secondary Stress

Secondary stress is caused by the constraint of adjacent parts or by self-constraint of the structure, and yielding can cause the magnitude of the stress to be reduced. One load cycle can cause local yielding and stress redistribution but cannot result in failure or gross distortion. Secondary stresses are membrane plus bending stresses that can occur at gross structural discontinuities, from general thermal stress, from mechanical preload conditions, or from combinations of these sources.

C.3.6 Local Membrane Stress

Local membrane stress is caused only by mechanical loads. Discontinuities are considered while areas of stress concentrations are not.

C.3.7 Stress Category Examples

Principal stress components can be separated into more than one stress category. For example, consider a bolt in a bolted flange. The stress in the bolt is equal to the sum of a primary membrane stress caused by the loads applied to the flange and a secondary stress caused by the bolt preload. The preload stresses are considered to be secondary stresses because they are self-limiting. However, once the applied load reaches a magnitude that relieves all of the connector preload (i.e. the flange face separates), the stresses in the bolts are considered to be primary stresses only.

It should be noted that functional requirements should also be considered when evaluating stress levels in the riser components. In the bolted flange example given above, allowing the combined primary plus secondary stresses in the bolts to exceed yield would result in loss of preload and possible leakage when the load is relieved.

Some of these stresses, such as general primary membrane stresses, can be accurately calculated using hand calculations, but most cannot due to the complex geometry and loading of riser couplings. For this reason it is required that the stresses in each component be calculated with a finite element analysis method as described in Annex D.

The load cases for which a component shall be analyzed depend on whether or not the component is preloaded and if the preload stresses are considered as primary or secondary.

If a component is not preloaded, only one load case shall be analyzed: design axial tension (coupling design load) or combined maximum operational conditions.

If a component is preloaded, the component shall be analyzed for three load cases:

— design preload,

— design preload plus design axial tension, and

— design axial tension only.

Classifying stresses induced by preload as primary or secondary depends on component function and not on overstressing the component. If preload stresses are classified as secondary, they are allowed to be twice the yield strength. This can result in large permanent deformations, but not in structural failure.

Some component designs can tolerate large permanent deformations without jeopardizing their ability to safely function, and other component designs will not function after large permanent deformations. Sealing is an example of a functional requirement that often is affected by large permanent deformation.

If preload stresses are considered as secondary, the designer shall demonstrate that the permanent deformations induced by preload do not cause the component to lose any necessary functional capability.

Normally, riser components exhibit a linear or bilinear relationship between load and stress. For these components, stresses at loads other than the analysis loads can be calculated using the rules of linear interpolation or extrapolation. For those components with a nonlinear relationship between load and stress, linear interpolations or extrapolations cannot be used. These components shall be analyzed for several values of load, and plots of load vs stress shall be developed. The component's rated load shall be determined from these curves.

C.4 Stress Linearization

In general there are six components of stress across any section: three normal components and three shear stress components.

Each of the significant stress components shall be linearized and separated into membrane and bending components.

This is graphically shown in Figure C.1. This figure shows the axial stress across the wall of a riser coupling at a section where the wall thickness changes. The load on the components is axial tension. The solid line shows the stress distribution reported by the finite element model, and the dashed line represents the linearized stress distribution. The membrane stress component is the average value of the linearized stress distribution and the bending stress component is the difference between the largest and the average values of the linearized stress distribution.

Membrane and bending stress components shall be categorized into one of the stress categories as described in C.3.

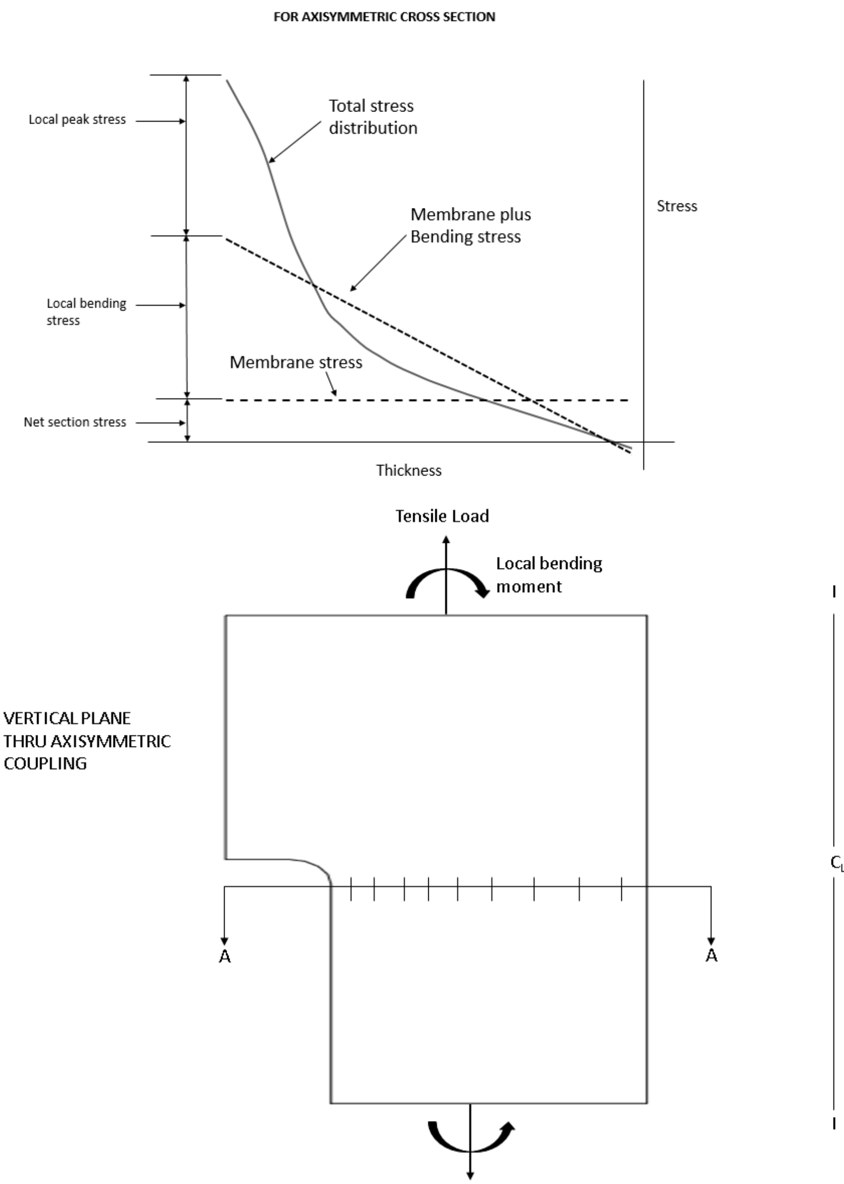

Figure C.1—Stress Distribution Across Section A-A

For example, in Figure C.1 the membrane stress is the axial stress induced by the axial force. Since this stress is necessary to equilibrate the axial force, it is general primary membrane stress. The bending stress is induced by the local bending moment caused by the discontinuity in the wall thickness. This stress is necessary only to ensure the coupling has continuity of deformations at the discontinuity; thus, it is secondary stress.

This procedure is repeated for all of the six stress components that are significant, then the von Mises effective stress is calculated using Equation (C.4):

$$\sigma_e = \frac{1}{\sqrt{2}}\left[\left(S_x - S_y\right)^2 + \left(S_y - S_z\right)^2 + \left(S_z - S_x\right)^2 + 6\left(T_{xy}^2 + T_{yz}^2 + T_{xz}^2\right)\right]^{1/2} \tag{C.4}$$

where

σ_e is the von Mises effective stress;

S_x, S_y, S_z are the three normal stress components;

T_{xy}, T_{yz}, T_{zx} are the three shear stress components.

All stresses are not included when calculating every von Mises effective stress. For example, when the general primary membrane stress is being checked, only general primary membrane stresses are included in the equation; secondary stresses, bending stress, and local primary stresses are not included.

The maximum shear stress theory of failure can be used in lieu of von Mises theory of failure. Using the maximum shear stress theory of failure shall require that twice the maximum shear stress, defined as the stress intensity, be compared with the allowable stresses instead of the von Mises effective stress. This approach is equal to or slightly conservative when compared to the von Mises approach, but is much easier to use.

Annex D
(informative)

Finite Element Stress Analysis

For nonaxisymmetric components, three-dimensional analysis is necessary to account for variation in stress around the circumference. If a coupling has axial planes of symmetry (planes that include the pipe axis), the three-dimensional analysis may be based on a single sector bounded by two such planes. For example, a component having six planes of symmetry would require analysis of a 30° sector ($^{1}/_{12}$). The axial loading on such a 30° sector can be considered to be that caused by the design tension uniformly distributed around the pipe. Determination of the equivalent load for bending is discussed in 4.4. Two-dimensional analysis may be valid for axisymmetric components.

The use of finite element analysis permits determination of stresses in complex structures, but accuracy of the analysis is very sensitive to the skill of the analyst. Exercise care and judgment in developing the finite element model. For example, highly stressed regions of the structure require a fine mesh of elements. Therefore, the analyst shall predict where high stresses are likely to occur. Some stresses will be affected by the structural properties of the riser pipe. Therefore, the model shall be continued far enough away from critical areas to ensure that results are free from boundary effects. The finite element model shall be designed so that the finite elements are not distorted beyond their ability to produce accurate results.

Analysis of the effects of preload and the possibility of separation may require special treatment in the finite element analysis. All subcomponents that affect the stiffness of the components shall be considered in the model. If separation can occur, then provision for it shall be included in the analysis if possible. If not possible, then an iterative method involving several solutions shall be required.

Maximum stresses almost always occur at surfaces. The finite element model shall be designed so that, in critical regions, stresses are calculated on the surface as well as near it.

Annex E
(informative)

Thermal Sprayed Aluminum

E.1 Description

Coating shall consist of a sealed aluminum sprayed coating, as a minimum in conformance to SSPC CS 23.00, Section 6: TSC Requirements or ISO 2063.

Feedstock for the metal spraying process shall be aluminum wire of 99.5 % minimum purity in conformance to ISO 14919 Code Number 3.2, or equivalent

Sealing materials shall be selected for the associated operating temperature specified for the application.

E.2 Manufacturing Procedure Specification (MPS)

Primary surface preparation and coatings application activities shall be performed under environmentally controlled shop conditions.

Content of the MPS shall conform to SSPC CS 23.00, Appendix B: Model Job Control Method and Appendix D: Application Process Method.

Proposed thermal sprayed aluminum (TSA) system shall be fully documented. The MPS shall include the type, size, and manufacturer name for all abrasives, blasting and thermal spray equipment, spray materials, and sealer and topcoat materials.

MPS shall detail the full range of process parameters to be monitored and recorded and the tests to be conducted on the coating with acceptance criteria.

E.3 Procedure Qualification Trial (PQT) Requirements

Prior to start of production, the supplier shall perform a PQT.

For PQT test material areas:

a) unless otherwise approved, a minimum of 5 m^2 (54 ft^2) of each type of surface included in the scope of the purchase order, e.g. tubulars, angles, box section, and plates, shall be coated;

b) representative longitudinal and circumferential weld areas for each material type shall be coated;

c) in addition, four plates 50 mm (2 in.) × 100 mm (4 in.) × 6 mm (1/4 in.) thick shall be coated in parallel with each set of PQT test pieces, for each material type;

d) equipment for PQT shall be the actual equipment to be used for production.

The PQT shall include repair to damage including, but not limited to:

— mechanical impact,

— flame burning,

— welding,

— contamination.

Adhesion testing requirements are as follows.

1) Each operator shall prepare and spray one test panel of minimum thickness 6 mm ($^1/_4$ in.) and minimum surface area of approximately 1 m^2 (10 ft^2).

2) Coated surface shall not be sealed or top coated.

3) Adhesive between the dolly and the thermal spray coating shall be an epoxy.

4) A minimum of three pull-off adhesion tests shall be performed in conformance to Table E.3.

5) Minimum thickness of TSA shall be 200 μm (7.9 mil) and maximum thickness shall be 350 μm (13.8 mil). This shall be confirmed by visual inspection of the cross section under minimum 10× magnification.

6) If any one of these fail, the procedure and/or sprayer shall be deemed to have failed the qualification test. Procedures shall be adjusted and sprayers shall be retrained prior to further testing.

Bend testing requirements are as follows.

— Bend test shall be in conformance to SSPC CS 23.00, Section 6.5: Bend Test.

— Each operator shall prepare and spray five panels of the following dimensions: 50 mm (2 in.) × 100 mm (4 in.) × 1.3 mm (0.05 in.).

— A bend test shall consist of five coupons, which shall be bent 180° around a 13 mm ($^1/_2$ in.) diametrel mandrel.

— Bend test shall pass if:

  — no cracking or spalling, or

  — only minor cracking that cannot be lifted from the substrate with a knife blade.

— Bend test fails if the coating cracks with lifting from the substrate.

— Visual examination.

  The sealed surface area of the thermal spray coated test panel shall be examined by microscope with minimum 10× magnification. Sealed surface shall show 100 % coverage, and no open pores shall be present at the surface.

— As a minimum, the report shall contain the following:

  — properties of raw materials,

  — production parameters used,

  — results of all tests performed at the PQT,

  — recommendations for revision of the MPS and repeat PQT.

— If any PQT test fails to conform to the specification requirements, supplier shall be responsible for:

  - — evaluating the reasons for the failure,
  - — modifying the MPS,
  - — repeating the PQT.

- — Coating applied up to this stage shall be rejected.

E.4 Summary of Process Checks and Testing Requirements

For the minimum requirements for monitoring and recording process parameters, and for checking and testing the coating during the coating process, the following shall apply.

- — Surface preparation, see Table E.1.
- — Sealer application, see Table E.2.
- — TSA application, see Table E.3.

Table E.1—Surface Preparation

Property	Acceptance Criteria	Frequency PQT	Frequency Production	Method Reference
Initial item condition	Item specification	Every item	Every item	—
Clean and prewash	No contaminants detectable by supplier's approved test methods	Every item	Every item	SSPC-SP 1 NACE WJ-4 WC
Surface salt after prewash	Less than 2 μg/cm^2 (0.31 μg/in.^{2})	Every item	Start of shift	ISO 8502-9/ approved salt meter
Wall thickness after defect removal	Wall thickness not less than data sheet minimum	Every ground area	Every ground area	—
Environmental checks	Air temperature above 10 °C (50 °F)	Start of shift, then maximum 4 hours	Start of shift, then maximum 4 hours	—
	RH less than 85 %	Start of shift, then maximum 4 hours		
	Steel temp 5 °C (41 °F) above dew point	Every item		
Surface condition after blasting	No defects or irregularities	Every item	Every item	—
Surface cleanliness	Sa 3	Every item	Every item	ISO 8501-1
Blast profile (carbon steel)	75 μm (Rz) to 125 μm (Rz)	Every item	Start of shift, then maximum 4 hours	ISO 8503-1/2/4/5
Blast profile (DSS/SDSS)	30 μm (Rz) to 50 μm (Rz)	Every item	Start of shift, then maximum 4 hours	ISO 8503-1/2/4/5
Surface dust check	Rating 2 or better	Every item	Every item	ISO 8502-3

Table E.2—Sealer Application

Property	Acceptance Criteria	Frequency PQT	Frequency Production	Method Reference
Raw materials testing	Manufacturer data	Every batch	Every batch	—
TSA inspection prior to application	No contamination of TSA by dust, moisture, etc.	Every item	Every item	—
Application equipment settings	PQT ±5 %	Every item	Start of shift, then as required based on quality control feedback	—
Sealant thinning	≤ 15 % solids; viscosity ≤ 3 poise	Every mix	Every mix	—
Sealer appearance	Uniform and free from runs, sags, pinholes, or overspray	Every item	Every item	—
Coating thickness	No measurable overlay on TSA thickness, 50 µm (2 mil) average	Every item	Every item	—

Table E.3—TSA Application

Property	Acceptance Criteria	Frequency PQT	Frequency Production	Method Reference
Raw materials testing	Manufacturer data	Every batch	Every batch	—
Masking	Company approved drawings	Every item	Start of shift, then as required based on quality control feedback	—
Environmental checks	Air temperature above 10 °C (50 °F)	Start of shift, then maximum 4 hours	Start of shift, then maximum 4 hours	—
	RH less than 85 %	Start of shift, then maximum 4 hours		
	Steel temp 5 °C (41 °F) above dew point	Every item		
Spray air quality	No oil or water present	Start of shift, then maximum 1 hour	Start of shift, then maximum 4 hours plus after any stoppage	ASTM D4285
Application equipment settings	Current, voltage, gas flow etc., PQT ±5 %	Every item	Start of shift, then as required based on quality control feedback	—
TSA appearance	Uniform and free from blisters, cracks, and loose particles	Every item	Every item	100 % coverage, no open pores
	Examination at 10× magnification or higher	Every item	One test per 50 m^2 (540 ft^2) coated	
Coating thickness	250 µm ± 50 µm (10 mil ±2 mil) average	Every item	Every item	SSPC-PA 2, Type 2 probe
Dry adhesion	≥9 MPa (1305 psi); failure in glue at <9 MPa (1305 psi) requires retest/different glue	Every item, see E.3	Three tests (each 5 dollies) per 100 m^2 (1070 ft^2) coated	ISO 4624, using portable self-aligning tester
Bend test	Refer to E.3	5 test panels	Each work shift or crew change	SSPC CS 23.00
Porosity	≤10 % porosity	Witness panels	Not required	ASTM E2109
Flexibility (bend test)	— 180° on 13 mm ($^1/_2$ in.) mandrel — No blisters, loose particles, disbanding, or loosely adhering TSA — Minor cracking that cannot be lifted is not cause for failure.	Witness panels	Start of shift, on witness panels	SSPC CS 23.00, Section 6.5
End damage and bore contamination	ITP	Every item	Every item	—

Annex F
(normative)

Manufacturing Data Book Requirements

The following are the manufacturing data book requirements.

Manufacturing Data Book (MDB)	Delivered to Equipment Owner	Maintained by Manufacturer
Document Contents		
Date of manufacturing	X	X
Purchase order number/sales order numbers	X	X
Date of factory acceptance testing (FAT)	X	X
Part and serial numbers of equipment and locations	X	X
Assembly drawings showing:	X	X
a) actual overall package dimensions	X	X
b) pressure rating	X	X
c) end connection/outlet description	X	X
d) mass	X	X
e) center of gravity	X	X
f) basic description of assembly	X	X
Manufacturer's Certificate of Conformance—include specification to which equipment is certified	X	X
Design verification documentation	X	X
3rd party review certificate	When in purchase order	X
3rd party approval certificate	When in purchase order	X
Material Test Records (including the following):		
a) chemical analysis	X	X
b) tensile tests	X	X
c) impact tests	X	X
d) hardness tests	X	X
e) NDE reports	X	X
f) heat treatment	X	X

Manufacturing Data Book (MDB) (continued)	Delivered to Equipment Owner	Maintained by Manufacturer
Document Contents		
Material specification number	X	X
WPS/PQR 3rd party customer review records	As required on purchase order	X
NDE Records (including the following):		
a) surface NDE records	X	X
b) volumetric NDE	X	X
c) repair weld NDE records	X	X
d) final hardness records	X	X
Inspector qualification records	As required on purchase order	X
Welding Process Records (including the following):		
a) welder ID	X	X
b) filler metal classification, heat and/or batch number	X	X
c) flux type and lot	X	X
d) WPS number(s)	X	X
e) PWHT charts	X	X
f) total remaining PWHT time per weld	X	X
g) weld map	X	X
h) weld inspection records	X	X
i) sketch of local PWHT heater size location and thermocouples locations	X	X
Welder qualification records	As required on purchase order	X
Test Report(s), Pressure Testing, and Final Acceptance Testing (including the following):		
a) hydrostatic pressure test records	X	X
b) final acceptance testing reports	X	X
Dimensions (as defined by OEM/CEM)	—	X
Bolting traceability records per API 16F	X	X
All remaining documentation required as defined in API 16F are kept at OEM/CEM facility for required retention period	—	X

Annex G
(informative)

Example Calculations for Tensioners

G.1 General

The following (Table G.1) is a spreadsheet based calculation that displays the input data and the calculated tensioner performance as a function of tensioner stroke. In this example, real gas characteristics are imported from the National Institute of Standards and Technology (NIST) as listed in 7.4.1. Other forms of calculations are acceptable as long as similar data and results are depicted.

Table G.1—Tensioner Example Calculation

API 16F Summary Data:		
Maximum Supply Pressure (MSP)	3,000	psig
Maximum Compression Pressure (MCP)	3,869	psig
Maximum Allowable Working Pressure (MAWP)	4,160	psig
Maximum Tension Limit (MTL)	337,502	lb
Rated Tension (RT)	260,076	lb

Calculation Method:		
Method:	Real Gas, Isentropic - NIST	
Gas:	Air	
Temperature:	80	°F
Base Entropy:	1.2482	(BTU/lb_m-R)

Tensioner Rating Calculation:			
Maximum Supply Pressure (MSP)	3,000	psig	*This is the maximum pressure that can be applied to the system*
PRV Tolerance Factor	93.0%		*This is the PRV tolerance factor to allow for inaccuracies with PRV settings*
Net Volume (BE)	386,737	in.^{3}	*Includes APV, pipe, and HP accumulator air volume*
Net Volume (RE)	23,991	in.^{3}	*Includes LP accumlator and rod side annulus volume, less min. oil volume*
Area BE	355	in.^{2}	*This is the area of the blind end of the tensioner*
Area RE	75	in.^{2}	*This is the annulus area of the rod end of the tensioner*
HP Accumulator Diameter	22.83	in.	
HP Accumulator Volume	58,827	in.^{3}	
HP Accumulator Min. Oil Volume	53,247	in.^{3}	*This is equal to tensioner cylinder total volume*
Tensioner Cylinder OD	24.02	in.	
Tensioner Cylinder ID	21.26	in.	
Rod OD	18.90	in.	
Stroke	150	in.	*This is the tensioner's total stroke*
Number of Line Parts	4		*This is the number of line falls/mechanical advantage*
Min. LP Accum. Oil Volume	0	in.^{3}	*This is the LP accumulator's minimum oil volume*
Min. LP Accum. Pressure	7.25	psig	*This is the LP accumulator's minimum pressure*
LP Accumulator Volume	12,816	in.^{3}	*This is the LP accumulator's total volume*
APV Volume	366,142	in.^{3}	*APV volume per tensioner (6000 liters)*
Air Line Volume	15,015	in.^{3}	*Pipeline volume to tensioners from APVs*
Dead Weight	22,753	lb	*Total dead load on tensioner (e.g., sheaves, rod, wire rope)*
Polytropic Gas Exponent (n)	1.4		*Polytropic constant for use with gas compression calculation for low pressure*

Table G.1—Tensioner Example Calculation (Continued)

Stroke (in.)	P_{BE} (psig)	V/V_0	Volume (ft^3/lb$_m$)	P_{RE} (psig)	Dead Weight (lb)	Tension (lb)	Effective Polytropic Constant	T (°F)	Tension Variation
0	3,869	0.8809	0.0607	7.3	22,753	337,502	1.996	119.0	19.5%
5	3,821	0.8862	0.0610	7.7	22,753	333,283	1.993	117.0	18.0%
10	3,775	0.8915	0.0614	8.2	22,753	329,152	1.991	115.0	16.6%
15	3,729	0.8968	0.0617	8.8	22,753	325,105	1.988	113.0	15.2%
20	3,685	0.9021	0.0621	9.3	22,753	321,140	1.985	111.0	13.7%
25	3,641	0.9073	0.0625	9.9	22,753	317,255	1.983	109.1	12.4%
30	3,598	0.9126	0.0628	10.5	22,753	313,447	1.980	107.1	11.0%
35	3,556	0.9179	0.0632	11.1	22,753	309,715	1.978	105.2	9.7%
37.5	3,536	0.9206	0.0634	11.4	22,753	307,876	1.977	104.3	9.1%
40	3,515	0.9232	0.0636	11.7	22,753	306,056	1.975	103.4	8.4%
45	3,475	0.9285	0.0639	12.4	22,753	302,468	1.973	101.5	7.1%
50	3,435	0.9338	0.0643	13.1	22,753	298,949	1.970	99.6	5.9%
55	3,397	0.9391	0.0647	13.8	22,753	295,497	1.968	97.8	4.7%
60	3,359	0.9444	0.0650	14.6	22,753	292,110	1.965	96.0	3.5%
65	3,321	0.9497	0.0654	15.4	22,753	288,787	1.963	94.2	2.3%
70	3,285	0.9550	0.0658	16.2	22,753	285,526	1.961	92.5	1.1%
75	3,249	0.9603	0.0661	17.1	22,753	282,325	1.958	90.7	0.0%
80	3,214	0.9656	0.0665	18.0	22,753	279,183	1.956	89.0	1.1%
85	3,179	0.9709	0.0669	19.0	22,753	276,097	1.954	87.3	2.3%
90	3,145	0.9762	0.0672	20.0	22,753	273,067	1.952	85.6	3.4%
95	3,112	0.9815	0.0676	21.1	22,753	270,091	1.949	83.9	4.5%
100	3,079	0.9868	0.0679	22.2	22,753	267,167	1.947	82.2	5.7%
105	3,047	0.9921	0.0683	23.4	22,753	264,294	1.945	80.6	6.8%
110	3,016	0.9974	0.0687	24.7	22,753	261,470	1.943	79.0	8.0%
112.5	3,000	1.0000	0.0689	25.4	22,753	260,076	N/A	78.1	8.6%
115	2,985	1.0026	0.0690	26.0	22,753	258,695	1.941	77.3	9.1%
120	2,954	1.0079	0.0694	27.5	22,753	255,966	1.938	75.7	10.3%
125	2,924	1.0132	0.0698	29.0	22,753	253,283	1.936	74.2	11.5%
130	2,895	1.0185	0.0701	30.6	22,753	250,645	1.934	72.6	12.6%
135	2,866	1.0238	0.0705	32.3	22,753	248,049	1.932	71.1	13.8%
140	2,838	1.0291	0.0709	34.1	22,753	245,495	1.930	69.5	15.0%
145	2,810	1.0344	0.0712	36.0	22,753	242,981	1.928	68.0	16.2%
150	2,782	1.0397	0.0716	38.1	22,753	240,507	1.926	66.5	17.4%

Normal Working Range (± 25% of Midstroke)

G.2 Performance Plot

Figure G.1 is produced from the calculated data shown in G.1 for 100 % rated tension. Separate plots may be made for the 25 %, 50 %, and 75 % curves or all curves may be shown on a single plot. See 7.4.1 for detailed tensioner performance curve requirements.

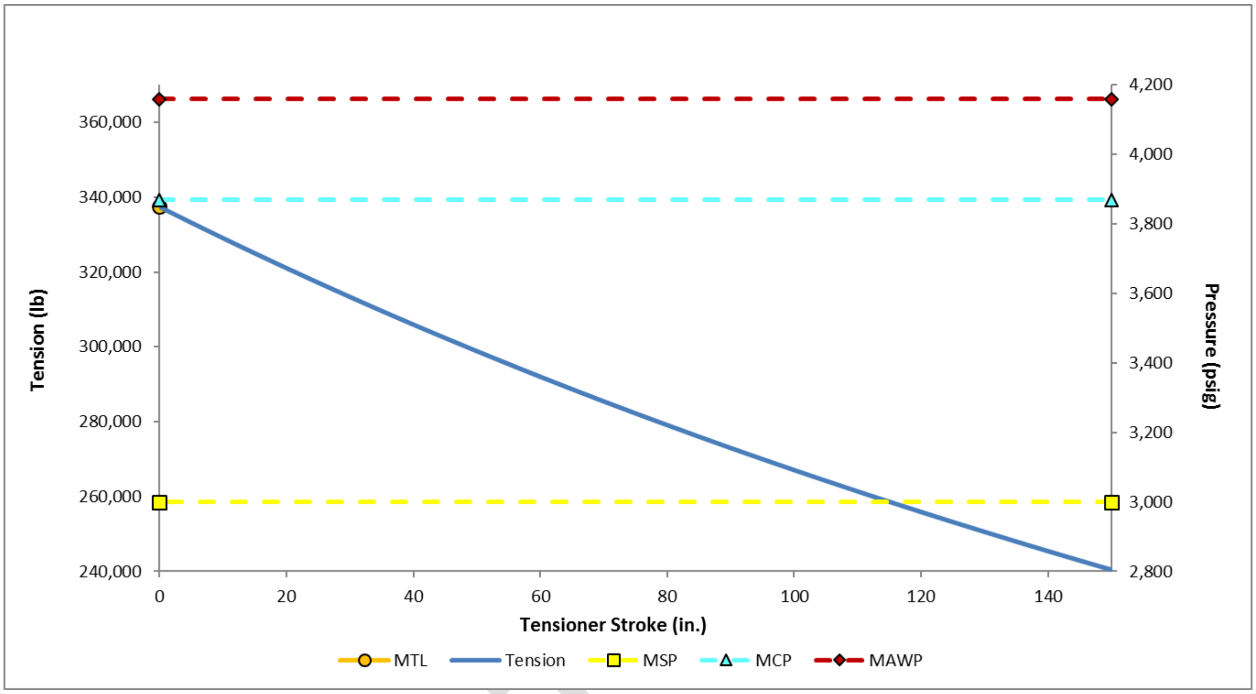

Figure G.1—Tension and Pressure vs Stroke

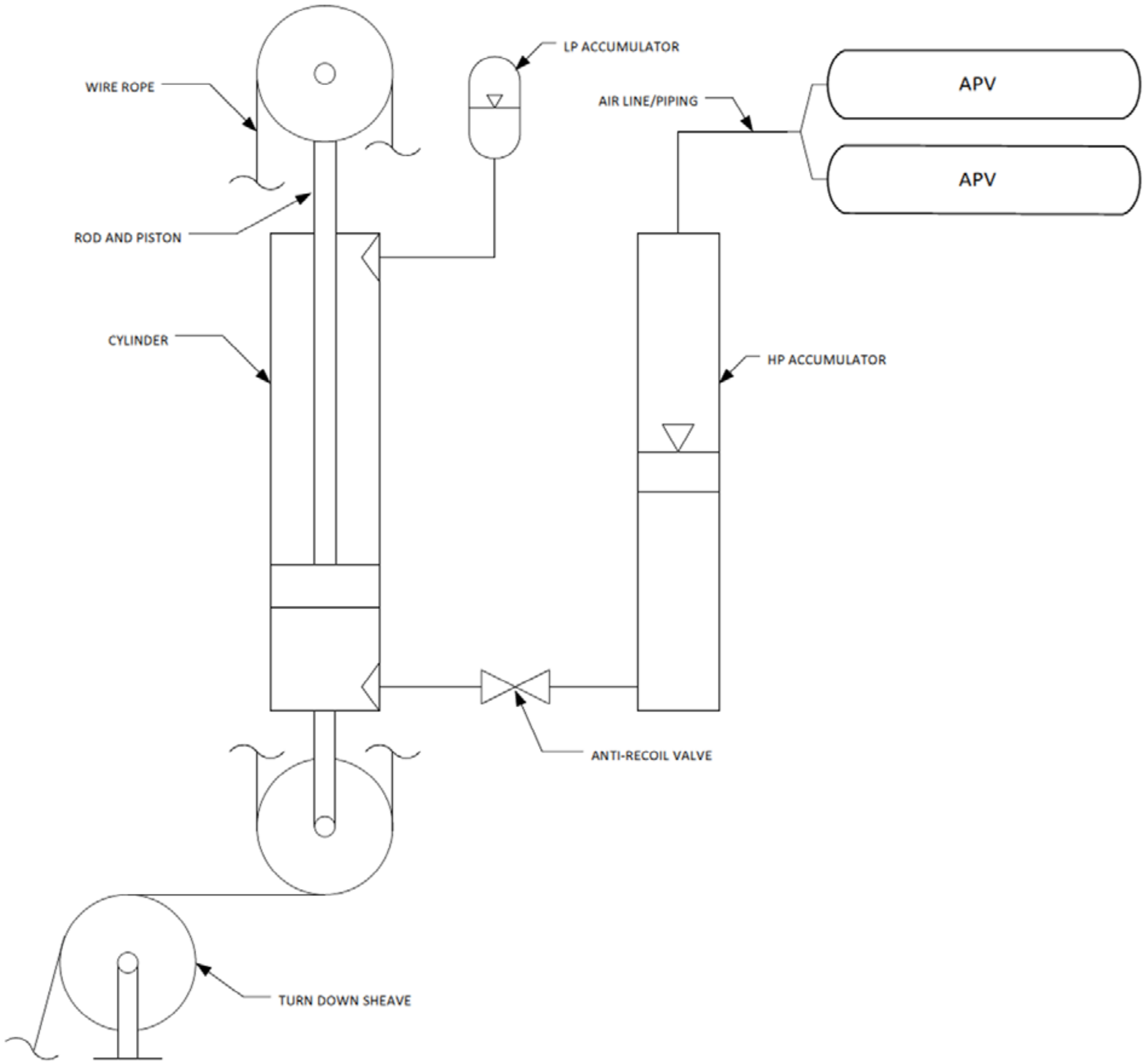

Figure G.2—Typical Wire Rope Tensioning System

Annex H
(informative)

Effective Polytropic Constants for Isentropic Compression and Expansion of Air and Nitrogen

Tables H.1 through H.12 are polytropic constants that can be used for tensioner performance curves as an alternative to the NIST, Benedict–Webb–Rubin EOS, van der Waals EOS, or actual test data as described in 7.4.1.

NOTE Use Tables H.1 through H.6 for compressed air or Tables H.7 through H.12 for compressed nitrogen.

Table H.1—Polytropic Constant Table—Air Compressed to 85 % of Initial Volume

Isentropic Compression of Air to 85 % of Initial Volume										
Initial Pressure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	640	639	639	638	638	1.4772	1.4720	1.4663	1.4617	1.4573
1000	1302	1296	1292	1289	1286	1.6009	1.5763	1.5549	1.5401	1.5279
1500	2009	1988	1972	1961	1954	1.7831	1.7190	1.6684	1.6363	1.6119
2000	2784	2728	2687	2662	2645	2.0226	1.8985	1.8053	1.7491	1.7079
2500	3642	3527	3444	3396	3362	2.3039	2.1071	1.9616	1.8757	1.8142
3000	4588	4390	4248	4166	4110	2.6039	2.3331	2.1312	2.0125	1.9284
3500	5617	5317	5099	4975	4888	2.9014	2.5646	2.3078	2.1557	2.0479
4000	6719	6305	5998	5821	5698	3.1825	2.7922	2.4858	2.3015	2.1703
4500	7882	7348	6942	6705	6539	3.4400	3.0094	2.6606	2.4469	2.2934
5000	9093	8438	7928	7624	7411	3.6718	3.2126	2.8293	2.5896	2.4154

Table H.2—Polytropic Constant Table—Air Compressed to 90 % of Initial Volume

Isentropic Compression of Air to 90 % of Initial Volume										
Initial Pres-sure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	586	586	586	586	585	1.4739	1.4690	1.4638	1.4594	1.4553
1000	1185	1182	1180	1178	1177	1.5916	1.5686	1.5485	1.5346	1.5232
1500	1810	1798	1789	1783	1779	1.7648	1.7045	1.6569	1.6267	1.6036
2000	2471	2440	2418	2404	2394	1.9928	1.8756	1.7876	1.7345	1.6956
2500	3177	3114	3069	3043	3024	2.2617	2.0748	1.9369	1.8555	1.7973
3000	3929	3823	3746	3702	3671	2.5503	2.2914	2.0992	1.9865	1.9066
3500	4726	4566	4449	4381	4334	2.8391	2.5146	2.2688	2.1238	2.0211
4000	5559	5341	5177	5081	5015	3.1148	2.7353	2.4403	2.2639	2.1386
4500	6425	6144	5929	5801	5712	3.3701	2.9475	2.6096	2.4042	2.2571

5000	7315	6972	6702	6540	6426	3.6022	3.1477	2.7738	2.5422	2.3748

Table H.3—Polytropic Constant Table—Air Compressed to 95 % of Initial Volume

Isentropic Compression of Air to 95 % of Initial Volume										
Initial Pres-sure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	540	540	540	540	540	1.4708	1.4663	1.4615	1.4574	1.4535
1000	1086	1085	1084	1083	1082	1.5832	1.5616	1.5428	1.5296	1.5188
1500	1642	1637	1633	1631	1629	1.7484	1.6916	1.6466	1.6180	1.5961
2000	2214	2201	2192	2186	2182	1.9659	1.8550	1.7717	1.7214	1.6844
2500	2804	2778	2759	2749	2741	2.2233	2.0456	1.9146	1.8374	1.7820
3000	3413	3369	3338	3319	3306	2.5011	2.2536	2.0703	1.9630	1.8869
3500	4039	3974	3927	3899	3879	2.7812	2.4687	2.2333	2.0948	1.9969
4000	4680	4592	4526	4486	4459	3.0509	2.6826	2.3988	2.2298	2.1099
4500	5334	5221	5134	5082	5046	3.3031	2.8897	2.5627	2.3651	2.2240
5000	5997	5860	5752	5686	5639	3.5346	3.0863	2.7224	2.4988	2.3377

Table H.4—Polytropic Constant Table—Air Expanded to 105 % of Initial Volume

Isentropic Expansion of Air to 105 % of Initial Volume										
Initial Pres-sure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	464	465	465	465	465	1.4655	1.4617	1.4574	1.4538	1.4503
1000	925	926	927	927	928	1.5688	1.5496	1.5328	1.5210	1.5113
1500	1378	1382	1384	1386	1387	1.7202	1.6692	1.6288	1.6030	1.5831
2000	1820	1829	1836	1840	1843	1.9196	1.8195	1.7442	1.6986	1.6651
2500	2249	2267	2280	2288	2294	2.1566	1.9951	1.8761	1.8059	1.7555
3000	2665	2695	2717	2730	2739	2.4145	2.1875	2.0201	1.9222	1.8528
3500	3070	3113	3147	3166	3180	2.6774	2.3879	2.1714	2.0445	1.9549
4000	3465	3524	3569	3597	3616	2.9342	2.5888	2.3257	2.1700	2.0599
4500	3852	3926	3986	4021	4047	3.1781	2.7852	2.4796	2.2965	2.1663
5000	4232	4323	4396	4441	4474	3.4058	2.9738	2.6305	2.4220	2.2727

Table H.5—Polytropic Constant Table—Air Expanded to 110 % of Initial Volume

Isentropic Expansion of Air to 110 % of Initial Volume										
Initial Pressure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	433	433	433	433	434	1.4632	1.4596	1.4557	1.4523	1.4489
1000	860	861	862	863	864	1.5625	1.5444	1.5285	1.5173	1.5080
1500	1272	1278	1283	1286	1289	1.7079	1.6595	1.6210	1.5964	1.5775
2000	1666	1682	1693	1700	1706	1.8995	1.8041	1.7323	1.6887	1.6566
2500	2038	2069	2092	2105	2115	2.1274	1.9730	1.8594	1.7922	1.7440
3000	2389	2439	2477	2500	2516	2.3762	2.1585	1.9982	1.9044	1.8379
3500	2720	2794	2850	2884	2908	2.6310	2.3522	2.1443	2.0225	1.9365
4000	3036	3135	3212	3258	3291	2.8810	2.5470	2.2935	2.1438	2.0380
4500	3339	3463	3562	3623	3667	3.1201	2.7381	2.4427	2.2662	2.1410
5000	3631	3781	3903	3979	4034	3.3449	2.9225	2.5894	2.3879	2.2440

Table H.6—Polytropic Constant Table—Air Expanded to 115 % of Initial Volume

Isentropic Expansion of Air to 115 % of Initial Volume										
Initial Pressure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	405	405	405	406	406	1.4610	1.4578	1.4540	1.4508	1.4476
1000	802	804	805	807	808	1.5567	1.5396	1.5245	1.5138	1.5049
1500	1180	1188	1194	1198	1201	1.6967	1.6506	1.6139	1.5904	1.5723
2000	1534	1554	1569	1578	1585	1.8811	1.7899	1.7213	1.6796	1.6489
2500	1860	1899	1929	1946	1959	2.1006	1.9528	1.8440	1.7796	1.7334
3000	2159	2223	2272	2301	2322	2.3409	2.1319	1.9780	1.8880	1.8242
3500	2433	2527	2599	2642	2673	2.5877	2.3192	2.1193	2.0022	1.9196
4000	2688	2813	2911	2971	3013	2.8311	2.5081	2.2638	2.1197	2.0179
4500	2927	3083	3210	3287	3343	3.0651	2.6941	2.4085	2.2383	2.1176
5000	3153	3341	3496	3593	3664	3.2864	2.8742	2.5512	2.3564	2.2175

Table H.7—Polytropic Constant Table—Nitrogen Compressed to 85 % of Initial Volume

Isentropic Compression of Nitrogen to 85 % of Initial Volume										
Initial Pres-sure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	640	640	639	638	638	1.4823	1.4765	1.4706	1.4660	1.4617
1000	1304	1298	1294	1290	1288	1.6121	1.5864	1.5642	1.5489	1.5365
1500	2014	1993	1976	1966	1958	1.7968	1.7329	1.6817	1.6491	1.6241
2000	2788	2734	2694	2669	2651	2.0319	1.9126	1.8208	1.7646	1.7231
2500	3640	3533	3453	3405	3372	2.3012	2.1170	1.9767	1.8923	1.8311
3000	4573	4391	4256	4177	4121	2.5840	2.3348	2.1435	2.0285	1.9458
3500	5582	5310	5106	4986	4901	2.8625	2.5556	2.3151	2.1694	2.0645
4000	6657	6284	5999	5831	5712	3.1253	2.7712	2.4865	2.3116	2.1851
4500	7788	7308	6935	6711	6552	3.3665	2.9763	2.6538	2.4523	2.3053
5000	8964	8377	7908	7624	7421	3.5841	3.1679	2.8145	2.5896	2.4238

Table H.8—Polytropic Constant Table—Nitrogen Compressed to 90 % of Initial Volume

Isentropic Compression of Nitrogen to 90 % of Initial Volume										
Initial Pres-sure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	587	586	586	586	586	1.4787	1.4734	1.4679	1.4635	1.4595
1000	1187	1184	1181	1179	1178	1.6024	1.5784	1.5574	1.5430	1.5313
1500	1812	1801	1791	1786	1781	1.7782	1.7181	1.6698	1.6390	1.6154
2000	2473	2444	2421	2408	2398	2.0022	1.8895	1.8027	1.7495	1.7102
2500	3176	3118	3074	3048	3030	2.2599	2.0848	1.9518	1.8717	1.8137
3000	3922	3824	3751	3708	3677	2.5321	2.2939	2.1116	2.0022	1.9236
3500	4707	4562	4453	4388	4342	2.8026	2.5068	2.2765	2.1375	2.0376
4000	5528	5330	5178	5087	5023	3.0603	2.7161	2.4420	2.2744	2.1535
4500	6377	6124	5925	5805	5720	3.2993	2.9168	2.6043	2.4104	2.2694
5000	7249	6941	6693	6541	6432	3.5172	3.1057	2.7610	2.5435	2.3840

Table H.9—Polytropic Constant Table—Nitrogen Compressed to 95 % of Initial Volume

Isentropic Compression of Nitrogen to 95 % of Initial Volume										
Initial Pressure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	540	540	540	540	540	1.4754	1.4705	1.4654	1.4612	1.4575
1000	1086	1085	1084	1083	1083	1.5936	1.5711	1.5514	1.5378	1.5267
1500	1643	1638	1635	1632	1630	1.7615	1.7047	1.6591	1.6299	1.6075
2000	2215	2203	2193	2188	2183	1.9755	1.8686	1.7864	1.7359	1.6986
2500	2804	2780	2762	2751	2743	2.2224	2.0558	1.9293	1.8531	1.7980
3000	3410	3370	3340	3322	3309	2.4846	2.2566	2.0826	1.9784	1.9035
3500	4032	3973	3928	3901	3882	2.7469	2.4621	2.2414	2.1085	2.0132
4000	4668	4588	4526	4489	4462	2.9989	2.6652	2.4012	2.2405	2.1248
4500	5315	5214	5133	5084	5049	3.2349	2.8610	2.5586	2.3720	2.2367
5000	5971	5848	5748	5686	5642	3.4520	3.0467	2.7112	2.5011	2.3475

Table H.10—Polytropic Constant Table—Nitrogen Expanded to 105 % of Initial Volume

Isentropic Expansion of Nitrogen to 105 % of Initial Volume										
Initial Pressure (psig)	**Final Pressure**					**Effective Polytropic Constant**				
	Initial Temperature (°F)					**Initial Temperature** (°F)				
	−40	**−4**	**40**	**80**	**120**	**−40**	**−4**	**40**	**80**	**120**
500	464	464	465	465	465	1.4698	1.4655	1.4610	1.4573	1.4540
1000	925	926	927	927	928	1.5786	1.5585	1.5408	1.5286	1.5186
1500	1377	1381	1383	1385	1387	1.7327	1.6817	1.6405	1.6141	1.5938
2000	1819	1828	1834	1839	1842	1.9293	1.8327	1.7582	1.7123	1.6784
2500	2249	2266	2278	2286	2292	2.1571	2.0053	1.8902	1.8209	1.7707
3000	2667	2694	2715	2728	2737	2.4009	2.1915	2.0324	1.9371	1.8687
3500	3074	3114	3145	3164	3178	2.6472	2.3832	2.1800	2.0580	1.9706
4000	3473	3526	3569	3595	3614	2.8869	2.5742	2.3294	2.1811	2.0746
4500	3863	3931	3986	4020	4045	3.1147	2.7601	2.4773	2.3042	2.1792
5000	4248	4330	4398	4440	4471	3.3278	2.9383	2.6218	2.4257	2.2832

Table H.11—Polytropic Constant Table—Nitrogen Expanded to 110 % of Initial Volume

Isentropic Expansion of Nitrogen to 110 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	−40	−4	40	80	120	−40	−4	40	80	120
500	433	433	433	433	433	1.4674	1.4634	1.4591	1.4556	1.4524
1000	859	860	862	863	864	1.5720	1.5530	1.5362	1.5246	1.5150
1500	1271	1277	1282	1285	1287	1.7202	1.6716	1.6324	1.6072	1.5878
2000	1665	1680	1691	1698	1704	1.9093	1.8170	1.7459	1.7021	1.6696
2500	2038	2067	2089	2102	2112	2.1285	1.9833	1.8732	1.8069	1.7587
3000	2392	2438	2474	2496	2512	2.3639	2.1630	2.0104	1.9191	1.8535
3500	2728	2795	2848	2880	2903	2.6026	2.3484	2.1531	2.0359	1.9520
4000	3049	3139	3210	3255	3287	2.8361	2.5336	2.2976	2.1550	2.0526
4500	3358	3471	3563	3620	3662	3.0592	2.7146	2.4412	2.2743	2.1539
5000	3657	3793	3906	3978	4030	3.2692	2.8888	2.5818	2.3922	2.2547

Table H.12—Polytropic Constant Table—Nitrogen Expanded to 115 % of Initial Volume

Isentropic Expansion of Nitrogen to 115 % of Initial Volume										
Initial Pressure (psig)	Final Pressure					Effective Polytropic Constant				
	Initial Temperature (°F)					Initial Temperature (°F)				
	−40	−4	40	80	120	−40	−4	40	80	120
500	405	405	405	405	406	1.4651	1.4614	1.4574	1.4541	1.4510
1000	801	803	804	806	807	1.5660	1.5480	1.5320	1.5209	1.5118
1500	1178	1186	1192	1196	1199	1.7088	1.6625	1.6250	1.6009	1.5823
2000	1532	1551	1566	1576	1583	1.8909	1.8027	1.7346	1.6926	1.6615
2500	1860	1897	1925	1942	1955	2.1023	1.9632	1.8576	1.7940	1.7478
3000	2162	2222	2268	2296	2317	2.3297	2.1367	1.9902	1.9025	1.8395
3500	2442	2528	2596	2637	2667	2.5611	2.3161	2.1282	2.0156	1.9348
4000	2704	2818	2909	2966	3007	2.7884	2.4959	2.2683	2.1309	2.0323
4500	2951	3093	3210	3283	3337	3.0067	2.6720	2.4077	2.2466	2.1305
5000	3186	3356	3499	3590	3658	3.2132	2.8422	2.5445	2.3612	2.2284

Annex I
(informative)

Fatigue Considerations

I.1 General Fatigue Considerations

Fatigue life evaluation of equipment may be accomplished by the use of design fatigue S-N (stress-cycle) curves along with alternating local peak principal stresses.

The manufacturer shall provide the information described in this section for use by others for the purpose of fatigue analysis.

The relationship of alternating peak stresses to alternating reference stresses or alternating loads (as may be determined by a global riser analysis) may be determined by using either SAFs or SLRs.

The manufacturer shall provide either SAFs or SLRs.

The local peak alternating stress is the principal stress with the largest dynamic amplitude in the region of the riser component under consideration. The basic characteristic of a peak stress is that it causes no significant distortion and is only objectionable as a possible cause of fatigue failure. These stresses are highly localized and occur at geometric discontinuities.

Due to possible changes in load path, preload, etc., the SAF or SLR can vary significantly as a function of the magnitude of the external applied loads. It is the responsibility of the manufacturer to ensure that an appropriate selection of load increments is used in the analysis to determine the SAF or SLR values. The analysis to determine the SAF or SLR should use linear elastic material behavior and nonlinear geometry (large displacement theory).

Stresses in bolts (threaded fasteners) shall be calculated by accepted engineering methods, taking into account the effect of preload and the relative stiffness of the fasteners and the structural component parts they fasten. The reference section for bolt SAFs shall also be stated. It is recommended that this reference section be consistent with the reference section used for other SAFs.

It is the responsibility of the manufacturer to account for the effect of geometric tolerances on SAF or SLR. When applicable, SAF or SLR shall account for the effects of load sharing, preload, and other relevant nonlinearities.

The SAF or SLR values reported shall state if they have been determined by analysis or physical testing. The SAFs or SLRs shall be determined for the riser component base material, welds, bolts, and other stress concentration areas unique to the design, as applicable. This information shall account for tension and bending moment as described below.

In certain cases, the SAF or SLR at various load levels for specific locations may be significantly lower than the maximum SAF or SLR. In these cases, the use of a SAF or SLR curve, which reports SAF or SLR values for various load magnitudes, may be more appropriate for comprehensive fatigue studies.

The SAF or SLR curve shall be available, if requested. As a minimum, the maximum SAF (and the section used to determine the reference stress) or SLR values for tension and bending shall be reported.

I.2 SAF

The SAF is defined as the ratio of the incremental change of local peak stress (maximum alternating principal stress) to the corresponding incremental change of the reference stress. The reference stress and reference section dimensions shall be defined and documented. Typical examples of the incremental change in reference stresses are the incremental change in stress due to tension/compression ($\Delta F/A$) or bending moment ($\Delta M \times c/I$).

where

ΔF is total change in axial force in the component;

A is cross-sectional area of the reference section;

ΔM is total change in bending moment in the component;

c is distance from neutral axis to the reference location;

I is moment of inertia of the reference section.

$$\text{SAF} = \frac{\text{The incremental change of peak stress at the location of interest}}{\text{The incremental change in stress in the reference section}}$$

"Incremental change" refers to changes in stress that arise from small changes in load above and below the load at which the SAF has been calculated.

I.3 SLR

When multiple load paths exist in a piece of equipment (as in auxiliary line load sharing in a riser joint), confusion may arise as to the section used for determination of the reference stress. Stresses calculated by riser analysis software for load shared risers may also be misinterpreted by the end user. These misunderstandings can lead to the incorrect determination of the alternating peak stress. A more direct determination of the alternating peak stress may be accomplished by the use of SLR.

The SLR is defined as the ratio of the incremental change of peak stress (maximum alternating principal stress) to the corresponding incremental change of the global load (tension/compression or bending).

$$\text{SLR} = \frac{\text{The incremental change of peak stress at the location of interest}}{\text{The incremental change of global load}}$$

Incremental load refers to either the change in tension (tension SLR), change in compression (compression SLR), or the change in bending moment (bending SLR). Each can be expected to vary as mean tension increases. The change in global loads can then be used with the appropriate SLR to determine the change in peak stresses. The intermediate step of determining the reference stress is avoided with this approach.

"Incremental change" refers to changes in stress or load that arises from small changes in load above and below the load at which the SLR has been calculated.

I.4 Tension and Bending Stiffness Properties for Global Riser Analysis

Fatigue loading and stresses that are predicted by a global riser analysis can be sensitive to assumptions about tension stiffness ("EA"), bending stiffness ("EI"), and the location of the neutral axis. In some riser components, these values can vary with load. One example is a load-sharing riser joint in which load sharing does not occur below some level of tension. Thermal and pressure effects in the main tube and all peripheral lines may influence load sharing and the loads at which changes in stiffness properties may occur.

To facilitate proper application of the SAFs and/or SLRs to a global riser analysis, the manufacturer shall also provide the relevant stiffness properties for tension (EA) and bending (EI). If these values change with load, temperature, or pressure, the manufacturer shall quantify these changes. If the bending SAFs, SLRs, and/or neutral axis vary with the plane of rotation (e.g. in-plane vs orthogonal to the plane that contains the choke/kill lines), the manufacturer shall provide this information. A minimum of eight different directions (45° increments) shall be analyzed.

I.5 Finite Element Analysis Summary

The manufacturer shall provide a basic description of the finite element model used to determine the SAFs or SLRs with enough detail to clarify the proper use of the SAFs, SLRs, EA, and EI for fatigue analysis. This shall include at least the following as applicable:

— at least one representative rendering of the model;

— definition of coordinate axes and neutral axis for each EI;

— geometric assumptions such as gaps for load-sharing lines;

— location where each set of SAFs or SLRs is defined.

I.6 Fatigue S-N Curves

For each SAF or SLR, a corresponding fatigue stress-cycle (S-N) curve shall be specified. If welds are fatigue critical, the SAF or SLR values, the weld classification, and the appropriate fatigue S-N curve for the weld shall be reported.

Both stress amplification due to geometric features and/or to the weld itself (hi-lo, etc.) shall be appropriately used and documented. Geometric SAFs or SLRs (as defined in I.2 and I.3) at the weld location shall be provided even if the fatigue S-N curve accounts for stress concentrations within the weld.

Annex J
(informative)

Coupling Optional Qualification Tests

J.1 General

Test couplings used to perform the optional qualification tests should meet the requirements stated in 16.5.

J.2 Cyclic Load Test

To simulate in-service load fluctuations, tension plus cyclic bending loads may be applied (as well as internal pressure) to represent a chosen loading condition. Extended testing can be conducted to compare with fatigue life predictions.

J.3 Spider Load Reaction Test

The ability of the coupling to carry the most severe loads applied when a long string of riser supporting a BOP stack is hung off on the spider may be checked. The loads experienced when landing on and hanging from the spider while running and pulling riser may be simulated. When simulating the spider hangoff loads, only the box or pin end (whichever hangs in the spider) should be loaded.

J.4 Handling Tool Reaction Test

The ability of the coupling box or pin (as appropriate) to carry the most severe loads applied when a long string of riser supporting a BOP stack is suspended from the handling tool may be checked. The application of dynamic and static loading on the coupling box or pin interface with the handling tool may be simulated.

J.5 C&K Support Test

The ability of the C&K stabs to hold pressure and the C&K support brackets to react to loads induced by line pressure may be checked. C&K line test pressure may be applied to C&K stabs installed on the coupling and supported by standard brackets.

Bibliography

[1] AISC 303-89, *Code of Standard Practice for Steel Buildings and Bridges*

[2] API Recommended Practice 2RD, *Dynamic Risers for Floating Production Systems*

[3] API Technical Report 6AM, *Technical Report on Material Toughness*

[4] API Recommended Practice 16Q, *Design, Selection, Operation, and Maintenance of Marine Drilling Riser Systems*

[5] API Standard 64, *Diverter Equipment Systems*

[6] ASTM A703, *Standard Specification for Steel Casings, General Requirements, for Pressure-containing Parts*

[7] ASTM B850, *Standard Guide for Post-coating Treatments of Steel for Reducing Risk of Hydrogen Embrittlement*

[8] ASTM D4285, *Standard Test Method for Indicating Oil or Water in Compressed Air*

[9] ASTM E399, *Standard Test Method for Linear-elastic Plane-strain Fracture Toughness K_{Ic} of Metallic Materials*

[10] ASTM E8/E8M, *Standard Test Methods for Tension Testing of Metallic Materials*

[11] ASTM E1290, *Standard Test Method for Crack-tip Opening Displacement (CTOD) Fracture Toughness Measurement*

[12] ASTM E2109, *Standard Test Methods for Determining Area Percentage Porosity in Thermal Sprayed Coatings*

[13] ISO 2063, *Thermal spraying – Zinc, aluminium and their alloys – Part 1: Design considerations and quality requirements for corrosion protection systems*

[14] ISO 4624, *Paints and varnishes – Pull-off test for adhesion*

[15] ISO 8501-1, *Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

[16] ISO 8502-3, *Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)*

[17] ISO 8502-9, *Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 9: Field method for the conductometric determination of water-soluble salts*

[18] ISO 8503-1, *Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*

[19] ISO 8503-2, *Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel – Comparator procedure*

[20] ISO 8503-4, *Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile – Stylus instrument procedure*

[21] ISO 8503-5, *Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates – Part 5: Replica tape method for the determination of the surface profile*

[22] ISO 13625 [12], *Petroleum and natural gas industries—Drilling and production equipment—Marine drilling riser couplings*

[23] ISO 14919, *Thermal spraying – Wires, rods and cords for flame and arc spraying – Classification – Technical supply conditions*

[24] NACE WJ-4 WC, *Waterjet Cleaning of Metals—Light Cleaning*

[25] SSPC PA

[26] SSPC SP1, *Solvent Cleaning*

[27] *Operating Guidelines for Emergency Disconnect of Deepwater Drilling Risers*, M.J. Stahl and F. Abbassian, OMAE2000/OSU OFT-4040, Proceedings of ETCE/OMAE2000 Joint Conference, February 14–17, 2000.

[28] *Design of a Riser Recoil Control System and Validation Through Full-scale Testing*, M.J. Stahl and C.J. Hock, SPE 62959, 2000 SPE Annual Technical Conference, October 1–4, 2000.

[29] *Design Installation and Testing of a Deepwater Riser Emergency Disconnect Anti-recoil System*, C.J. Hock and R.D. Young, IADC/SPE 23858, 1992 IADC/SPE Drilling Conference, February 18–21, 1992.

[30] *Comparison of Analysis and Full-sale Testing of Anti-recoil System for Emergency Disconnect of Deepwater Riser*, C.J. Hock, G. Karlsen, and J.W. Albert, OTC 6892, 24th Annual OTC, May 4–7, 1992.

[31] *Analysis and Design of Anti-recoil System for Emergency Disconnect of a Deepwater Riser: Case Study*, R.D. Young, C.J. Hock, G. Karlsen, and J.E. Miller, OTC 6891, 24th Annual OTC, May 4–7, 1992.

[32] Langer, B.F., “Criteria of the ASME Boiler and Pressure Vessel Code for Design by Analysis in Sections III and VIII, Division 2,” *Pressure Vessels and Piping: Design and Analysis*, Volume 1, American Society of Mechanical Engineers, New York.

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