

Specification for Ancillary Equipment for Flexible Pipes and Subsea Umbilicals

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Specification for Ancillary Equipment for Flexible Pipes and Subsea Umbilicals

1 Scope

This specification defines the technical requirements for safe, dimensionally and functionally interchangeable ancillary equipment that is designed and manufactured to uniform standards and criteria.

Minimum requirements are specified for the design, material selection, manufacture, testing, documentation, marking, and packaging of ancillary equipment used in flexible pipe systems and subsea umbilical systems, with reference to existing codes and standards where applicable. See API 17L2 for guidelines on the use of ancillary equipment.

The applicability relating to a specific item of ancillary equipment is stated at the beginning of the particular section for the ancillary equipment in question.

This specification applies to the following ancillary equipment:

- bend stiffeners;
- bend restrictors;
- bellmouths;
- buoyancy modules and ballast modules;
- subsea buoys;
- tethers for subsea buoys and tether clamps;
- riser and tether bases;
- subsea buoy clamps;
- tether clamps;
- piggy-back systems;
- repair clamps;
- I/J-tube seals;
- pull-in heads/installation aids;
- connectors;
- load-transfer devices;
- mechanical protection;
- fire protection;
- VIV (vortex-induced vibration) suppression strakes.

This specification does not cover flexible pipe and umbilical ancillary equipment beyond the connector, with the exception of riser bases and load-transfer devices. Therefore this document does not cover turret structures or

I-tubes and J-tubes for example. In addition, this document does not cover storage devices such as reels, for example.

This specification is intended to cover ancillary equipment made from several material types, including metallic, polymer, and composite materials.

This specification applies to ancillary equipment used in association with the flexible pipe and umbilical applications listed in API 17B, API 17J, API 17E, and API 17K.

Annexes to this specification are not mandatory and are intended to be used as informative guidelines.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Recommended Practice 2A-WSD, *Planning, Designing, and Constructing Fixed Offshore Platforms—Working Stress Design*

API Specification 2F, *Specification for Mooring Chain*

API Recommended Practice 2RD:1998, *Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)*

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

API Specification 9A, *Specification for Wire Rope*

API Recommended Practice 17B, *Recommended Practice for Flexible Pipe*

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

API Specification 17E, *Specification for Subsea Umbilicals*

API Specification 17J:2014, *Specification for Unbonded Flexible Pipe*

API Specification 17K, *Specification for Bonded Flexible Pipe*

API Recommended Practice 17L2, *Recommended Practice for Flexible Pipe Ancillary Equipment*

API Recommended Practice 17R, *Recommended Practice for Flowline Connectors and Jumpers*

API Recommended Practice 17P, *Recommended Practice for Subsea Structures and Manifolds*

AISC,¹ *Steel Construction Manual*

ASME *Boiler and Pressure Vessel Code*,² Section VIII: Rules for Construction of Pressure Vessels

ASTM C177,³ *Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus*

¹ American Institute of Steel Construction, One East Wacker Drive, Suite 700, Chicago, Illinois 60601, www.aisc.org.

² ASME International, Two Park Avenue, New York, New York 10016–5990, www.asme.org.

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



ASTM C518, *Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*

ASTM D256, *Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics*

ASTM D570, *Standard Test Method for Water Absorption of Plastics*

ASTM D624, *Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers*

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

ASTM D648, *Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position*

ASTM D695, *Standard Test Method for Compressive Properties of Rigid Plastics*

ASTM D732, *Standard Test Method for Shear Strength of Plastics by Punch Tool*

ASTM D792, *Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement*

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

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

ASTM D2990, *Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics*

ASTM D4060, *Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser*

ASTM E1269, *Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry*

BS PD 5500,⁴ *Specification for Unfired Fusion Welded Pressure Vessels*

BS 903-A9, *Physical Testing of Rubber. Determination of Abrasion Resistance*

BS/EN 10083-1, *Steels for Quenching and Tempering. General Technical Delivery Conditions*

BS/EN 10083-2, *Steels for Quenching and Tempering. Technical Delivery Conditions for Non Alloy Steels*

DNVGL-OS-D301,⁵ *Fire Protection*

ISO 34-1,⁶ *Rubber, Vulcanized or Thermoplastic—Determination of Tear Strength—Part 1: Trouser, Angle and Crescent Test Pieces*

ISO 37, *Rubber, Vulcanized or Thermoplastic—Determination of Tensile Stress-strain Properties*

ISO 62, *Plastics—Determination of Water Absorption*

ISO 75-1, *Plastics—Determination of Temperature of Deflection Under Load—Part 1: General Test Method*

ISO 75-2, *Plastics—Determination of Temperature of Deflection Under Load—Part 2: Plastics and Ebonite*

⁴ British Standards Institution, Chiswick High Road, London, W4 4AL, United Kingdom, www.bsi-global.com.

⁵ Det Norske Veritas, Veritasveien 1, NO-1322 Hovik, Oslo, Norway, www.dnv.com.

⁶ International Organization for Standardization, ISO Central Secretariat Chemin de Blandonnet 8, CP 401 - 1214 Vernier, Geneva, Switzerland, www.iso.org.

ISO 178, *Plastics—Determination of Flexural Properties*

ISO 179-1, *Plastics—Determination of Charpy Impact Properties—Part 1: Non-instrumented Impact Test*

ISO 179-2, *Plastics—Determination of Charpy Impact Properties—Part 2: Instrumented Impact Test*

ISO 180, *Plastics—Determination of Izod Impact Strength*

ISO 527-1, *Plastics—Determination of Tensile Properties—Part 1: General Principles*

ISO 527-2, *Plastics—Determination of Tensile Properties—Part 2: Test Conditions for Moulding and Extrusion Plastics*

ISO 604, *Plastics—Determination of Compressive Properties*

ISO 868, *Plastics and Ebonite—Determination of Indentation Hardness by Means of a Durometer (Shore Hardness)*

ISO 899-1, *Plastics—Determination of Creep Behavior—Part 1: Tensile Creep*

ISO 1183 (all parts), *Plastics—Methods for Determining the Density of Non-cellular Plastics*

ISO 1431-1, *Rubber, Vulcanized or Thermoplastic—Resistance to Ozone Cracking—Part 1: Static and Dynamic Strain Testing*

ISO 1827, *Rubber, Vulcanized or Thermoplastic—Determination of Shear Modulus and Adhesion to Rigid Plates—Quadruple-shear Methods*

ISO 4649, *Rubber, Vulcanized or Thermoplastic—Determination of Abrasion Resistance Using a Rotating Cylindrical Drum Device*

ISO 7743, *Rubber, Vulcanized, or Thermoplastic—Determination of Compressive Stress-strain Properties*

ISO 7784-2, *Paints and Varnishes—Determination of Resistance to Abrasion—Part 2: Rotating Abrasive Rubber Wheel Method*

ISO 10474, *Steel and Steel Products—Inspection Documents*

ISO 15156/NACE MR0175, *Petroleum and Natural Gas Industries—Materials for Use in H₂S Containing Environments in Oil and Gas Production*

ISO 19902, *Petroleum and Natural Gas Industries—Fixed Steel Offshore Structures*

Lloyd's Register of Shipping,⁷ *Code for Lifting Appliances in a Marine Environment*

NORSOK M-501,⁸ *Surface Preparation and Protective Coating*

NORSOK U-001, *Subsea Production Systems*

⁷ Lloyd's Register of Shipping, 71 Fenchurch Street, London EC3M 4BS, United Kingdom, www.lr.org.

⁸ Norwegian Technology Centre, Oscarsgt. 20, Postbox 7072 Majorstuen, NO-0306 Oslo, Norway, www.nts.no/norsok.

3 Terms, Definitions, Abbreviations, and Symbols

3.1 Terms and Definitions

For the purposes of this document, the terms and definitions given in API 17B, API 17K, API 17J, and the following apply. For description and additional information, see Section 4.2 of API 17L2.

3.1.1

anchor base

Structure used to secure one end of a tether to the seabed.

3.1.2

ancillary component

Component that is attached to the flexible pipe or umbilical to perform one or more of the following functions:

- a) to control the flexible pipe or umbilical behavior;
- b) to provide a structural transition between the flexible pipe or umbilical and adjacent structures;
- c) to attach other structures to the flexible pipe or umbilical;
- d) to protect or repair the flexible pipe or umbilical;
- e) to provide a seal along the flexible pipe or umbilical length.

3.1.3

ballast module

Negatively buoyant component of which a number are used at discrete points over a length of flexible pipe or umbilical to provide added weight.

3.1.4

banding

Device used to secure mechanical protection to the flexible pipe or umbilical.

3.1.5

batch

Quantity of product made of a unique mixture of one or more polymer components, given as either a percentage of total output, or produced over a short period of time as specified by the manufacturer.

NOTE A short period of time can be for example up to 24 hours, or across shift changes etc., which is based on manufacturing capacity, job length and product line.

3.1.6

bend restrictor

Mechanical device made of interlocking vertebrae that functions as a mechanical stop and limits the local radius of curvature of the flexible pipe or umbilical to a minimum value.

3.1.7

bend stiffener base

Face of the interface structure on the support structure side at which the bend stiffener begins.

3.1.8

bend stiffener body

Polymeric part of a bend stiffener that provides extra stiffness to the flexible pipe or umbilical to prevent it from overbending and fatigue failure.

3.1.9**bend stiffener cap**

Structural component of some bend stiffener designs comprising a cylindrical metallic shell that fits externally around part of the bend stiffener length adjacent to the bend stiffener base.

3.1.10**bend stiffener tip**

End of the bend stiffener body opposite the base.

NOTE The bend stiffener tip, for a particular bend stiffener configuration, is shown in Figure 48 in API 17L2.

3.1.11**bending stress**

Portion of primary stress proportional to the distance from the centroid of a cross section, excluding the effects of discontinuities and stress concentrations.

NOTE Definition taken from API 2RD:1998.

3.1.12**blown foam**

Polymer foam containing no microspheres or macrospheres.

3.1.13**bridle**

Load-bearing Y-shape structure that forms the transition between a subsea buoy frame and its tethers.

3.1.14**buoyancy element**

Part of a buoyancy module or some subsea buoys that gives uplift to the module or buoy.

NOTE The buoyancy element comprises a buoyant material and external skin. It does not include buoyancy tanks.

3.1.15**buoyancy module**

Discrete component, consisting of a buoyancy element, and means of securing it to the pipe or umbilical, used to provide net uplift by attaching a series of such components along a length of pipe or umbilical.

3.1.16**buoyancy tank**

Part of some subsea buoys that consists of a pressure vessel filled with gas at ambient or higher pressure that gives uplift to the subsea buoy.

3.1.17**Chinese finger**

Device used during installation that consists of a meshed structure that grips around the flexible pipe or umbilical outer sheath.

NOTE The mesh is configured such that the higher the load applied to it, the tighter its grip.

3.1.18**clamp body**

Part of a clamp that is in surface contact with the pipe or umbilical outer sheath.

3.1.19**clamp inner liner**

Part of some clamp bodies that consists of a compliant lining of material in contact with the flexible pipe or umbilical outer sheath that allows for variations in the pipe or umbilical external diameter.



3.1.20**composite**

Combination of a polymer material and a reinforcing material that enhances the properties of the polymer.

3.1.21**composite syntactic foam**

Composite material consisting of a polymer matrix containing both microspheres and macrospheres.

3.1.22**connector**

Device used to provide a leak-tight structural connection between the end fitting and adjacent piping.

NOTE It does not include flexible pipe end fittings.

3.1.23**crushing capacity**

Maximum localized radial compressive load that a flexible pipe or umbilical can resist.

3.1.24**design methodology verification report**

Evaluation report prepared by an independent verification agent at the time of an initial review, for a specific manufacturer, confirming the suitability and appropriate limits on the manufacturer's design methodologies.

NOTE The design methodology verification report can include occasional amendments or revisions to address extensions beyond previous limits or revisions of methodologies.

3.1.25**design verification**

Process of proving design by analysis and/or testing.

3.1.26**dry repair**

Repair of a flexible pipe or umbilical that has been retrieved from the water.

3.1.27**end fitting adjacent interface structure**

Bend stiffener interface structure where the end fitting is positioned within the interface structure.

3.1.28**final net buoyancy**

Net buoyancy at the end of the service life.

3.1.29**fire protection**

Layer of material that provides passive fire protection to the flexible pipe or umbilical for a specified duration of time in the event of a fire.

3.1.30**flexible pipe system**

Fluid conveyance system for which the flexible pipe(s) is the primary component and which includes ancillary components attached directly or indirectly to the pipe.

3.1.31**flexible riser base connection**

Part of a riser base that forms the transition between the flexible pipe end fitting and the riser base structure.

3.1.32**free-locking radius**

Radius of a bend restrictor during lock-up without applied loading. Free-locking radius also referred to as geometric locking radius.

3.1.33**galling**

Gradual removal of material from a surface due to repetitive relative motion with an adjacent surface.

3.1.34**gutter**

Part of a subsea arch that the flexible pipe or umbilical rests on and may be clamped to.

3.1.35**heat distortion temperature**

Temperature at which an applied load causes a test sample to deflect by a specified amount.

3.1.36**hybrid bend restrictor**

Bend restrictor with a combination of polymer and metallic elements.

3.1.37**hydrogen embrittlement**

Weakening of metallic material due to free hydrogen released by connection to the CP system.

3.1.38**hydrostatic collapse pressure**

For syntactic foams, the hydrostatic collapse pressure is defined as the pressure relating to a nonrecoverable change in the "pressure vs time chart" (or on the load vs deflection chart), which is measurement dependent. For composite syntactic foams, the hydrostatic collapse pressure is defined as the pressure that results in an immediate 5 % buoyancy loss.

3.1.39**hysteresis**

Bending behavior of a flexible pipe or umbilical characterized by a change in the bending stiffness, observable in the moment-curvature relationship, when the friction among adjacent flexible pipe tensile layers or umbilical components is overcome at a critical curvature value beyond which slippage occurs.

NOTE When the direction of curvature is changed, the higher stiffness due to friction resumes until it is again overcome. The moment-curvature relationship is similar to an elastic-plastic response and, for regular cyclic bending, forms a closed loop.

3.1.40**I/J-tube seal**

Device that fits around a flexible pipe or umbilical and is used to provide a pressure-tight seal in an I/J-tube to contain corrosion-inhibited fluid within, or prevent gas escaping from topsides.

3.1.41**independent verification agent (IVA)**

Independent party or group, selected by the manufacturer, who is responsible for the review and certification of: the indicated ancillary equipment product, associated design, manufacturing methodologies and criteria, material qualification and prototype performance; based on the technical literature, analyses, results, and other information provided by the manufacturer to establish the range of applicability.

NOTE An agent may also be called upon to witness some measurements and tests related to material qualification, manufacturing process control, validation of design methodologies, and prototype tests.

3.1.42**initial net buoyancy**

Net buoyancy before immersion in seawater.

3.1.43**interface structure**

Structure that transfers loads from a bend stiffener or bend restrictor to the adjacent structure.

3.1.44**internal clamp strap**

Part of some buoyancy modules that secures the internal clamp body to the pipe or umbilical.

NOTE The internal clamp strap is positioned within the interior of the buoyancy element.

3.1.45**lifting point**

Connection point on a structure used to interface with lifting equipment.

3.1.46**loaded locking radius**

Radius of a bend restrictor during lock-up with applied loading.

3.1.47**load-transfer device**

Device that is used to transfer loads from the pipe or umbilical end fitting or bend limiter interface structure to the topsides structures but does not have any pressure-containing capacity.

3.1.48**lock-up**

Locking together of individual bend restrictor elements.

3.1.49**lower catenary**

Length of pipe or umbilical between the riser base and the subsea buoy.

3.1.50**macrosphere**

Ceramic, polymer, or composite spheres greater than 1 mm in diameter that form a structural part of composite syntactic foams.

3.1.51**manufacturer**

For the purposes of this specification, the manufacturer of the ancillary equipment.

3.1.52**membrane stress**

σ_m

Average stress value across the thickness of a solid section, excluding the effects of discontinuities and stress concentrations.

EXAMPLE The general primary membrane stress in a pipe loaded in pure tension is the tension divided by the cross-sectional area. σ_m may include global bending as in the case of a simple pipe loaded by a bending moment.

NOTE Definition taken from API 2RD:1998.

3.1.53**microsphere**

Ceramic, polymer, or composite sphere between 1 μm and 1000 μm in diameter that forms a structural part of syntactic and composite syntactic foams.

3.1.54**module element**

Part of a buoyancy or ballast module that gives uplift or added weight to the module.

NOTE The module element does not include buoyancy tanks.

3.1.55**net buoyancy**

Resulting buoyancy after considering all buoyant and nonbuoyant components in a subsea buoy or buoyancy module.

3.1.56**overboarding chute**

Arch-shaped structure positioned at the edge of a vessel that is used as an installation aid for pipe or umbilical.

3.1.57**passive fire protection**

Coating, cladding, or free-standing system that provides thermal protection in the event of a fire and that requires no manual, mechanical, or other means of initiation, replenishment, or sustenance.

NOTE Definition taken from DNVGL-OS-D301.

3.1.58**permanent ancillary equipment**

Ancillary equipment that is to be used for the entire service life of the pipe or umbilical.

3.1.59**permanent bend stiffener**

Bend stiffener that is to be used for the entire service life of the flexible pipe or umbilical.

3.1.60**piggy-back clamp**

Spacer in a piggy-back system that is clamped to the supporting and supported pipe and does not allow relative movement of the supported pipe.

3.1.61**piggy-back guide**

Spacer in a piggy-back system that is clamped to the supporting pipe and allows relative movement of the supported pipe.

3.1.62**prototype test**

Test performed to establish or verify a principal performance characteristic for a particular design, which may be a new or established design.

3.1.63**pull-in head**

Device used during installation to connect the flexible pipe or umbilical end fitting to a pull-in wire, consisting of structure that connects to end-fitting and a connection that interfaces with lifting equipment.

3.1.64**raw materials supplier**

Supplier of raw materials for any of the components of an item of ancillary equipment.

3.1.65**reaction collar**

Bend restrictor interface structure comprising a split-shell configuration that clamps around the pipe or umbilical end fitting.

3.1.66**reaction flange**

Bend restrictor interface structure comprising a split flange arrangement that bolts directly to the support structure over which a bend restrictor element is assembled.

3.1.67**repair clamp**

Clamp that is positioned over a damaged area of pipe as a means to repair such an area.

3.1.68**riser base**

Structure positioned on the seabed used to provide a structural and pressure-tight connection between a riser and a flowline.

NOTE The riser base can be a pipeline end termination or a pipeline end manifold.

3.1.69**seabed connection**

Connection between riser end fitting and riser base.

3.1.70**secant modulus**

Slope of line drawn through the origin of a stress strain curve and intersecting a point on the stress strain curve corresponding to specified strain.

3.1.71**service life**

Period of time during which the flexible pipe or umbilical is designed to fulfil all specified performance requirements.

3.1.72**setting time**

Time required for polymer or composite component to reside in mold before being removed.

3.1.73**snatch load**

Sudden load that acts on a slack tether with resulting dynamic amplification up to several times the applied tension.

3.1.74**spacer**

Discrete component of which a number in series are used to piggy-back one or more supported pipes to a supporting pipe over a prescribed length.

3.1.75**subsea buoy frame**

Structural part of a subsea buoy. Includes the gutters, housings for clamps, and buoyancy tanks or buoyancy elements and connection points for tether connection hardware.

3.1.76**support structure**

Structure that supports and transfers loads from a pipe or umbilical or bend limiter at either the topside, seabed, or intermediate connection.

3.1.77**supported pipe**

Pipe or umbilical that is attached via a series of piggy-back clamps or guides to a supporting pipe over a prescribed length.

3.1.78**supporting pipe**

Pipe that supports one or more pipes or umbilicals via a series of piggy-back clamps or guides over a prescribed length.

NOTE A supporting pipe can be a flexible pipe.

3.1.79**syntactic foam**

Composite material consisting of a polymer matrix containing microspheres only.

3.1.80**system owner**

Purchaser of pipe system from pipe system provider.

3.1.81**tear strength**

Measure of the force necessary to cause tearing of a sample of material (nicked or un-nicked) under specified conditions.

3.1.82**temporary bend stiffener**

Bend stiffener that is required to satisfy its functional requirements temporarily for flexible pipe or umbilical installation, handling, or other activities but not in service.

3.1.83**tether**

Chain or rope used to connect a pipe or a subsea buoy to a tether base, including connecting hardware necessary at each end termination.

3.1.84**tether base**

Structure that secures one or a group of tethers to the seabed, including tether connection points and lifting points.

3.1.85**thermal shock**

Exposure to a large temperature variation within a short time period.

3.1.86**topside connection**

Connection between flexible pipe or umbilical end fitting and platform.

3.1.87**upper catenary**

Length of riser between the platform and the subsea buoy.

3.1.88**wet repair**

Repair of a flexible pipe in situ.

3.2 Abbreviations and Symbols

For the purposes of this document, the following symbols and abbreviated terms apply:

σ_b	bending stress
σ_m	membrane stress
σ_q	secondary stress
σ_{sc}	stress at structural capacity
$(\sigma_x)_e$	Von Mises component of stress for σ_x

EXAMPLE $(\sigma_m)_e$ is the Von Mises membrane stress.

AISI	American Iron and Steel Institute
API	American Petroleum Institute
AWS	American Welding Society
BS	standard issued by British Standards Institute
BV	Bureau Veritas
CEN	Committee on European Normalization
CP	corrosion protection
DIN	Deutsches Institut für Normung e.V.
EEMUA	Engineering Equipment and Materials Users Association
EPDM	ethylene propylene diene monomer
FAT	factory acceptance testing
FEA	finite element analysis
GVI	general visual inspection
HCP	Hydrostatic Collapse Pressure
HMPE	high modulus polyethylene
IAPSO	<i>International Association for Physical Sciences of the Oceans</i>
IBL	Instrumented Buoyancy Loss
IVA	independent verification agent
MBL	minimum breaking load
MBR	minimum bend radius
MBS	minimum breaking strength
MWL	mean water line
NDE	nondestructive examination
PCD	pitch circle diameter
PD	Published Document
PLEM	pipeline end manifold

PLET	pipeline end termination
ROV	remotely operated vehicle
SBR	styrene butadiene rubber
SWL	safe working load
UV	ultraviolet
VIV	vortex-induced vibration

4 General Requirements

4.1 Description

All flexible pipe/umbilical ancillary equipment shall comply with Section 4 (i.e. General Requirements). Specific ancillary equipment shall comply with the subsequent sections (i.e. Section 5 onward). Clamping devices (buoyancy module clamps, subsea buoy clamps, tether clamps, piggy-back clamps and guides, repair clamps, and I/J-tubes seals with clamps) shall comply with Section 11 (i.e. General Clamping Device Requirements).

This section covers minimum requirements for ancillary equipment that are general in nature. For a particular item of ancillary equipment, all applicable requirements in this section are cross-referenced in the subsequent sections.

Requirements of other standards included by reference in this specification are essential to the safety and interchangeability of the product provided.

Standards referenced in this specification may be replaced by other international or national standards that can be shown to meet or exceed the requirements of the referenced standard. Manufacturers who choose to use other standards in lieu of standards referenced herein are responsible for documenting the equivalency of the standards.

When a purchaser does not specify requirements as requested in this section, then manufacturers shall propose solutions for purchaser approval.

4.2 Functional Requirements

4.2.1 General

The purchaser shall specify their functional requirements for the ancillary equipment. The purchasing guidelines in Annex A to Annex S give a sample format for the specification of the functional requirements.

Functional requirements not specifically required by the purchaser which may affect the design, materials, manufacturing, and testing of the ancillary equipment shall be specified by the manufacturer for purchaser approval.

4.2.2 Overall Requirements

The minimum overall functional requirements of the ancillary equipment that shall be demonstrated by the manufacturer are as follows.

- The ancillary equipment shall be capable of withstanding all design loads defined in the design requirements section applicable to the ancillary equipment in question.
- The ancillary equipment shall perform its function for the specified service life and installation and decommissioning, if required.
- The ancillary equipment materials shall be compatible with the environment to which the material is exposed.

- d) Ancillary equipment metallic materials shall conform as a minimum to the corrosion requirements specified in 4.3.9 and in the corrosion requirements section applicable to the ancillary equipment in question.

4.2.3 Flexible Pipe/Umbilicals Design Parameters

The purchaser shall provide a data sheet for all the pipes and umbilicals to which the ancillary equipment is attached.

4.2.4 Temperature

4.2.4.1 Air

For ancillary equipment that is to comprise polymer or composite components, the purchaser shall specify the minimum and maximum air temperatures associated with the following conditions:

- a) storage;
- b) transport;
- c) installation;
- d) service, where applicable (only relevant to ancillary equipment situated wholly or partly above the mean water line [MWL]).

4.2.4.2 Seawater

The purchaser shall specify the minimum and maximum seawater temperatures during installation and operation for ancillary equipment that are to be submerged underwater wholly or partly.

4.2.4.3 Pipe Outer Surface

Where polymer or composite components of the ancillary equipment are in direct contact with the pipe outer surface, on either a continuous or intermittent basis, the purchaser shall specify one of the following:

- a) minimum and maximum temperature of the pipe outer surface due to the internal fluid temperature, on the basis of the following minimum set of considerations associated with the pipe:
 - 1) operating temperatures;
 - 2) upset temperatures (number and range of cycles);
 - 3) gas cooling effects (time/temperature curve);
 - 4) fluid thermal characteristics;
 - 5) flow characteristics;
 - 6) storage, transport, and installation conditions where applicable.
- b) U-value or overall heat transfer coefficient (OHTC) of the pipe and minimum and maximum internal fluid temperature on the basis of the considerations in Item 1) to Item 6) above. The purchaser shall specify the reference diameter (internal or external) used to calculate the U-value. Where U-value is specified per unit length, the purchaser shall specify to which reference length this refers.

4.2.5 External Environment

The purchaser shall specify whether ancillary equipment external polymer or composite components will be exposed to abnormally high levels of sunlight. This is relevant to hotter climates such as west of Africa. The purchaser shall consider the expected cumulative length of exposure during storage, transport, installation and operation (if applicable). Nonmetallic ancillary equipment shall be designed with UV (ultraviolet) resistance or UV protection when exposed to sunlight during storage, transportation, installation, and operation

NOTE Painted equipment may also need to be assessed for UV protection.

4.2.6 Corrosion Protection

All metallic parts of the ancillary components used in flexible pipe system or umbilical system (e.g. the metallic components of: bend stiffeners, buoyancy module clamping device [clamping body, bolts, or straps], submerged buoyancy arch, and supporting mooring chains, etc.) shall be selected to be corrosion resistant, or, alternatively, be designed with adequate corrosion protection (CP) that will prevent loss of functionality throughout the service life.

Buoyancy modules/arches shall also include permanent sacrificial anodes sufficient for protection of the structure. The buoyancy module structure shall be electrically isolated from the flexible pipe or umbilical.

The corrosion resistance, protection, and coating requirements for metallic structures, including interface structures and fasteners, shall be specified by purchaser.

The CP system requirements for metallic structures shall be specified. All surfaces electrically connected to the CP system shall be taken into account when designing the CP system anode quantity.

4.2.7 Installation

The purchaser shall specify ancillary equipment installation requirements, as soon as they are available. These installation requirements shall provide sufficient information to the manufacturer to be able to determine the installation loads (if not specified separately, see 4.2.8) on the ancillary equipment and any parameters that could have implications on the ancillary equipment design.

4.2.8 Design Loads

Ancillary equipment load cases that are induced by the pipe or umbilical shall be specified as in accordance with all load conditions specified in Table 6 of API 17J: 2014.

The purchaser shall specify any safety factors and their corresponding magnitude that have been incorporated into the design loads they've specified.

The purchaser shall specify whether all the load-bearing components of permanent ancillary equipment are to be inspected during operation under an integrity and condition-monitoring program such that the manufacturer can determine the fatigue safety factor to use in accordance with 4.3.6.5.

The purchaser shall, where applicable, specify the points of application of design loads acting on the ancillary equipment. The purchaser shall also, where applicable, describe the axis system relating to the direction of the design loads acting on the ancillary equipment such that there is sufficient information for the manufacturer to convert the loads to another axis system.

4.2.9 Quantities

The purchaser shall specify, where applicable, the quantity of the ancillary equipment required.

4.2.10 Spares

The purchaser shall specify any requirements for numbers of spare items or components of ancillary equipment to offset any losses due to damage, for example.

4.2.11 Marking

The purchaser shall specify any requirements for marking of the ancillary equipment in addition to the minimum marking requirements specified in 4.8.1.

4.2.12 Pigmentation

The purchaser shall specify any preferences for pigmentation of the ancillary equipment.

4.2.13 Project Information

The purchaser shall specify, as a minimum, the following information relating to the project in question:

- a) project title;
- b) location of development;
- c) delivery date;
- d) location of delivery;
- e) delivery terms and conditions.

4.3 Design Requirements

4.3.1 General

The ancillary equipment design is based on the information supplied by the purchaser (see guidelines of Annex A to Annex S) in accordance with the functional requirements section for the ancillary equipment in question. All this information shall be defined in the design premise (see 4.6.2), including design load cases and design acceptance criteria.

The design load cases shall be defined to analyze, as applicable, the effect on the ancillary equipment of functional, environmental, and accidental loads, where applicable.

4.3.2 Load Combinations and Conditions

The ancillary equipment design shall be shown to meet the design requirements under all load combinations specified in this section and the subsequent section applicable to the ancillary equipment. Variation of the loads in time and space, load effects from the pipe or umbilical and its supports as well as environmental conditions shall be analyzed.

The design load conditions that shall be analyzed are (where applicable) transportation, installation, operating, nonoperating, survival, testing and fatigue of the pipe or umbilical (where loads are induced in the ancillary equipment). Load combinations shall be as defined in Table 6 of API 17J:2014. Load combinations with a yearly probability of occurrence less than 10^{-4} can be ignored. Factory acceptance test load combinations, where applicable, shall be defined by the manufacturer based on the FAT procedures and shall be agreed by the purchaser.

Results of the design load case analyses shall be shown to meet the design acceptance criteria and shall be documented in the design report.

Design checks shall be performed for any temporary conditions specified by the purchaser or the manufacturer. These shall include temporary conditions experienced by the ancillary equipment during storage, transport, and installation. These shall be subject to the same design criteria as the design load conditions, as specified in the design criteria sections of this specification.

The simultaneous occurrence of different load combinations shall be defined in the manufacturer's design premise (see 4.6.2).

4.3.3 Load Interface Management

The manufacturer shall have documented procedures to ensure that global loads supplied by the purchaser are applied in the correct position in local analyses of the ancillary equipment. The manufacturer shall also have documented procedures to ensure that any differences between global and local axis systems are accounted for in the transfer of loads between global and local analyses.

4.3.4 Design Load Effects

For fatigue analysis, the distribution of loads over the service life of the ancillary equipment shall be based on methods that include all load parameters. Simplified methods are acceptable if the resulting load distribution can be shown to be conservative.

4.3.5 Design Methodology

4.3.5.1 Design Documentation

Initially and whenever revisions occur, the design methodology and manufacturing processes for permanent ancillary equipment shall be verified by an independent verification agent or documentation shall be issued for verification by the purchaser. The documentation submitted for verification of the design methodology shall include methodologies, any calculations performed, and software tools used for the following, as applicable:

- a) description of theoretical basis, including calculation procedures for the design parameters required for the design report;
- b) overview of stress/strain analysis methodology (in accordance with 4.3.7);
- c) validation of design methodologies and software tools with prototype tests, initially and whenever the current design is outside the envelope or set of previously verified designs (4.3.7). See API 17L2 for guidelines on when the design is outside the envelope of previously verified designs. The validation shall include the capacity of all the ancillary equipment components. Simplified conservative analysis methods for checking of noncritical components are acceptable if the method does not influence the reliability of the calculation of stresses in the other components and if approved by the purchaser;
- d) documented basis for stress concentration factors used including results of supporting finite element analysis (FEA) analysis;
- e) documented basis for utilization factors, if these factors are not already specified;
- f) documented basis for polymer and composite material endurance limits or fatigue safety factors where applicable;
- g) overview of CP system design methodology;
- h) manufacturing and design tolerances;
- i) description of procedures and devices used to control manufacturing processes;

- j) calculations demonstrating that design satisfies functional requirements accounting for variations within manufacturing tolerance envelopes;
- k) description of welds used for metallic components;
- l) other effects that influence structural capacity;
- m) documentation of service life methodology, subject to the requirements of 4.3.8 to 4.3.8.3.

4.3.5.2 Independent Verification

The independent verification agent shall review and evaluate the design methodology, including manufacturing processes and material qualification, to establish the qualified envelope for ancillary equipment design. The independent verification agent shall issue a certificate, and a design methodology verification report describing the limits and constraints of the design methodology. The certificate shall be included by the manufacturer in the design report (see 4.6.3) and the design methodology verification report shall be available for review by the purchaser and flexible pipe system owner at the manufacturers' premises. The independent verification is independent of project or region of application.

The design methodology shall account for the effects of the following unless the design is documented not to suffer from such effects:

- a) corrosion of metallic components, unless the metal is documented to be corrosion resistant in the specified environment;
- b) creep of polymer and composite materials subjected to constant loading;
- c) water absorption of polymer and composite materials in subsea ancillary equipment or ancillary equipment in contact with water;
- d) aging of polymer and composite materials (due to mechanical, chemical, and thermal degradation), see 4.4.4;
- e) exposure of polymer and composite materials to sudden temperature variations;
- f) effects of nonlinear material properties;
- g) effect of design temperatures on material properties;
- h) rupture or cracking of polymer and composite materials.

If the ancillary equipment design is outside the envelope of previously verified designs, then the manufacturer shall perform sufficient prototype tests to verify the design methodology for this new design and obtain a revision or amendment of the design methodology verification report by an independent verification agent. The manufacturer shall revise or amend the fabrication specification such that the design requirements are met within the range of applicability of the design methodology. The prototype tests shall verify fitness for purpose for those design parameters which are outside the previously validated envelope. See API 17L2 for guidelines on the tests which should be performed and recommendations on the test procedures.

4.3.6 Design Criteria

4.3.6.1 Steel Components

Steel components (but not truss structures, pressure vessels, or ancillary equipment that performs a lifting function) shall be designed to the criteria specified in Table 1, and components comprising other materials (i.e. other metallic and polymer and composite components) shall be designed to independently verified and documented criteria specified by the manufacturer (see 4.3.5.1.e), subject to the requirements of this section.

truss structures, allowable deformations shall be in accordance with an appropriate international standard such as API 2A-WSD or AISC *Steel Construction Manual*. Ancillary equipment that performs a lifting function shall be designed in accordance with national regulations and an appropriate international standard such as those listed in Table 2. Allowable stresses for the other structures shall be in accordance with appropriate international standards of which examples are listed in the relevant sections of this specification.

4.3.6.2 Corrosion

Corrosion analysis (as per 4.3.9) shall show that the material loss from corrosion does not cause utilization factors to exceed the criteria in Table 1 under all load combinations.

4.3.6.3 Stress

The utilizations as specified in Table 1, which are not applicable to truss structures, pressure vessels, ancillary equipment that perform a lifting function or tethers, shall be calculated as the ratio of stress to structural capacity. The stress shall be calculated using the design methodology specified in 4.3.5 and the subsequent design methodology sections, subject to the design requirements of 4.3.7 and the subsequent design sections. The calculated value shall include dynamic loads where applicable. The structural capacity shall be the minimum of the yield strength and 0.9 times the ultimate tensile strength of the material where tensile testing will accurately identify only this latter property. The yield or ultimate strength value used for design shall be either the mean value minus two standard deviations from the documented test data, or the minimum value as certified by the supplier.

NOTE The steel utilization values have been selected to be consistent with the utilizations specified for steel components of the flexible pipe in API 17J. In accordance with 4.3.5.1.e, the manufacturer is required to submit as part of the design methodology a documented basis for utilization values not already specified in this specification, i.e. nonsteel metallic materials and polymer and composite materials.

4.3.6.4 Polymers/Composites

Polymer and composite material utilizations may be a factor of either the maximum allowable strain or stress and shall account for the following:

- a) material stress/strain behavior established by small-scale material testing covering the range of expected operating temperatures;
- b) reduction in mechanical properties due to aging in the specified environment, if the maximum allowable strains or stresses are for unaged material. Accounting for the effect of the reduction in properties through utilization factors may be ignored for loads that act at the start of the service life (installation and FAT/flexible pipe hydrostatic test loads);
- c) creep behavior, if component is subjected to constant loading (the utilization factor shall be such as to prevent creep failure or loss of functional requirements during the service life, unless a creep analysis has been performed and demonstrated that there will not be any creep failure of the material or loss of functional requirements).

4.3.6.5 Fatigue

Fatigue life shall be calculated using peak stress or peak strain, and associated stress or strain ranges, in accordance with the requirements of 4.3.8.3. For nonmetallic equipment fatigue design shall consider temperature and load frequency. Where calculated, the predicted fatigue life of steel components whose external surfaces are noninspectable for crack sizes that are critical for fatigue shall be at least 10 times the required service life. Where calculated, the predicted fatigue life of other metallic materials (e.g. titanium) and polymer and composite components shall use an independently verified fatigue safety with a documented basis. However, this fatigue safety factor shall be at least 10 times the required service life for noninspectable components and at least three for inspectable components. Where it is practical to inspect all the surfaces of all the load-bearing components of the ancillary equipment for crack sizes that are critical for fatigue under the integrity and condition monitoring

program, this factor may be reduced to three. See the relevant integrity and condition-monitoring sections of API 17L2 for guidelines and recommendations on integrity and condition monitoring.

NOTE The fatigue life factor of 10 has been selected to be consistent with the corresponding factor of the flexible pipe fatigue life in API 17J and umbilical fatigue life in API 17E. This factor relates to the steel pressure and tensile armor layers of the pipe. The factor of 3 represents industry practice, such as in API 2RD:1998, for steel components where all potential fatigue-induced flaws are accessible for inspection.

4.3.6.6 Reliability-based Design

NOTE Reliability-based design may be applied as an alternative design method. It shall be proven that the level of safety obtained is not less than that given by this specification for comparable design cases.

Table 1—Steel Permissible Utilization Factors (Not Applicable to Truss Structures, Pressure Vessels, Ancillary Equipment That Perform a Lifting Function or Tethers)

Design Criteria	Operating Conditions ^a			Installation		Hydrostatic Pressure Test—Field Acceptance ^{a b}
	Permanent		Abnormal			
	Normal	Extreme				
	Functional and Environmental	Functional, Environmental and Accidental	Functional, Environmental and Accidental	Functional and Environmental	Functional, Environmental and Accidental	
Membrane stress	0.67/0.55 ^c	0.85	0.85	0.67	0.85	0.91
^a The load conditions in the table refer to the load conditions of the flexible pipe to which the ancillary equipment is attached.						
^b Applicable to ancillary equipment that restrain flexible pipe outer diameter variations such as clamping devices, for example.						
^c Pressure-retaining ancillary equipment only.						

Table 2—Lifting Standards

Designation	Title
API 2A-WSD	<i>Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms</i>
DNVGL	<i>DNVGL-ST-E271</i>
DNVGL	<i>DNVGL-ST-0378</i>
DNVGL	<i>DNVGL-ST-N001</i>
Lloyd's Register of Shipping	<i>Code for Lifting Appliances in a Marine Environment</i>

4.3.7 Ancillary Equipment Design Requirements

It shall be demonstrated through calculation (in accordance with 4.3.6.3) that stresses and strains in ancillary equipment are within allowable limits for their respective materials. See 4.3.6 for requirements on utilizations for metallic, polymer, and composite materials. The analysis shall account for the following:

- design loads specified by the purchaser in accordance with the functional requirements section and the design loads specified in the loads section for the ancillary equipment in question;
- preloads in fasteners and straps;
- stresses in all components, including fasteners and welds;
- any stress concentrations, in areas of geometric discontinuity such as bolt holes and fillet radii. Stress concentrations shall be determined using FEA.

Local stress analysis of metallic structures shall be performed in accordance with an appropriate international standard, some of which are listed in Table 3. Although some of the standards apply to fixed structures, some of the requirements are relevant to structures that are not fixed.

Table 3—Examples of Metallic Structural Design Standards

Designation	Title
ISO 19902	<i>Petroleum and Natural Gas Industries—Fixed Offshore Steel Structures</i>
API 2A-WSD	<i>Planning, Designing, and Constructing Fixed Offshore Platforms—Working Stress Design</i>
API 2RD:1998	<i>Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms</i>
DNVGL OS-C101	<i>Design of Offshore Steel Structures, General (LRFD Method)</i>
NORSOK N-001	<i>Integrity of Offshore Structures</i>
ASME VIII Div 2	<i>ASME Boiler and Pressure Vessel Code Section VIII Rules for Construction of Pressure Vessels, Division 2 Alternative Rules</i>

Preload in fasteners for static applications shall be selected to provide sufficient compression in the bolted members to resist external loads and to create sufficient frictional forces between members to resist shear loads without exceeding the design criteria of Table 1 or, if not applicable, the relevant structural design standard. In dynamic applications, the preloads shall additionally be sufficient to limit the proportion of the cyclic stresses taken by the bolt such that the fatigue life criteria of 4.3.6.5 are satisfied.

4.3.8 Service Life

4.3.8.1 General

The service life of permanent ancillary equipment shall be as a minimum equal to the required service life of the flexible pipe or umbilical to which it is attached, if it is not explicitly specified by the purchaser.

4.3.8.2 Static Applications

The service life analysis of permanent ancillary equipment shall document the properties of the materials for the specified service life, in accordance with the requirements of the materials requirements section for the ancillary equipment in question. The minimum strength for metallic materials and minimum strength or elongation at break for polymer and composite materials, during the service life of the pipe, shall be used in the design calculations.

The analysis shall include as a minimum the following:

- a) creep due to long-term loads, dimensional changes, and strain to failure in the operating environment;
- b) corrosion of metallic components, unless the metal is documented to be corrosion resistant in the specified environment;
- c) aging of polymer and composite materials (due to mechanical, chemical, and thermal degradation).

Further to 4.3.8.2.a, it shall be documented in the design report that creep of polymer and composite components that are subjected to constant loading does not cause stresses/strains in the material to exceed allowable limits or cause the product to fail to meet its functional requirements over the specified service life. The manufacturer shall have available documentation from the material supplier or other party that supports the material creep properties being used in the design.

4.3.8.3 Dynamic Applications

The requirements of 4.3.8.2 shall apply.

For metallic components in dynamic applications, if it has been demonstrated from material testing that all material stress ranges inclusive of stress concentrations (including fasteners and welds) are below a documented and verifiable endurance limit established by testing and approved by purchaser, fatigue calculations are not required. If any fatigue stress is above this endurance limit or an endurance limit cannot be established, fatigue damage shall be based on Miner's method, or other methods from an appropriate international standard, using design S-N curves that have been validated for the metallic materials used, under the applicable service environments.

Fatigue analysis of metallic components shall be performed in accordance with an appropriate international standard.

For polymer and composite components in dynamic applications where it has been demonstrated from material testing that all material stress ranges inclusive of stress concentrations are below a documented and verifiable endurance limit approved by the purchaser, fatigue calculations are not required. When any fatigue stress is above this endurance limit or an endurance limit cannot be established, fatigue damage shall be calculated, using design fatigue curves that have been validated for the materials used for the specified cyclic load frequencies and under the applicable service environments. Adequate fatigue design may also be demonstrated by prototype testing. Where prototype testing is used, the test conditions including as a minimum the load range magnitude and material temperature shall be representative of the specified application. The number of load cycles shall be sufficient to demonstrate the required fatigue safety factor. The demonstration of fatigue life shall account for the effects of the manufacturing process and the dimensions of the full-scale product on the materials fatigue life.

4.3.9 Corrosion Protection

All external metallic surfaces of permanent ancillary equipment shall be prepared and coated in accordance with an appropriate international standard such as NORSOK M-501 for CP in the environmental conditions in question, unless the material is documented to be corrosion resistant in the specified environment or a suitable corrosion allowance is being employed. The selection of the CP system shall consider the length of time that the component will be in storage and shall, if applicable, consider the length of time that the component is to be located in a subsea environment before installation operations commence. Temporary ancillary equipment shall be protected in accordance with above requirements should its storage duration before use either onshore, offshore, or subsea lead to corrosion that would affect its functional requirements.

Selection of materials shall account for the effect of galvanic corrosion if this could increase utilization factors above allowable limits. When dissimilar metals are used causing galvanic corrosion, they shall be electrically isolated from one another, or a CP system shall be incorporated to cover both metals. CP system and coatings shall be designed for potential damage of fasteners (e.g. bolt scratching) during handling, transportation, installation, temporary abandonment, and operation.

Requirements for internal and external corrosion allowances shall be evaluated in accordance with the location, conditions of installation, and the requirements specified in the functional requirements section for the ancillary equipment in question. The manufacturer shall document this evaluation and its effect on the ancillary equipment components.

NOTE Corrosion-resistant overlay or corrosion-resistant alloys may be used in preference to a corrosion allowance.

The manufacturer shall have documented records on the suitability of the corrosion-resistant overlay or alloys for the specified application and environment. Corrosion-resistant fasteners shall be selected in accordance with an appropriate international standard such as those listed in Table 4.

Table 4—Corrosion-resistant Fastener Standards

Designation	Title
ISO 3506–1	<i>Mechanical properties of corrosion-resistant stainless-steel fasteners—Part 1: Bolts, screws and studs</i>
ASTM A276	<i>Standard Specification for Stainless Steel Bars and Shapes</i>

Table 4—Corrosion-resistant Fastener Standards (Continued)

Designation	Title
ASTM A484/ A484M	<i>Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings</i>
ASTM A1014	<i>Standard Specification for Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service</i>
ASTM B348	<i>Standard Specification for Titanium and Titanium Alloy Bars and Billets</i>
ASTM B446	<i>Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar</i>
ASTM B637	<i>Standard Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service</i>
ASTM F2281	<i>Standard Specification for Stainless Steel and Nickel Alloy Bolts, Hex Cap Screws, and Studs, for Heat Resistance and High Temperature Applications</i>
NOTE This table is not an exhaustive list. In accordance with Section 4.1, standards referenced in this table may be replaced by other international or national standards that can be shown to meet or exceed the requirements of the referenced standard.	

The calculation of thickness for permanent metallic components shall include allowances for uniform corrosion rates calculated for the service life unless the material is documented to be corrosion resistant in the specified environment or protected by a CP system.

The effect of corrosion of metallic components shall account for permanent contact with seawater of appropriate salinity and oxygen content.

All external metallic surfaces shall be protected by a dedicated CP system that shall have sufficient capacity to provide CP for the specified service life, in accordance with an appropriate international standard such as DNVGL RP-B401 or ISO 15589–2, unless any of the following apply. The manufacturer shall demonstrate and document if one of these exceptions applies.

- a) The material is documented to be corrosion resistant in the specified environment.
- b) A corrosion allowance is being employed.
- c) The structure is being protected by an adjacent CP system.
- d) The structure is only required on a temporary basis, i.e. for installation, maintenance, or repair.

The cathodic protection system design methodology shall be documented. If the ancillary equipment is reliant on the CP system of an adjacent structure, then the manufacturer shall have documented justification in the design report that this adjacent CP system is both compatible with and has sufficient capacity to give protection to the ancillary equipment for the specified service life. Each CP system shall provide a list of the components being protected, including all bolts and nuts.

The manufacturer shall design the ancillary equipment such that it is compatible with the CP system (if any) specified by the purchaser.

4.4 Material Requirements

4.4.1 General

The manufacturer shall have records of tests demonstrating that the materials selected for a specific application meet the functional requirements specified for the ancillary equipment, for the service life for storage, transport, installation, and operation conditions. The documented test records shall conform to the qualification requirements sections for the ancillary equipment in question. Where qualification records do not fully cover the application, the

manufacturer shall perform testing relevant to the application according to the qualification requirements section for the ancillary equipment in question.

All materials used in the ancillary equipment construction shall be documented to be compatible with seawater at the design temperatures where applicable.

The manufacturer shall document that all lubricants and coatings are compatible with all materials in the ancillary equipment with which they are in contact.

Material selection and coatings shall account for potential damage of fasteners (e.g. bolt scratching) and other components during handling, transportation, installation, temporary abandonment, and operation.

4.4.2 Qualification Requirements—General

The physical, mechanical, chemical, and performance characteristics of all materials in the ancillary equipment shall be verified by the manufacturer through a documented qualification program. The program shall confirm the adequacy of each material based on test results and analyses that shall demonstrate the documented fitness for purpose of the materials for the specified service life of the ancillary equipment. Table 5 lists general procedures for typical qualification tests, some of which may be a part of the ancillary equipment qualification program. As a minimum, the qualification program shall include the tests specified in the qualification requirements section for the ancillary equipment in question. The qualification of materials by testing shall consider all processes (and their variation) adopted to produce the ancillary equipment that may impair the properties and characteristics required by the design.

Documented operational experience may be accepted as validation of long-term properties in environments that are equal to or less severe than the documented experience. This shall be supplied in the form of a bridging document that relates previous experience to the current material application and operating conditions on the basis of surveyable logic and clearly defined acceptance criteria in terms of the following:

- a) fatigue load mean stresses/strains, stress/strain ranges, and associated numbers of cycles;
- b) stresses/strains due to constant loads (creep loads);
- c) water depth, temperature, including air and seawater temperature ranges and temperatures due to proximity to the pipe or umbilical as applicable;
- d) UV exposure where applicable;
- e) corrosivity of environment with respect to metallic materials, including temperature and seawater-dissolved oxygen content and salinity;
- f) environmental parameters that cause aging of polymer and composite materials (see 4.4.4).

The bridging document shall include any combinations of the above that will affect the long-term properties of materials.

The test methods shall be as specified in Table 5 or, if not, shall have their equivalency documented. The manufacturers may use their own test methods and acceptance criteria or alternatives developed by the raw material suppliers. In such cases, the methods/criteria shall be documented and the results correlated with the specific material application. The documented qualification performance shall be verified by an independent verification agent.

The manufacturer shall define allowable levels of UV exposure for all nonmetallic materials that are exposed to sunlight during storage, transport, installation, or service.

The manufacturer shall have documented methods for predicting the polymer properties for the specified service life. The manufacturer shall have available for review by the purchaser records of tests and evaluations that demonstrate that the methods yield conservative results.

Table 5—General Test Procedures for Polymer Materials

Tests	Test Procedure
Abrasion resistance	ISO 7784-2 ^a , ASTM D4060 ^a , BS 903-A9, DIN 53516
Aging resistance	See 4.4.4
Creep resistance ^c	ASTM D2990, ISO 899-1
Compressive properties	ISO 7743, ISO 604 ^b , ASTM D575, ASTM D695 ^b
Density	ISO 1183, ISO 2781, ASTM D792
Hardness	ISO 868 ^b , ASTM D2240
Heat distortion temperature	ISO 75-1, ISO 75-2, ASTM D648
Impact resistance	ISO 179-1, ISO 179-2, ISO 180 ^b , ASTM D256
Ozone resistance	ISO 1431-1
Shear properties	ISO 1827, ASTM D732
Tear strength	ISO 34-1, ASTM D624
Tensile properties	ISO 37, ISO 527-1 ^b , ISO 527-2 ^b , ASTM D638 ^b
Water absorption	ISO 62 ^b , ASTM D570 ^b
Thermal Conductivity	ASTM C177, ASTM C518
Compression Set	ISO 815-1, ISO 815-2, ASTM D395, ASTM D1229
Flexural properties	ISO 178
Stress Relaxation	ISO 3384-1
^a Standards similar in content but not technically equivalent. ^b Standards are technically equivalent or identical for the test in question. ^c A creep test should be performed if it can be demonstrated to be relevant to the design of the product.	

Abrasion resistance and impact strength as measured using small-scale material tests shall only be used as comparative measures since it is difficult to accurately simulate the response to specific abrasion or impact loading scenarios.

4.4.3 Qualification Requirements—Metallic Materials

Metallic materials for structural components shall conform to the grades or quality levels specified in appropriate international standards.

NOTE See a list of possible international standards in Table 6.

Table 6—Examples of Metallic Material Selection Standards

Designation	Title
API 2A-WSD	<i>Planning, Designing, and Constructing Fixed Offshore Platforms—Working Stress Design</i>
DNVGL-RP-B101	<i>Corrosion Protection of Floating Production and Storage Units</i>
EN/BS 10025	<i>European Structural Steel Standard</i>
NORSOK M-001	<i>Materials Selection</i>
NORSOK M-120	<i>Material Data Sheets for Structural Steel</i>

Metallic materials selection for permanent ancillary equipment shall consider the corrosive attack appropriate to the environment that the material will be exposed to over the specified service life of the ancillary equipment.

Metallic materials for fasteners shall be selected in accordance with the grades or quality levels specified in appropriate international standards such as those listed in Table 7.

Table 7—Fastener Standards

Designation	Title
ISO 898–1	<i>Mechanical properties of fasteners made of carbon steel and alloy steel—Part 1: Bolts, screws and studs</i>
ISO 3506–1	<i>Mechanical properties of corrosion-resistant stainless-steel fasteners—Part 1: Bolts, screws and studs</i>
API 20E	<i>Alloy and Carbon Steel Bolting for use in the Petroleum and Natural Gas Industries</i>
API 20F	<i>Corrosion-resistant Bolting for Use in the Petroleum and Natural Gas Industries</i>
ASTM A193	<i>Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications</i>
ASTM A276	<i>Standard Specification for Stainless Steel Bars and Shapes</i>
ASTM A320	<i>Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service</i>
ASTM A484	<i>Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings</i>
ASTM A1014	<i>Standard Specification for Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service</i>
ASTM B637	<i>Standard Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service</i>
ASTM F2281	<i>Standard Specification for Stainless Steel and Nickel Alloy Bolts, Hex Cap Screws, and Studs, for Heat Resistance and High Temperature Applications</i>
EN 10025	<i>European Structural Steel Standard</i>
BS/EN 10083-1	<i>Steels for quenching and tempering. General technical delivery conditions</i>
BS/EN 10083-2	<i>Steels for quenching and tempering. Technical delivery conditions for non-alloy steels</i>
EEMUA 194	<i>Guidelines for Materials Selection and Corrosion Control for Subsea Oil and Gas Production Equipment</i>
NORSOK M-001	<i>Materials Selection</i>
NOTE This table is not an exhaustive list. As stated in 4.1, standards referenced in this table may be replaced by other international or national standards that can be shown to meet or exceed the requirements of the referenced standard.	

Metallic materials that are to be connected to CP systems shall be documented not to suffer from hydrogen embrittlement because of the CP system during the specified service life. Specifically, titanium materials connected to CP systems shall be protected against the formation of titanium hydrides, by the inclusion of electrically resistive coatings, etc. Qualification of metallic materials against hydrogen embrittlement shall establish, based on test results, the acceptable ranges of mechanical properties (e.g. hardness and yield strength) of processed materials (finished products). Qualification process shall also include the definition of appropriate test methods to check these properties during manufacturing.

There shall be measures in place to prevent galling of titanium components by use of protective coatings, lubrication, or otherwise.

Corrosion rate shall be measured through testing. The general corrosion rate and occurrence of pitting shall be documented and used to identify a minimum and most likely service life based upon expected mean service conditions.

4.4.4 Polymer and Composite Material Aging

The manufacturer shall have documented aging prediction models for polymer and composite materials in the ancillary equipment. The models shall be based on testing and experience and shall predict the aging or deterioration under the influence of environmental and load conditions that have been identified to be relevant.

through testing. Resistance to deplasticization, hydrolysis, water absorption, creep, and changes of dimensions shall be demonstrated for project conditions. Aging resistance shall be determined and documented (through accelerated aging testing in accordance with ISO 2578).

The manufacturer shall document, as part of the material qualification program, methods for predicting the material properties of polymer and composite materials for the specified service life. The manufacturer shall have available for review by the purchaser records of tests and evaluations that demonstrate that the methods yield conservative results. The prediction of material properties at the end of the service life shall account for all expected aging phenomena, including thermal, oxidative, and chemical aging, where applicable, and other failure mechanisms of the material.

The manufacturer shall have documentation that demonstrates that the material does not degrade over the service life to an extent such that the functional requirements are not satisfied. The effects and parameters that shall be considered are:

- a) exposure to seawater;
- b) exposure to ozone in the air, if material is susceptible to ozone degradation;
- c) exposure to sunlight;
- d) maximum design temperature;
- e) mechanical loads.
- f) service life.

4.4.5 Quality Control

4.4.5.1 General

All materials used in the ancillary equipment shall be purchased in accordance with either a written material specification or an industry standard. The specification shall include measurable physical, mechanical, chemical, and performance characteristics and tolerances.

All suppliers to the manufacturer shall have a documented quality assurance system.

As a minimum, metallic materials shall be certified to 3.1 b) of ISO 10474. Materials shall be tested at raw materials suppliers' or manufacturers' work site in accordance with the requirements of Table 8. Test results shall be recorded on material test certificates.

Test results shall conform to the manufacturer's specifications. The results of all tests made by the manufacturer and/or raw material suppliers shall be available for review by the purchaser.

Quality control of raw metallic materials shall be performed in accordance with the standard that the particular grade or quality level of metal has been selected in accordance with.

4.4.5.2 Documentation

The manufacturers' written specifications for metallic, polymer, and composite materials shall include as a minimum the requirements of Table 9.

4.4.5.3 Storage

The manufacturers' quality plan shall show procedures for handling, storage, and control of raw materials, which reflects the importance of material cleanliness, dryness, purity, and traceability during each stage of manufacture.

4.4.5.4 Traceability

Materials shall be traceable and suitably marked for easy identification. Raw materials used as constituent components for polymer or composites shall identify the supplier's name and designation.

Polymer and composite materials used in the manufacture of ancillary equipment are usually a blend of different raw materials and the quality assurance requirements, including test requirements, are defined within each ancillary equipment type section.

Table 8—Minimum Raw Material Quality Control Test Requirements

Material	Test	Frequency
Polymer	Gel time ^a	One per batch ^b
Microspheres and macrospheres	Hydrostatic crush pressure	One per batch ^b
Metal	See 4.4.5.1	See 4.4.5.1 ^b
^a Applies to mixed system.		
^b Agreed upon by purchaser.		

Table 9—Requirements of Material Specifications

Requirements	Metallic Materials	Polymer and Composite Materials
Material composition/chemistry requirements, with tolerances	X	
Generic base polymer (ASTM D1418)		X
Physical and mechanical property requirements	X	X
Storage and age control requirements	X	X
Nondestructive examination (NDE) requirements	X	X
Acceptance and/or rejection criteria	X	X
Certification and records requirements	X	X
Marking, packaging, handling and traceability requirements	X	X

All raw hydroscopic polymer materials shall be bulk packaged in sealed containers having a moisture-resistant liner. Damaged packages shall be evaluated to determine if the damage has resulted in contamination of the material. Contaminated material shall be rejected.

4.5 Manufacturing Requirements

4.5.1 Quality Assurance Requirements—General

Manufacturing operations shall be performed in accordance with the manufacturer's written specifications, which shall conform to the requirements of this section and the manufacturing requirements section for the item of ancillary equipment in question.

Quality control requirements for materials to be used in the ancillary equipment manufacture shall be as specified in 4.4.5.2 to 4.4.5.4

4.5.2 Quality Assurance Requirements—Documentation

All processing that converts or affects material properties, including molding, curing, finishing, welding, and coating shall be documented in the manufacturer's specifications. The specification shall include a statement of applicable scope, limits on critical process parameters, inspection methods, test methods, and acceptance/rejection criteria. The specifications shall be approved by the engineering and manufacturing personnel

designated by the manufacturer. The manufacturer's specifications shall be controlled documents and shall be readily available to the process machine operator.

The manufacturer's specification documentation shall be available for review by the purchaser and shall document the following, as a minimum:

- a) methodology for all manufacturing procedures, including quality control and NDE, for the ancillary equipment, i.e. all components including fasteners, straps, lubricants, and any other items forming an integral part of the final product. See 4.5.3 for processes that require a documented methodology. See the factory acceptance testing section for the particular ancillary equipment in question for FAT requirements for the finished product;
- b) references to specifications and sources of all materials used in the manufacture of the ancillary equipment, including materials such as lubricants and coating materials. See Table 6 for examples of specifications for metallic materials;
- c) all parameters related to the quality of the final product that can be monitored during the manufacturing process. Both nominal values and ranges of these parameters shall be specified. See 4.5.3.4 for a minimum set of parameters that shall be monitored for polymer and composite components.

The manufacturer shall keep on file for the service life of the ancillary equipment all documentation pertaining to manufacture, including manufacturing records, certificates, inspection, and FAT documentation.

4.5.3 Quality Assurance Requirements—Process Control

4.5.3.1 General

All the main steps in the manufacturing process shall be subject to inspection. The manufacturer's quality plan shall specify inspection points, inspection methods, and acceptance criteria. Results of all inspections shall be recorded. The manufacturer shall record every nonconformance verified during manufacture of the ancillary equipment.

4.5.3.2 Metallic Components

The manufacturer shall as a minimum have a documented methodology, where applicable, for the following manufacturing processes for metallic components:

- a) machining;
- b) welding of structural members of components together;
- c) NDE of welds;
- d) application of coatings such as CP and antifouling coatings;
- e) attachment of CP system anodes where applicable.

Manufacturing processes for metallic components including welding operations shall be performed in accordance with an appropriate international standard. Examples of such standards for welding are listed in Table 10.

Table 10—Examples of Fabrication and Welding Standards

Designation	Title
ISO 15607, ISO 15609, ISO 15610, ISO 15611, ISO 15612, ISO 15613, ISO 15614	<i>Specification and qualification of welding procedures for metallic materials</i>
API 2A-WSD	<i>Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms</i>
AWS D1.1	<i>Structural Welding Code Steel</i>
ISO 19902	<i>Petroleum and Natural Gas Industries—Fixed Offshore Steel Structures</i>
NORSOK M-101	<i>Structural Steel Fabrication</i>

4.5.3.3 Fasteners

Manufacturing processes for fasteners shall be performed in accordance with an appropriate international standard such as those listed in Table 7.

The fastener manufacturer shall have documented procedures for the quality control of the heat treatment of the fasteners. These procedures shall include requirements on temperature monitoring and duration of heat treatment that will ensure that the yield strength/hardness, required to avoid hydrogen embrittlement or ensure other functional requirements, is in accordance with the relevant fastener standard.

The fastener manufacturer shall have appropriate test methods during manufacture to ensure that acceptable ranges of mechanical properties in accordance with the relevant fastener standard (e.g. hardness and yield strength) of processed materials (finished products), required to avoid hydrogen embrittlement or ensure other functional requirements, are satisfied.

4.5.3.4 Polymer Components

The manufacturer shall as a minimum have a documented methodology for the following manufacturing processes for polymer components:

- a) mixing of constituent components;
- b) preparation of mold and casting system;
- c) molding process;
- d) removal from mold;
- e) curing;
- f) finishing of surfaces, i.e. removal of flash;
- g) application of protective coatings such as abrasion resistance and antifouling coatings;
- h) preventative maintenance system for casting equipment and molds.

The manufacturer shall have procedures to ensure that constituent raw materials for polymer and composite materials are mixed in the ratios specified in the raw materials supplier's instructions. The manufacturer shall have available records of the mix ratios that have been used during manufacture, and these records shall be approved by the responsible manufacturing personnel.

The manufacturer's fabrication specification shall include procedures that ensure that when mixing polymer material constituent components the resulting temperatures from exothermic reactions do not cause damaging residual stresses that may result in allowable temperature limits for the materials being exceeded.

4.5.3.5 Molding

During the molding process for polymer and composite components, the following process parameters shall as a minimum be monitored and recorded:

- a) temperature of mold;
- b) injection rate of material into mold, where applicable;
- c) curing temperature;
- d) curing time.

The manufacturer shall determine and document an acceptable curing time for polymer and composite components based on the result of small-scale or full-scale tests that demonstrates that the material properties required to satisfy the functional requirements (in accordance with the relevant material requirements sections of this specification) are attained. This curing time shall be adhered to during manufacture.

4.5.3.6 Hand Lay-up Manufacturing

The manufacturer shall, as a minimum, have a documented methodology for the following hand lay-up manufacturing processes for composite components:

- a) processes listed in 4.5.3.4;
- b) coating of fiber reinforcements;
- c) brushing layers of matrix material;
- d) laying of fiber reinforcements;
- e) use of roller, if required to removed trapped air between layers;
- f) application of matrix material.

4.5.3.7 Coatings

Where applicable, the manufacturer's fabrication specification shall include procedures to ensure that the process for applying coatings gives a uniform coating to the thickness specified. The manufacturer shall have available records of the monitored procedures during manufacture. The records shall be approved by the responsible manufacturing personnel.

4.5.3.8 Nonconforming Components

The acceptance of a component that is nonconforming shall be at the discretion of the purchaser.

4.5.3.9 Bolts

Bolts shall be tightened in accordance with an appropriate international standard such as AFNOR NF E25-030-1.

Torque-tightening of bolts shall be validated by measurements of torque vs tension, specific to interface connections and lubricant type. Manufacturers shall indicate friction coefficient associated to lubricants and materials used.

4.5.4 Quality Assurance Requirements—Handling During Manufacture

The manufacturer shall have documented procedures for handling of intermediate and finished products during manufacture, packaging, and storage. The procedures shall include requirements for the following:

- a) minimizing the damage to protective coatings on components;
- b) avoiding damage to components by handling devices that have sharp or pointed parts, such as bolts or rivets;
- c) avoiding damage to components by them being dragged along the ground or impacted against sharp objects.

4.5.5 Manufacturing Tolerances

The manufacturer shall specify dimensional tolerances for all dimensions of the ancillary equipment on engineering drawings. These tolerances shall be verified in the design process to be acceptable, such that the functional requirements are unaffected by variations within the specified tolerances.

If dimensional criteria are based on manufacturing considerations rather than design considerations, the manufacturer shall document that the criteria used meet the design requirements.

4.5.6 Repairs

The manufacturer shall have documented qualified procedures for performing repairs, including repair of damage to surface coatings, and these procedures shall be available for review by the purchaser upon request.

4.6 Documentation

4.6.1 General

The minimum documentation that the manufacturer is to have available for the purchaser shall be as specified below. The documentation requirements for materials and manufacturing shall be as specified in the relevant sections of this specification and are summarized in this section. Any additional documentation requirement shall be specified by the purchaser.

The manufacturer shall have available for the purchaser the following documents for permanent ancillary equipment under the circumstances outlined and should have them available at the times specified:

- a) design methodology documentation—prior to design, if latest revision of manufacturers' design methodology has not yet been verified by an IVA (see design methodology sections of this specification);
- b) bridging document—prior to design, if documented operational experience is being submitted as validation of long-term material properties (see 4.4.2);
- c) design premise—prior to design;
- d) design report—prior to manufacture or at an agreed date after manufacture;
- e) manufacturing quality plan—prior to manufacturing;
- f) detailed engineering drawings—prior to manufacture;
- g) installation procedures—prior to installation;
- h) as-built documentation—with supplied ancillary equipment.

4.6.2 Design Premise

The design premise shall contain the following parameters:

- a) parameters specified by the purchaser (and listed in the purchasing guidelines Annex A to Annex S) in accordance with the functional requirements section for the ancillary equipment in question;
- b) design load cases;
- c) design criteria, including utilizations and safety factors;
- d) list of reference codes, standards, and sources of all design data.

If the manufacturer has made assumptions on any design parameters, then it shall be specified in the design premise that the values are assumed. All design changes shall be reflected in subsequent revisions of the design premise. See API 17L2 for guidelines relating to the design premise.

4.6.3 Design Report

The design report shall contain a description of the ancillary equipment, including the following:

- a) ancillary equipment identification;
- b) identification of pipe(s) or umbilical to which the ancillary equipment is associated;
- c) identification of the function, geometry, and properties of each component in the ancillary equipment;
- d) brief description of the design principle and methodology;
- e) material designation for all components, including material grades;
- f) mass in air and seawater;
- g) density of materials;
- h) description of fasteners used, with the following minimum information:
 - 1) materials and coatings;
 - 2) grade;
 - 3) tensile strength;
 - 4) yield strength.
- i) description of CP system;
- j) design criteria;
- k) results from analyses of load cases defined in the design premise;
- l) calculated stresses and strains in all the structural ancillary equipment components, including fasteners, for each design load case or where a component of the ancillary equipment design is based solely on structural strength, stresses, and strains for only the most onerous design load case for that component;
- m) demonstration that calculated stresses and strains do not exceed the design criteria;

- n) demonstration that calculated cyclic stresses do not exceed the material's documented and verifiable endurance limit (approved by purchaser) or, if not, demonstration that fatigue damage does not exceed the design criteria.

The design report shall make reference to the codes and standards used in the design of the ancillary equipment.

The design report shall state any assumptions that have been made on any of the input data. As a minimum, the manufacturer shall specify the source for all purchaser-supplied data, inclusive of design loads. The manufacturer shall specify in the design report or have available the source for all remaining input data that are used in the ancillary equipment design.

Unless separate material specification documentation is issued, material specification and data shall be included in the design report. Metallic material data shall include yield or tensile strengths and fatigue parameters for dynamic service (S-N curve slope, intercept, and endurance limit). Polymer or composite material data shall include the material properties specified in the qualification requirements section for the ancillary equipment in question.

Each component shall be documented to have sufficient structural capacity to sustain the design loads and stresses listed in the design report, with the utilizations or safety factors specified in the design premise. Design load case conditions shall be clearly described in accordance with 4.2.8.

The independent verification agent's certificate for the design methodology (as required in 4.3.5.1) shall be included in the design report.

4.6.4 Manufacturing Quality Plan

The manufacturing quality plan shall specify all quality control procedures, including inspection points and test procedures. The manufacturing quality plan may be included in the fabrication specification. The manufacturer's quality plan shall be in accordance with 4.4.5 and 4.5.3.

4.6.5 Installation Procedures

The manufacturer shall submit to the purchaser installation procedures for the ancillary equipment. The procedure shall contain where applicable the following as a minimum:

- a) equipment required;
- b) fastening forces for fasteners and straps;
- c) identification of which particular fasteners (e.g. M16) are to be used for securing a particular component;
- d) step-by-step installation procedures.

The above procedures shall ensure that, if the procedures are followed, the repeatability is such that the functional requirements of the ancillary equipment are satisfied.

4.6.6 As-built Documentation

The as-built documentation shall include, as a minimum, the following:

- a) purchase order reference number;
- b) equipment descriptions;
- c) references to design specifications and drawings;
- d) material certificates;

- e) dimension control measurements;
- f) FAT and prototype test procedures and test reports, including test results;
- g) all nonconformances identified during manufacture and repairs performed;
- h) welding procedure specifications and qualifications;
- i) welder qualification records;
- j) weld map;
- k) NDE operator qualifications and NDE test records;
- l) heat treatment records.

4.7 Factory Acceptance Tests

4.7.1 General

See the factory acceptance testing section for the ancillary equipment in question for specific FATs.

The ancillary equipment shall be subjected to factory acceptance tests, as specified in the factory acceptance testing sections of this specification, to verify the manufacture of the ancillary equipment to these requirements. The purchaser shall have the option of witnessing all tests and shall be given appropriate notice of the timing by the manufacturer.

A report for each factory acceptance test shall be submitted to the purchaser as part of the as-built documentation (see 4.6.6). Current certification/calibration certificates for all test equipment shall be included in the test report.

If the acceptance criteria for a test are not met, the cause of the failure shall be investigated and a report submitted to the purchaser. Proposed corrective action shall be included in the report. The purchaser shall have the option of retesting, rejecting the ancillary equipment, or accepting the corrective action plan from the report.

4.7.2 Visual Examination—Metallic Components

The surface of metallic components shall be visually examined for flaws, including dents, cracks, scratches, shavings, gouges, corrosion, and discolored areas such as blurring, scorching, and staining, except discoloring at welds. Any flaws that are identified that exceed the limits allowed in the manufacturer's procedures shall be recorded and subject to review by the purchaser.

NDE of welds shall be performed in accordance with an appropriate international standard such as those listed in Table 10. See API 2A-WSD for a description of the various NDE techniques and their applications.

4.7.3 Visual Examination—Polymer and Composite Components

The surface of finished polymer and composite components shall be visually examined for any flaws such as warping, cracks, scratches, bubbles, discoloring or indentations. Any flaws that are identified that exceed the limits allowed in the manufacturers procedures shall be recorded and subject to review by the purchaser.

4.7.4 Factory Acceptance Test Frequency

Where FATs on polymer and composite components apply to a fraction of production rather than the whole of the production, as specified in the subsequent factory acceptance test sections of this specification, such FATs shall include the first item molded, and their frequency shall be evenly distributed between the first and last items molded.

4.8 Marking and Packaging

4.8.1 Marking

The ancillary equipment marking shall make it permanently identifiable for the specified service life. The marking on ancillary equipment shall include the following as a minimum:

- a) API Specification 17L1;
- b) manufacturer's name or mark;
- c) manufacturer's serial number;
- d) mass in air;
- e) markings specified by the purchaser, if available.

4.8.2 Packaging

The ancillary equipment shall be packaged in accordance with the manufacturers' specifications. Ropes/wires, shackles, and other required handling equipment shall be identified in the packaging procedures. All packages shall be accompanied by a packing list.

The packaging shall be such that the ancillary equipment is protected against all expected environmental occurrences when stored outdoors.

Packaging of the ancillary equipment shall ensure its safety in all transport stages prior to installation or usage as agreed upon between manufacturer and purchaser.

5 Bend Stiffeners

5.1 Applicability

The requirements of Section 4 shall apply.

This section applies to static and dynamic bend stiffeners, temporary bend stiffeners, and permanent bend stiffeners.

The requirements in this section shall be applied to flexible pipe and umbilicals and some specific requirements are given for umbilical bend stiffeners.

5.2 Functional Requirements

5.2.1 General

Purchasing guidelines for bend stiffeners are given in Annex A.

The minimum overall functional requirements of the bend stiffener that shall be demonstrated by the manufacturer are as follows:

- a) functional requirements given in 4.2.2;
- b) to prevent the pipe or umbilical from overbending and to ensure their specified service life is met;
- c) to remain securely attached to the support structure for the specified service life;

- d) to transfer loads from the pipe or umbilical to the support structure;
- e) to ensure that the bend stiffener construction is such that no unacceptable localized loads are imparted at any location on the flexible pipe or umbilical (e.g. at the polyurethane/steel interface or the connector/transition piece).

5.2.2 Flexible Pipe or Umbilical Design Parameters

For the flexible pipe or umbilical to which the bend stiffener is associated, the purchaser shall specify the following parameters as a minimum:

- a) internal diameter for flexible pipe;
- b) service type;
- c) service life (service life shall only be specified for permanent bend stiffeners);
- d) external diameter;
- e) tolerance on external diameter;
- f) operating and storage MBR for flexible pipe or umbilical;
- g) umbilical tension-curvature capacity curves (note in the form of a graph or table);
- h) values of bending stiffness applicable for all design/operating conditions (these values shall account for the combinations of internal fluid temperature and ambient temperature (air or seawater as applicable) as well as internal pressure relating to such design/operating conditions);
- i) axial stiffness, if required by the manufacturer;
- j) detailed drawing of the end fitting at the bend stiffener end of the flexible pipe for end fitting adjacent interface structures.

5.2.3 Bend Stiffener Design Parameters

For the bend stiffener, the purchaser shall specify the following parameters:

- a) whether the bend stiffener is dynamic or static;
- b) whether the bend stiffener is temporary or permanent;
- c) departure and azimuth angle, including tolerance, of bend stiffener relative to mean orientation of the flexible pipe or umbilical;
- d) any constraints relating to physical dimensions of bend stiffener, expressed in terms of maximum length and maximum diameter;
- e) temperatures to which the bend stiffener is exposed, including pipe/umbilical surface temperature in the vicinity of the bend stiffener location and external environmental temperature (in accordance with 4.2.4).

5.2.4 Purchaser Support Structure

The purchaser shall provide detailed drawings of the support structure to which the bend stiffener interface structure is to be connected, such as a flange, end fitting (in accordance with 5.2.2.j)), I-tube, intermediate connection, need for a latching mechanism, for example.