Specification for Bonded Flexible Pipe

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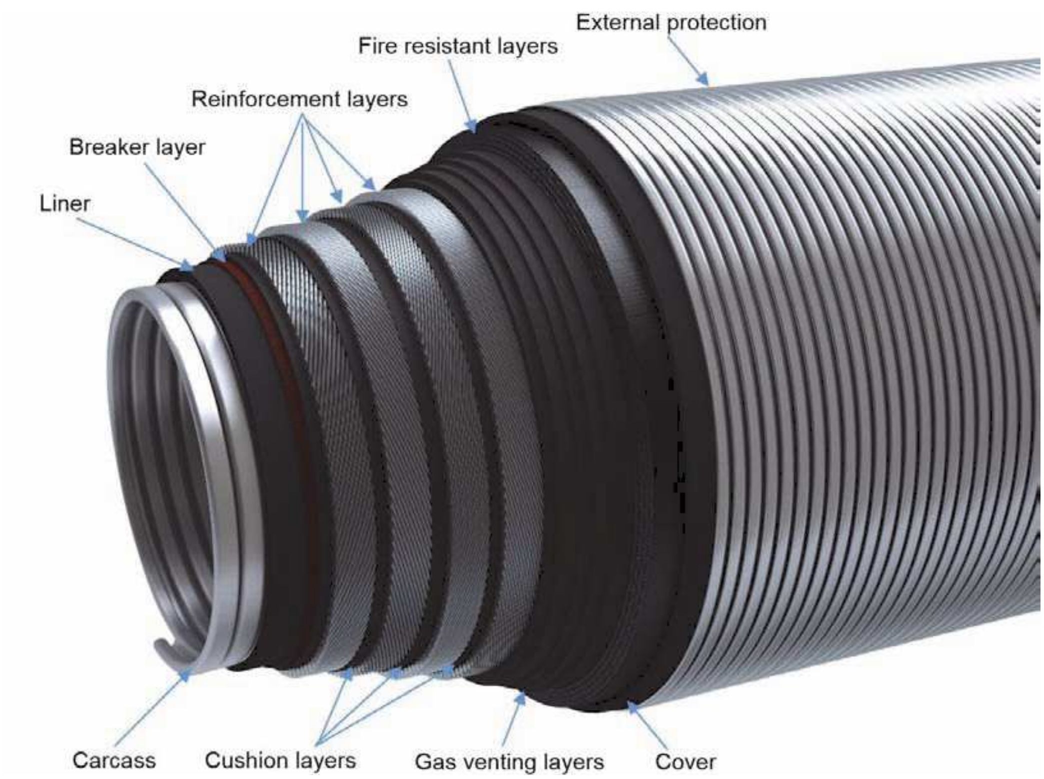
Introduction

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

Figures 1a, 1b, and 1c provide examples of typical bonded flexible pipe covered by this specification.



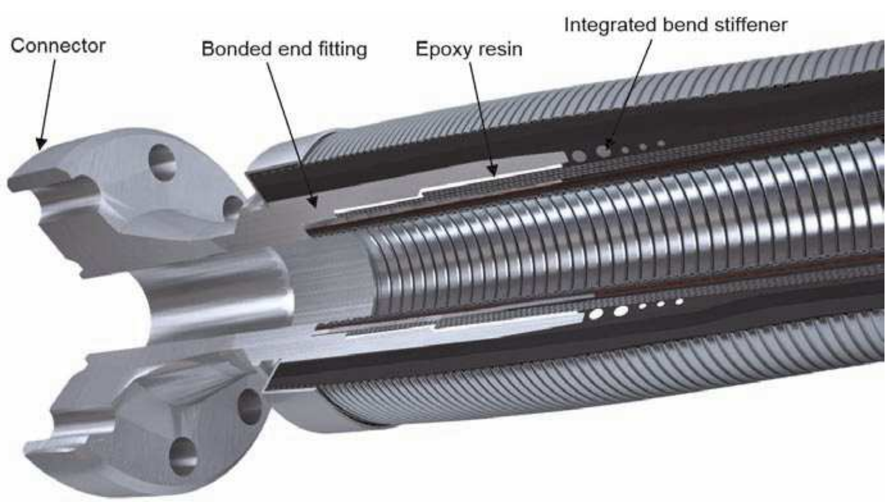


Figure 1a—Typical Bonded Flexible Pipe—Flowline and Riser

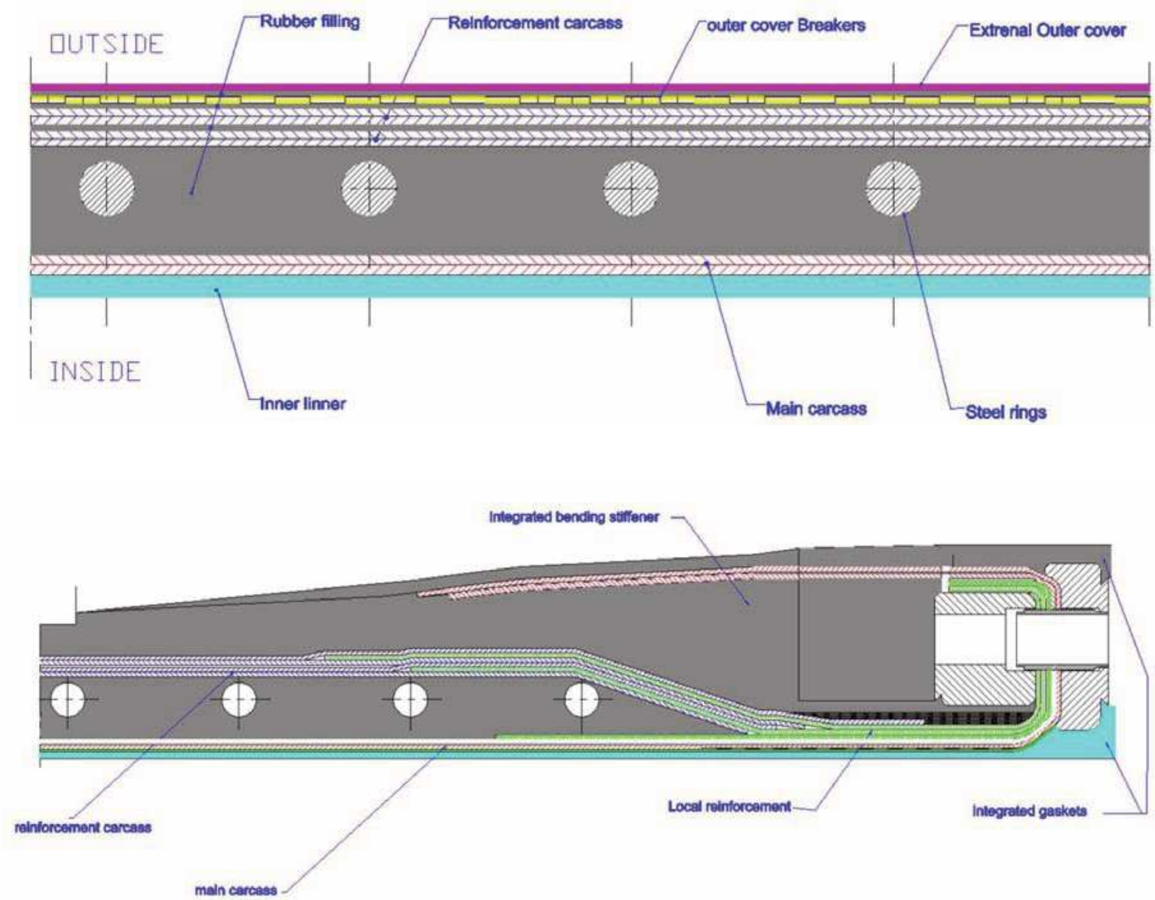


Figure 1b—Typical Bonded Flexible Pipe—Loading and Discharge Hose

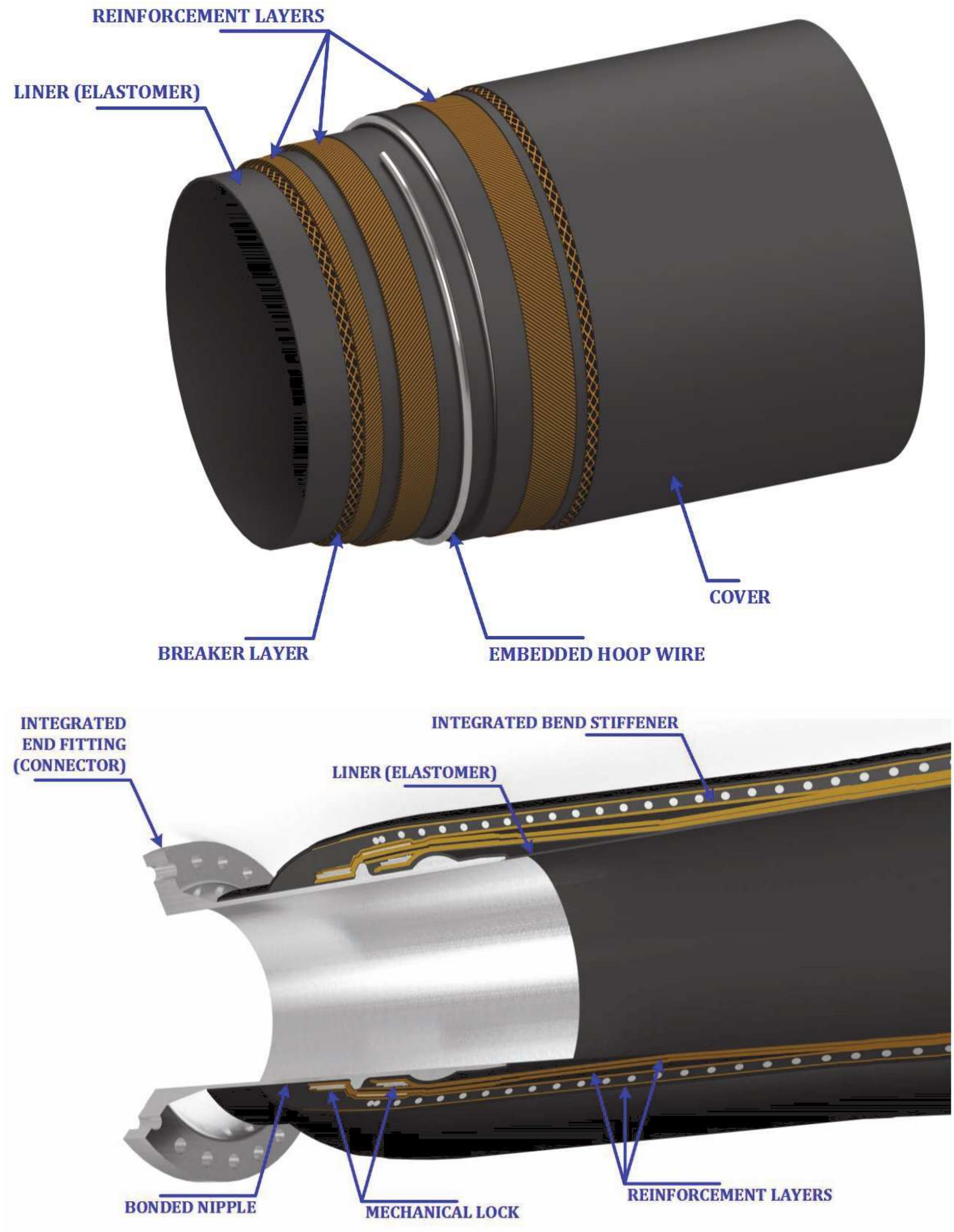


Figure 1c—Typical Bonded Hose—Body and End

Specification for Bonded Flexible Pipe

1 Scope

This specification defines the technical requirements for safe, dimensionally and functionally interchangeable bonded flexible pipes that are designed and manufactured to uniform standards and criteria. See Figure 1 for an explanatory figure on typical bonded flexible pipe.

Minimum requirements are specified for the design, material selection, manufacture, testing, marking, and packaging of bonded flexible pipes, with reference to existing codes and standards where applicable. See API 17B for guidelines on the use of flexible pipes. Refer to API 17L1 and API 17L2 for the specification and recommended practice for ancillary equipment including buoyancy, bend limiters, bell mouths, and non-integral stand-alone bend stiffeners.

This specification applies to bonded flexible pipe assemblies, consisting of segments of flexible pipe body with end fittings or integrated flanges attached to both ends. API 17K does not cover flexible pipes of unbonded structure. See API 17J for guidance on unbonded flexible pipes.

This specification can be applied to flexible pipes that include nonmetallic reinforcing layers. This specification can be applied to a bonded construction pipe that includes a material or layer construction that is covered in API 17J.

Supplementary requirements for loading and discharge hoses can be found in GMPHOM provided they do not contradict those of API 17K.

The applications addressed by API 17K are for sweet and sour service production, including export and injection and seawater intake applications. Production products include oil, gas, water, and injection chemicals. This specification applies to both static and dynamic flexible pipes used as flowlines, risers, jumpers, and offshore loading and discharge hoses.

This specification does not apply to flexible pipe ancillary components. Guidelines for ancillary components are given in API 17L1 and API 17L2. This specification does not apply to flexible pipes for use in choke and kill-line applications. See API 16C for guidance on choke and kill-line applications. This specification can be applied to flexible pipes for pile hammer, gas flare, water supply, and jetting applications, though no effort was made to address the specific and unique technological aspects relating to each of these requirements.

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

2 Normative References

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

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

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

API Specification 17D, *Specification for Subsea Wellhead and Christmas Tree Equipment*

API Standard 1104, *Welding of Pipelines and Related Facilities*

ASME [1] Section IX, Boiler & Pressure Vessel Code, *Welding and Brazing Qualifications*

ASTM [2] A29/A29M:2005, *Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought — General Requirements*

ASTM A105, *Standard Specification for Forgings, Carbon Steel, for Piping Applications*

ASTM A182/A182M:2005, *Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service*

ASTM A668/A668M:2004, *Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use*

ASTM A751, *Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products*

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

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

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

ASTM D413, *Standard Test Methods for Rubber Property—Adhesion to Flexible Substrate*

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

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

ASTM D746, *Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact*

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

ASTM D2084, *Standard Test Method for Rubber Property—Vulcanization Using Oscillating Disk Cure Meter*

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

ASTM D5028, *Standard Test Method for Curing Properties of Pultrusion Resins by Thermal Analysis*

ASTM E92, *Standard Test Method for Vickers Hardness of Metallic Materials*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

ASTM E328, *Standard Test Methods for Stress Relaxation Tests for Materials and Structures*

ASTM E1356, *Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry*

ASTM G48, *Standard Test Method for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*

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[1] American Society of Mechanical Engineers, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

[2] American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

DNV [3] Fire Test, *IMO Resolution A.753 (18) (Adopted on 4 November 1993) Guidelines for the application of plastic pipes on ships.*

DIN [4] 53505, *Shore A and Shore D hardness testing* of *rubber*

EN [5] 10204, *Metallic products—Types of inspection documents*

ISO [6] 34-2, *Rubber, vulcanized, or thermoplastic—Determination of tear strength—Part 2: Small (Delft) test pieces*

ISO 36, *Rubber, vulcanized, or thermoplastic—Determination of adhesion to textile fabrics*

ISO 37, *Rubber, vulcanized, or thermoplastic—Determination of tensile stress-strain properties*

ISO 812, *Rubber, vulcanized,—Determination of low-temperature brittleness*

ISO 1431-1:2004, *Rubber, vulcanized or thermoplastic—Resistance to ozone cracking—Part 1: Static and dynamic strain testing*

ISO 1817, *Rubber, vulcanized—Determination of the effect of liquids*

ISO 2781, *Rubber, vulcanized—Determination of density*

ISO 4647:1982, *Rubber, vulcanized—Determination of static adhesion to textile cord—H-pull test*

ISO 4649, *Rubber, vulcanized or thermoplastic—Determination of abrasion resistance using a rotating cylindrical drum device*

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

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

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

ISO 10474, *Steel and steel products—Inspection documents*

ISO 16120-1, *Non-alloy steel wire rod for conversion to wire—Part 1: General requirements*

Lloyds Fire Test, *Lloyds Register of Shipping, Fire Testing Memorandum ICE/Fire OSG 1000/499*

NACE [7] MR0175 (all parts), *Petroleum and natural gas industries—Materials for use in H_2S-containing environments in oil and gas production*

NACE TM0177, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments*

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3 Det Norske Veritas, Verittasveien 1, Høvik, Norway, www.detnorskeveritas.com.

4 Deutsches Institut für Normung e.V., Burggrafenstraße 6, 10787, Berlin, Germany, www.din.de.

5 European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, www.cen.eu.

6 International Organization for Standardization, Chemin de Blandonnet 8, 1214 Vernier, Genèva, Switzerland, www.iso.org.

7 National Association of Corrosion Engineers, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

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

3.1.1
ancillary components
Components that are attached to the flexible pipe in order to perform one or more of the following functions:

a) to control the flexible pipe behavior;

b) to provide a structural transition between the flexible pipe and adjacent structures;

c) to avoid excessive curvature;

d) to attach other structures to the flexible pipe, or the flexible pipe to other structures, or to connect flanges or proprietary connectors to the flexible pipe (e.g. stud bolts and nuts and clamps);

e) to protect or repair the flexible pipe;

f) to provide a seal between the flexible pipe and an I-tube or J-tube inner wall (in order to prevent corrosion-inhibited seawater escaping).

3.1.2
bellmouth
Part of a guide tube, formed in the shape of a bellmouth, and designed to prevent overbending of the flexible pipe.

3.1.3
bend limiter
Any device used to restrict bending of the flexible pipe.

NOTE Bend limiters include bend restrictors, bend stiffeners, and bellmouths.

3.1.4
bend radius
Radius of curvature of the flexible pipe measured from the pipe centerline.

NOTE Storage and operating minimum bend radii are defined in 5.3.1.

3.1.5
bend restrictor
Mechanical device that functions as a mechanical stop and limits the local radius of curvature of the flexible pipe to a minimum value.

3.1.6
bend stiffener
Integrated or stand-alone component which locally supports the pipe to limit bending stresses and curvature of the pipe to acceptable levels.

NOTE Non-integrated stand-alone bend stiffeners are defined in API 17L1 and API 17L2.

3.1.7
bending stiffness
Resistance to bending from an applied bending moment—product of the effective elastic modulus and the moment of inertia of the flexible pipe.

NOTE 1 The bending stiffness may vary with tension, pressure, and temperature.

NOTE 2 It is often quantified as the product of an applied bending moment ×the resultant bend radius of the pipe.

3.1.8
bonded flexible pipe
BFP
Flexible pipe in which the metallic or nonmetallic reinforcement is integrated and bonded to a vulcanized elastomeric material, where textile material is included in the structure to obtain additional structural reinforcement or to separate elastomeric layers.

3.1.9
breaker
Textile layer impregnated with rubber included in various layers in the pipe cross section to give additional strength to the pipe, to aid in reducing propagation of cuts in the pipe, and to aid the manufacturing process.

NOTE This layer can be incorporated into either the cover, reinforcing layer, or all of them.

3.1.10
cable
Series of round wires of metallic or fabric (circular cross section) spirally wound (stranded) together and used for structurally reinforcing the pipe.

NOTE Cable wires for flexible pipes are usually brass, copper, or zinc coated to promote chemical bonding of the elastomer to the wires.

3.1.11
calendering
Process of passing elastomer compound between rollers to produce smooth sheets of elastomer.

NOTE This process is also used to cover reinforcing cables and textiles with elastomer to form sheets for winding onto pipes.

3.1.12
carcass
Interlocked metallic construction that is normally used as the innermost layer in rough bore pipes to prevent, totally or partially, collapse of the pipe due to pipe decompression, external pressure, reinforcement layer pressure, and mechanical crushing loads.

NOTE It can be used externally to protect the external surface of the pipe; this is referred to as “abrasion protection.”

3.1.13
choke and kill line jumpers
Flexible pipe jumpers located between the steel choke and kill lines on the marine drilling riser, and the choke and kill connections on the blowout preventer.

3.1.14
compound
Mix of elastomer material and various additives prior to the curing process.

3.1.15
connector
Device used to provide a leak-tight structural connection between the end fitting and adjacent piping.

NOTE Connectors include bolted flanges, clamped hubs, and proprietary connectors. They can be designed for diver-assisted makeup or for diverless operation using either a mechanical or hydraulic apparatus.

3.1.16
cover
Layer of elastomer between the reinforcing layer and the external environment (or external carcass if provided) used to protect the pipe against penetration of seawater and other external environments, corrosion, abrasion, and mechanical damage.

3.1.17
creep damage ratio
Ratio of duration of time at a given creep load divided by the time to failure at the same creep load (concept analogous to fatigue damage ratio where Miner's linear summation rule apply).

3.1.18
crossover
Flexible flowline crossing another pipe already laid on the seabed.

NOTE 1 The underlying pipe may be a steel pipe or another flexible pipe.

NOTE 2 It is normally necessary to support the overlying pipe to prevent overbending or crushing of the new or existing pipes.

3.1.19
curing
Process of changing irreversibly, usually at elevated temperatures, the properties of a thermosetting resin or an elastomer compound by chemical reaction.

NOTE Cure can be accomplished by the addition of curing (cross-linking) agents, with or without heat and pressure.

3.1.20
design differential pressure
Difference between design external pressure and design pressure at a reference location.

NOTE Design pressure is defined in 4.3.2.

3.1.21
design methodology
Documented and verified approach to the design of a component or system.

3.1.22
design methodology verification report
Evaluation report prepared by an independent verification agent (IVA), for a specific manufacturer, confirming the suitability and appropriate limits on the manufacturer's design methodologies, manufacturing processes, and materials.

NOTE This report may include occasional amendments or revisions to address extensions beyond previous limits or revisions of methodologies.

3.1.23
dynamic application
Service in which flexible pipe is exposed to cyclically varying loads and deflections during normal operation.

NOTE The pipe is specially constructed to withstand a large number of bending/tensile/torsional cycles.

3.1.24
elastomer
Material that substantially recovers its original shape and size at room temperature after removal of a deforming force; material that shows a reversible elasticity up to a very high strain level (~ 100 %).

3.1.25
embedded wire or ring
Predominantly hoop-oriented wire or ring which is designed to add crush and pressure resistance to the construction.

NOTE The wire or ring may or may not be adhered to the rubber as specified by the manufacturer and verified by the IVA.

3.1.26
embedding compound
Elastomeric compound in which the steel reinforcing cables are embedded.

NOTE The compound assures bonding between the steel cables and surrounding layers.

3.1.27
end fitting
Structural/mechanical device for terminating different pipe layers in such a way as to transfer load between the flexible pipe and the connector, and seal all internal and external fluid containment layers.

3.1.28
event, abnormal operation
Event wherein the pipe is exposed to an infrequent load (e.g. pressures in excess of the design, accidental conditions).

3.1.29
event, extreme operation
Event having a low probability of being exceeded in the lifetime of the BFP (e.g. an event with a return period (RP) of 100 years).

3.1.30
event, extreme temporary
Event of short duration having a low probability of being exceeded in the lifetime of the BFP.

3.1.31
event, normal operation
Event wherein the pipe is exposed to loading in accordance with the operation plan.

3.1.32
event, normal temporary
Event of limited duration wherein the pipe is exposed to loading in accordance with the operation plan.

3.1.33
event, survival
Event involving conditions that exceed extreme design events where fluid containment is just maintained.

3.1.34
flexible flowline
Flexible pipe, wholly or in part, resting on the seafloor or buried below the seafloor, and used in a static application.

NOTE The term flowline is used in this document as a generic term for flexible flowline.

3.1.35
flexible pipe
Assembly of a pipe body and end fittings, where the pipe body comprises a composite of layered materials that form a pressure-containing conduit, and the pipe structure allows large deflections.

NOTE 1 Normally, the pipe body is built up as a composite structure comprising metallic and elastomer layers.

NOTE 2 The term *pipe* is used in this document as a generic term for flexible pipe.

NOTE 3 When specifically making reference to bonded flexible pipe, this document uses the abbreviation BFP.

3.1.36
flexible riser
Flexible pipe connecting a platform/buoy/ship to a flowline, seafloor installation, or another platform, where the riser can be freely suspended (free catenary), restrained to some extent (buoys, chains), totally restrained, or enclosed in a tube (I- or J-tube).

3.1.37
floating loading and discharge hose
Flexible pipe with integral buoyancy or clamped-on buoyancy modules so as to enable the buoyant pipe to float on the water surface.

3.1.38
gas service
Service conditions with a gas content, i.e. gas applications or live crude containing gas.

3.1.39
global buckling
Pipeline response to compressive axial force resulting in horizontal displacement (lateral buckling) or vertical displacement (upheaval buckling).

3.1.40
independent verification agent
Independent party or group, selected by the manufacturer, who is responsible for the review and certification of the indicated product concept (e.g. pipe and end-fitting concept) and flexible pipe, 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.

3.1.41
insulation layer
Additional layer added to the flexible pipe to increase the thermal insulation properties.

NOTE The layer is usually located between the outer reinforcement layer and the cover.

3.1.42
integrated end fitting
End fittings which are vulcanized together with the hose body during the manufacturing process.

3.1.43
internal fluid-structure interactions
Mechanical coupling in between the pipe and the fluid inside the pipe, resulting, for example, from floater motions (such as, but not limited to, sloshing).

3.1.44
jumper
Short flexible pipe used in subsea and topside, static, or dynamic applications, e.g. turret jumpers and drag chain jumpers.

3.1.45
lay angle
Angle between the axis of a spiral wound element (e.g. cables of reinforcing layer) and a line parallel to the longitudinal axis of the flexible pipe.

3.1.46
liner
Layer of elastomer in contact with the internal fluid which ensures fluid containment.

3.1.47
load, accidental
Loads that are a consequence of unplanned occurrences.

3.1.48
load, environmental
Loads that are imposed directly or indirectly by the ocean or atmospheric environment.

3.1.49
load, functional
Loads that are a consequence of the system's existence and use without consideration of environmental or accidental effects.

3.1.50
loading and discharge hose
Flexible pipe jumper used in the loading and offloading of tankers in both static and dynamic applications.

3.1.51
new pipe design
New pipe design is characterized by one, or both, of the following:

a) pipe concept whose constituting materials, design methodologies, manufacturing processes, and prototype testing results have not been reviewed and accepted by an IVA;

b) a pipe concept whose required performance, for a specific application, has not been accepted by an IVA or the purchaser.

3.1.52
operation plan
Purchaser-specified plan of operation for the flexible pipe.

3.1.53
oil shrinkage
Oil volume reduction occurring when the temperature is cooling down (e.g. in between offloading operations for an export line, or after a production shut down for a production riser) due to oil density variation.

NOTE Under certain conditions, this can result in partially emptying the pipes impacted.

3.1.54
ovalization
Out-of-roundness of the pipe at a given cross-section location, calculated as follows:

$$\frac{D_{\text{max}} - D_{\text{min}}}{D_{\text{max}} + D_{\text{min}}}$$

where D_{max} and D_{min} are maximum and minimum pipe diameter, respectively.

3.1.55
overall heat transfer coefficient
OHTC
Measure of the overall ability of the pipe cross-section to transfer heat.

NOTE OHTC is the heat transferred per unit area, per unit temperature. The area is usually taken as the internal surface area over which the transfer of heat takes place.

3.1.56
permanent operation
Operation condition in which pipe is exposed to loading in accordance with the operation plan.

3.1.57
piggyback
Two pipes attached at regular intervals with clamps, where either or both of the pipes can be flexibles.

3.1.58
pipe concept
That which is characterized by the following combination of parameters:

a) function (intended use or application);

b) structure of layers, sequence, and number of layers in the pipe body, type of wire cross section, etc.;

c) end fitting's structural body, details of sealing systems, anchoring system, and vent system.

3.1.59
prototype test
Test to establish or verify a principal performance characteristic for a particular pipe design, which may be a new or established design, and to also validate manufacturer design methodology and so provide a basis for the IVA verification.

3.1.60
pump start-up effects
Transient phenomena in the pipe resulting from a pump start-up and perturbing the fluid

EXAMPLE For an export line when the offloading operations are started, a large volume of oil is suddenly released in the pipe, modifying the previous fluid-steady state.

3.1.61
qualification testing
Testing by which the structural, functional, fabrication, and reliability performance of a pipe concept, its components, or materials used, may be evaluated in order to demonstrate suitability for the specified service life in a specific application.

NOTE The qualification test can also be used to validate the manufacturer's design methodology for a new pipe design.

3.1.62
quality
Conformance to specified requirements.

3.1.63
quality assurance
Those planned, systematic, corrective, and preventive actions that are required to ensure that materials, products or services will meet specified requirements.

3.1.64
quality control
Inspection, test, or examination to ensure that materials, products, or services conform to specified requirements.

3.1.65
reinforcing layer
Structural layer with a specific lay angle, typically around 55°, which consists of helically wound cables embedded in elastomer, and is used to sustain, totally or partially, tensile loads and internal pressure.

3.1.66
reverse end cap effect
RECE
Axial compressive load due to external overpressure.

3.1.67
rough bore
Flexible pipe with a steel strip carcass as the innermost layer.

3.1.68
seawater intake hose
Bonded flexible pipe used to supply seawater by suction for cooling purposes of topside facilities.

3.1.69
service life
Period of time during which the flexible pipe is designed to fulfill all specified performance requirements.

3.1.70
smooth bore
Flexible pipe with an elastomer or plastic layer as the innermost layer.

3.1.71
sour service
Service conditions with an H_2S content exceeding the minimum specified by NACE MR0175 at the design pressure.

NOTE For the purposes of this provision, ISO 15156 is equivalent to NACE MR0175.

3.1.72
static application
Application wherein the BFP is not exposed to significant cyclically varying loads or deflections during permanent operations.

3.1.73
survival
Survival of a component means that the component does not fail, but it can present one or more kinds of degradation that could jeopardize its specified performance or service life.

3.1.74
sweet service
Service conditions which have an H_2S content less than that specified by NACE MR0175 at the design pressure.

NOTE For the purposes of this provision, ISO 15156 is equivalent to NACE MR0175.

3.1.75
system
Fluid conveyance system, connected to field equipment in both extremities, in operation or ready to operate, for which the flexible pipe(s) is the primary component and includes ancillary components and accessories attached directly or indirectly to the pipe(s).

3.1.76
tensile strength
Tensile strength (elastomers) is defined in accordance with ISO 37.

NOTE For the purposes of this provision, ASTM D412 is equivalent to ISO 37.

3.1.77
tensioner
Mechanical device used to apply tension or support a pipe by applying radial loads to the pipe with moving tracks during its installation or retrieval.

3.1.78
thermal exchange coefficient
TEC
Coefficient that provides the heat loss (expressed in watts) of 1 m of pipe when subjected to 1 °C difference between its internal and external surfaces.

3.1.79
torsional balance
Pipe characteristic that is achieved by designing the structural layers in the pipe, such that axial and pressure loads do not induce significant twist or torsional loads in the pipe.

3.1.80
ultimate strength
Ultimate strength (metals) in this specification is defined in accordance with ISO 6892.

NOTE For the purposes of this provision, ASTM A370 is equivalent to ISO 6892.

3.1.81
unbonded pipe
Pipe construction that consists of separate unbonded polymeric and helical reinforcement layers, which allows relative movement between layers.

3.1.82
visual examination
Examination of parts and equipment for visible defects in material and workmanship.

3.1.83
yield strength
Yield strength (metals) in this standard for steel materials is defined as 0.2 % yield offset strength, as specified in ISO 6892.

NOTE For the purposes of this provision, ASTM A370 is equivalent to ISO 6892.

3.1.84
vulcanization
Process of cross-linking the elastomer chains to reduce the plasticity of the elastomer.

NOTE Otherwise referred to as “curing”.

3.2 Symbols and Abbreviations

The following symbols and abbreviations are used in this document.

BFP	bonded flexible pipe
CH_4	methane
CO_2	carbon dioxide
DSC	differential scanning calorimetry
EFAT	extended factory acceptance test
FAT	factory acceptance test
GA	general arrangement

H_2S	hydrogen sulfide
HIC	hydrogen-induced cracking
HV	hardness on Vickers Scale
ID	internal diameter
IVA	independent verification agent
MBR	minimum bend radius
MPI	magnetic particle inspection
NDE	nondestructive examination
OBR	operating bend radius
OD	outer diameter
OHTC	overall heat transfer coefficient
OLT	offshore leak test
PLEM	pipeline end manifold
PLET	pipeline end termination
PQR	welding procedure qualification record
RAO	response amplitude operator
RGD	rapid gas decompression
ROV	remotely operated [underwater] vehicle
RP	return period
SIT	structural integrity test
S-N	curves showing stress range vs. number of cycles
SSC	sulfide stress cracking
SWI	seawater intake
SWL	safe working load
TAN	titrated acid number
TEC	thermal exchange coefficient
TFL	through flowline
VIV	vortex induced vibrations
WPQ	welding performance qualification
WPQR	welding performance qualification record

WPS	welding procedure specification
UV	ultraviolet
F	design pulling force
F_y	anchoring system capacity
n	permissible stress utilization factor
t	thickness of component
σ_e	equivalent stress (von Mises or Tresca)
σ_t	tensile hoop stress
σ_y	material yield stress
σ_u	material ultimate stress
Ω	ohm

4 Functional Requirements

4.1 Purchasing

4.1.1 General

The purchaser shall specify the functional requirements for the flexible pipe.

NOTE 1 The purchasing guidelines in Annex B give a sample format for the specification of the functional requirements.

NOTE 2 Functional requirements not specifically required by the purchaser that may affect the design, materials, manufacturing, and testing of the pipe, shall be specified by the manufacturer.

NOTE 3 If the purchaser does not specify a requirement, and 4.1.2 does not apply, the manufacturer may assume that there is no requirement.

NOTE 4 Regulatory authority functional requirements that may affect the design, materials, manufacturing, and testing of the pipe shall be specified by the purchaser.

If a purchaser wishes to use this specification for the procurement of pipes with nonmetallic reinforcing layers, the manufacturer shall demonstrate by analysis and tests that the level of safety during the service life is not less than that given by this specification for metallic reinforced pipes.

If a purchaser wishes to purchase pipe that includes a material or layer construction that is covered in API 17J, that purchaser should prepare a supplemental specification with requirements for the manufacturer to meet, demonstrating by analysis and tests that the levels of safety are not less than those required by API 17J and this specification's overall requirements.

4.1.2 Flexible Pipe

The following minimum overall functional requirements of the flexible pipe shall be demonstrated by the manufacturer.

— The pipe shall provide a leak-tight conduit.

- The pipe shall be capable of withstanding all design loads and load combinations defined herein.
- The pipe shall perform its function for the specified service life.
- The flexible pipe materials shall be compatible with the environment to which the material is exposed.
- The flexible pipe materials shall conform to the corrosion-control requirements specified herein.

4.1.3 End Fitting

The manufacturer shall demonstrate that the end fitting, as a minimum, meets the same functional requirements as the flexible pipe. If relevant, this shall be demonstrated by the following.

- The end fitting shall provide a structural interface between the pipe and the support structure.
- The end fitting shall provide a structural interface between the flexible pipe and bend-limiting devices, including bend stiffeners, bend restrictors, and bellmouths, such that the bend-limiting devices meet their functional requirements.
- Dissimilar IDs between the end fitting and the pipe body shall be documented by manufacturers.

4.2 General Design Parameters

The purchaser shall specify any project-specific design requirements, which may include the requirements of 4.3 to 4.5 and the following:

- nominal internal diameter;
- length and tolerances of flexible pipe, including end fittings;
- service life;
- regulatory authority requirements.

4.3 Internal Fluid Parameters

4.3.1 General

The purchaser shall specify the internal fluid parameters for the application. The parameters listed in Table 1 should be specified. When known, the minimum, normal, and maximum conditions should be specified for the internal fluid parameters of Table 1. Expected variations in the internal fluid parameters over the service life should be specified.

Table 1—Internal Fluid Parameters

Parameter	Comment
Internal pressure	See 4.3.2
Temperature	See 4.3.3
Fluid composition	See 4.3.4
Service definition	Sweet or sour in accordance with 4.3.4, 1st bullet
Fluid/flow description	Fluid type and flow regime
Flow rate parameters	Flow rates, fluid density, viscosity, minimum inlet pressure, and required outlet pressure
Thermal parameters	Fluid heat capacity

4.3.2 Internal Pressure

The internal pressures that are relevant to the design, testing, and operation of a bonded flexible pipe are defined in Figure 1 and Table 2.

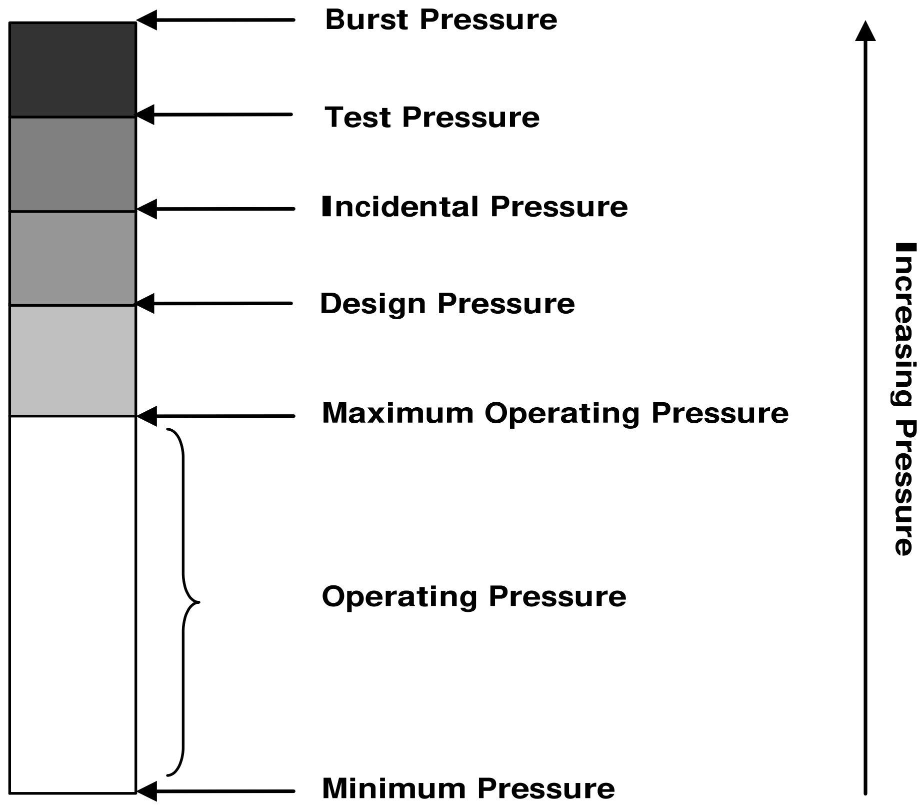

Figure 1—Internal Pressure Definitions

The following internal pressures shall be specified by the purchaser:

— design pressure,

— maximum operating pressure,

— incidental pressure.

The following internal pressures data should be specified by the purchaser:

— operating pressure profiles along the pipe and through the service life (including effects listed in Table 5);

— system design pressure;

— FAT, EFAT, OLT, and offshore SIT pressure requirements of the purchaser and/or governing certifying authorities;

— number of extreme pressure cycles (e.g. from the maximum to the minimum operating—or design—pressure and return to the specified operating pressure associated or not to the thermal cycles);

— minimum pressure (vacuum pressure if relevant).

Table 2—Internal Pressure Definitions

Pressure [1]	Definition
Minimum pressure [2]	The minimum internal pressure experienced by the pipe during its life (installation and operating conditions). A conservative estimate is to assume a vacuum.
Operating pressure	The internal pressure profile experienced by the pipe during permanent normal operation over its service life.
Maximum operating pressure	The maximum internal pressure, at a reference location [3] to which the pipe is subjected during permanent normal operation.
Design pressure	The maximum internal pressure, at a reference location, including planned shut-in pressure and associated surge.
System design pressure	The lowest maximum internal pressure of the pipe system.
Incidental pressure	The maximum internal pressure, at a reference location, that is unlikely to be exceeded during the life of the pipe, due to abnormal operation, unintended shut-in pressure, surge pressure, or other temporary incidental condition. Unless otherwise specified by the purchaser, the maximum incidental pressure is typically 1.1× the design pressure.
Factory acceptance test (FAT)	The internal pressure applied to the pipe or pipe section during testing after manufacture to test for latent defects. Unless otherwise specified by the purchaser, the FAT pressure is 1.5× the design pressure, and above the incidental pressure. If applicable, the maximum differential pressure can be used instead of design pressure.
Extended FAT	The internal pressure applied to hose strings including hose segments and connectors. Unless otherwise specified by the purchaser, the extended FAT pressure is 1.1× the design pressure
Offshore leak test (OLT)	The internal pressure applied to the pipe or pipe section during testing after installation to test for leak tightness. Unless otherwise specified by the purchaser, the OLT pressure is 1.1× either (a) the design pressure of the pipe, or (b) system design pressure, whichever is lower.
Structural integrity test (SIT) (on-board) [4]	The internal pressure applied to the pipe or pipe section during testing on-board the installation vessel to test the structural integrity of the pipe. Unless otherwise specified by the purchaser the structural integrity test (SIT) pressure shall be as per the FAT pressure.
SIT (offshore) [5]	The internal pressure applied to the pipe or pipe section during testing in situ after installation to test the structural integrity of the pipe. Unless otherwise specified by the purchaser the SIT pressure shall be 1.25× either (a) the design pressure of the pipe, or (b) system design pressure, whichever is lower.
Burst pressure	The pressure at which loss of fluid containment in the pipe occurs due to pipe or end fitting failure.

1 The pressure can be a function of location along the pipe and/or time.

2 Vacuum is not applicable for water intake hoses as minimum pressure.

3 Unless otherwise specified, for injection or export risers the reference location should be at the topside; for production risers the reference location should be at the wellhead or other equipment where the flexible pipe is connected to a manifold, PLET, PLEM, etc.

4 The on-board structural integrity pressure test is required if the pipe is fully retrieved and repaired on-board the installation vessel, and when the structural integrity of the reinforcement layers or end-termination pressure containment parts have been affected.

5 The offshore structural integrity pressure test is required post installation if the pipe is repaired in situ and when the structural integrity of the reinforcement layers or end-termination pressure containment parts have been affected, or to reassess the integrity versus suspected damage/reduced resistance.

4.3.3 Internal Fluid Temperature

NOTE The internal temperatures that are relevant to the design, testing, and operation of a bonded flexible pipe are defined in Table 3.

The temperatures shown in Table 3 and the duration of the incidental temperature shall be specified by the purchaser. The temperatures for storage, transport, and installation conditions shall be specified by the purchaser.

Table 3—Temperature Definitions

Temperature	Definition
Operating temperature	The internal [1] temperature profile experienced by the pipe over its service life during permanent normal operation
Maximum/minimum operating temperature	The maximum and minimum internal temperature to which the pipe is subjected during permanent normal operation
Design temperature	The maximum and minimum internal temperature to which the pipe is subjected during permanent operation
Incidental [2] temperature	The maximum and minimum internal temperature that is unlikely to be exceeded during the life of the pipe
NOTE "Permanent" operating conditions are defined in Table 6.	

1 At the inner surface of the pipe.

2 Incidental temperatures should be specified on the basis of abnormal operating considerations, including unplanned transient events.

Operating and design temperatures should be specified on the basis of the following minimum set of permanent operating considerations:

— gas cooling effects (time/temperature curve);

— fluid thermal characteristics;

— flow characteristics;

— number of extreme temperature cycles (e.g. from the maximum to the minimum operating or design temperature, and return to the specified operating temperature associated with the pressure cycles or otherwise).

4.3.4 Fluid Composition

The purchaser should specify produced fluids (composition of individual phases), injected fluids, and continual and occasional chemical treatments (dosages, exposure times, concentrations, and frequency). This should be specified for all phases including storage, transport, and installation conditions. In the specification of the internal fluid composition, the following should be defined:

— all parameters which define service conditions (for a reference location), including partial pressure (or concentration; include information about location, temperature, and pressure for specified data) of H_2S and CO_2, chloride concentration, organic acids (formic, acetic, propanoic), pH of aqueous phase in situ, titrated acid number (TAN) (in accordance with ASTM D664 or ASTM D974), water content, and ionic composition (produced water, seawater, and free water);

— gases, including oxygen, hydrogen, methane, and nitrogen;

— liquids, including oil composition and alcohols;

— aromatic components;

— corrosive agents, including bacteria, chlorides, organic acids, and sulfur-bearing compounds;

— injected chemical products, including alcohols, and inhibitors for corrosion, hydrate, paraffin, scale, and wax (including concentrations of dissolved oxygen);

— solids, including sand, precipitates, scale, hydrates, wax, and biofilm.

— drilling, completion, or workover fluids (including concentrations of dissolved oxygen).

4.4 External Environment

The purchaser should specify the project's external environmental parameters. The parameters listed in Table 4 should be considered. The design water depth shall be the maximum water depth to which the pipe section may be exposed.

Table 4—External Environment Parameters

Parameter	Comment
Location	Geographical data for the installation location
Water depth	Design water depth, variations over pipe location, and tidal variations
Seawater data	Density, salinity, pH value, and minimum and maximum temperatures
Air temperature	Minimum and maximum during storage, installation, and operation
Soil data	Description, undrained shear strength or angle of internal friction, friction coefficients, seabed scour, soil type description (from soft to hard, sand/clay), thermal conductivity, roughness, grain size, soil stability, liquefaction, and submerged/dry unit soil weight, sand waves, and variations along pipe route
Marine growth	Density and thickness variations with water depth
Ice	Maximum ice accumulation, or drifting icebergs and ice floes
Sunlight exposure	Length of pipe exposed during operation and storage conditions and time of exposure
Current data	As a function of water depth, direction, and return period, and including the known effects of local current phenomena
Wave data	In terms of significant and maximum waves, associated periods, wave spectra, spreading functions, and scatter diagrams, as a function of direction and return period
Wind data	As a function of direction, height above water level, and return period

4.5 System Requirements

4.5.1 Minimum System Requirements

4.5.1.1 General

The purchaser shall specify the system functional requirements of the project. The requirements of 4.5.1.2, 4.5.1.9, and 4.5.1.10 shall be specified by the purchaser. Specification of the other system requirements defined in 4.5.1 should be considered.

NOTE Annex B may be referenced for guidelines.

4.5.1.2 Application Definition

The flexible pipe system shall be specified as one of the following: flowline, riser, jumper, (floating) loading and discharge, or seawater intake hose. The flexible pipe application shall be specified as either static, dynamic, or reeling/unreeling, and the expected number of load cycles and magnitudes should be specified for dynamic cases. The flexible pipe global configuration shall be specified.

4.5.1.3 Corrosion Protection

The corrosion protection requirements for the flexible pipe should be specified considering the following:

— end fitting internal and external corrosion protection and bolting;

— electrical continuity/discontinuity of the hose as part of the cathodic protection consideration protection for storage (on-shore or subsea storage) and installation as applicable;

— compatibility with corrosion protection systems adjacent to the corrosion protection system of the flexible pipe.

4.5.1.4 Thermal Insulation

Performance requirements of the flexible pipe for heat loss or retention shall be specified. OHTCs shall be based on pipe nominal ID and shall differentiate between the pipe itself and any external effects, such as soil cover for buried pipe.

4.5.1.5 Gas Permeation

A gas venting system is required to prevent excessive pressure buildup in the wall of the pipe. Requirements the purchaser has for the gas venting system should be specified, considering the following:

— minimum required quantity of functional vent ports,

— allowable gas permeation rates,

— interface requirements,

— gas-monitoring system.

NOTE The requirements of 4.5.1.5 apply to pipes intended for live crude and gas service only.

4.5.1.6 Pigging and TFL Requirements

Any performance requirements, including ID, bend radius, and end-fitting transitions, for allowing tools for pigging, TFL, workover, or other operations through the flexible pipe, should be specified.

4.5.1.7 Fire Resistance

Fire resistance requirements for the pipe design should be specified, with reference to Lloyds or DNV fire test requirements (see 5.4.6).

4.5.1.8 Piggyback Lines

Any piggyback requirements for the flexible pipe shall be specified, including details of the piggyback pipe(s) and pipe operating conditions.

4.5.1.9 Connectors

The connector requirements for both end fittings in the flexible pipe shall be specified including, as a minimum, connector type, welding specification, seal type, and sizes. The connector shall be designed for the strength and fatigue loads of the application in accordance with a connector standard specified by the purchaser (alternatively, in accordance with 5.3.3).

4.5.1.10 Interface Definitions

Relevant interface details, including but not limited to the following shall be specified by the purchaser:

— regulations, codes, and standards including definition of code breaks;

— geometric, dimensional, and imposed loading data;

— purchaser-supplied installation aids and equipment;

— purchaser-supplied pull-in and connection tools and terminations;

— vessel/platform interface structures such as I-tubes and bellmouths;

— interfacing subsea equipment such as Christmas tree and manifolds;

— manufacturer scope of supply.

4.5.1.11 Inspection and Condition Monitoring

The requirements for the manufacturer to design and implement flexible pipe inspection, monitoring and condition assessment systems and procedures, should be specified by the purchaser or advised by the manufacturer.

4.5.1.12 Installation and Retrieval Requirements

The purchaser should specify performance requirements for installation and retrieval services to be provided, considering the following as a minimum.

— For installation/retrieval by the purchaser, the purchaser shall specify any requirements on load restrictions, clamping/tensioner loads and dimensions, vessel motions, overboarding or wheel requirements, reeling, installation tolerances, and port facility limitations.

— For installation/retrieval by the manufacturer, the purchaser shall specify any requirements for season, environment, location, vessel limitations, installation tolerances, reeling, restrictions due to conflicting activities and installation scope (including trenching, burial, testing, inspection, surveying, and documentation), and number of foreseen installation and retrieval operations.

Requirements for recoverability and reusability of the flexible pipe within its service life shall be specified.

4.5.1.13 Exothermal Chemical Reaction Cleaning

Relevant parameters for the pipe-cleaning operations by means of exothermal chemical reaction shall be specified, considering the following as a minimum:

— flow rate,

— pressure variation,

— maximum heat output,

— chemical composition.

4.5.2 Flowline and Riser Parameters

Requirements for design and analysis of the flowline and riser (or jumper) system additional to the requirements of Section 5 shall be specified by the purchaser to the manufacturer considering the parameters listed in Table 5 as a minimum.

Table 5—Flowline and Riser Parameters

Parameter	Details	Flowline	Riser
Line Routing	— Route drawings, topography, seabed/soil conditions, obstacles, and installed equipment and pipelines.	X	X
Line Configuration	— Specification of any requirements for the configuration, including description (lazy S, steep wave, etc.), layout, and components. — Selection of configuration or confirmation of suitability of specified configuration.		X
Load Cases	— Functional (inclusive of pressure cycling and slugging), environmental, and accidental load cases, and combined yearly probability for permanent operation (normal and extreme), abnormal, temporary (e.g. installation), and survival events.	X	X
Guides and Supports	— Proposed geometry of guides, I-tubes, J-tubes, hangoff, and bellmouths through which flowline and riser is to be installed, and mid-water arches.	X	X
Pipe Attachments	— Bend restrictors, bend stiffeners, clamps, buoyancy modules, and attachment methods.	X	X
Connection Systems	— Descriptions of upper and lower connection systems, including quick disconnection systems and buoy disconnection systems, connection angles, and location tolerances	X	X
Protection Requirements	— Trenching, rock dumping, mattresses, external coatings, and extent of protection requirements over length of pipe. — Design impact loads, including those from trawl boards, dropped objects, and anchors/anchor chains.	X	X
On-bottom Stability	— Allowable displacements.	X	
Upheaval Buckling	— Specification of design cases to be considered by manufacturer.	X	
Crossover Requirements	— Crossing of pipes (flexible and rigid), including already installed pipes and gas lines.	X	X
Interference Requirements	— Specification of possible interference areas. — Definition of allowable interference/clashing.		X
Attached Vessel Data	— Data for attached floating vessels, including but not limited to the following: a) vessel data, dimensions, drafts, heading, etc. b) static offsets; c) first- (response amplitude operators for extreme and fatigue analyses) and second-order motions; d) vessel motion phase data; e) vessel motion reference point; f) mooring system interface data; g) position tolerances.		X

5 Section Design Requirements

5.1 Loads and Load Effects

5.1.1 General

The pipe design is based on the information supplied by the purchaser (see guidelines of Annex B), with reference to the requirements of Section 4.

5.1.2 Definition of Load Classes

NOTE Loads are classified as functional (permanent and variable), environmental (external), or accidental. Typical load combinations and load classes are listed in Table 6 and Table 7, respectively.

Table 6—Load Combinations of Load Classes, Load Conditions

<table>
<tr><th rowspan="4">Load Classes [1]</th><th colspan="6">Load Conditions</th></tr>
<tr><th colspan="3">Operating Conditions</th><th colspan="2">Non-operating Conditions</th><th rowspan="3">Survival</th></tr>
<tr><th colspan="2">Permanent</th><th rowspan="2">Abnormal</th><th colspan="2">Temporary</th></tr>
<tr><th>Normal [2]</th><th>Extreme</th><th>Normal</th><th>Extreme [3]</th></tr>
<tr><td>Permanent functional</td><td colspan="6">Permanent functional load associated with the corresponding load condition.</td></tr>
<tr><td rowspan="2">Variable functional</td><td>Max. and min. operating pressure [4]</td><td>Design pressure</td><td>≤ Max incidental pressure</td><td colspan="3">Purchaser-specified pressure</td></tr>
<tr><td>Max. and min. operating temp.</td><td>Design temp.</td><td>≤ Incidental temp.</td><td colspan="3">Purchaser-specified temperature</td></tr>
<tr><td>Environmental</td><td>Operating plan</td><td>$\geq 10^{-2}$</td><td>$\leq 10^{-2}$</td><td>Seasonal [5]</td><td>Specified by purchaser</td><td>$\geq 10^{-4}$</td></tr>
<tr><td>Accidental</td><td>N/A [6]</td><td>X [7] [8]</td><td>X</td><td>N/A</td><td>X</td><td>X</td></tr>
<tr><td>Combined probability, P_c [10]</td><td>Assoc. [9]</td><td>10^{-2}</td><td>$\leq 10^{-2}$</td><td>Assoc.</td><td>$\geq 10^{-2}$</td><td>$\geq 10^{-4}$</td></tr>
</table>

1 See Table 7 for details.

2 for offloading hoses, the period between offloadings are considered to be normal operation

3 The environment cannot be controlled or the variable functional loads exceed the maximum incidental values.

4 Differential pressure should be considered.

5 Purchaser-specified return period. If not specified assume a three-month return period.

6 N/A—not applicable.

7 For extreme operating condition, the event itself may represent the condition following an accidental event (e.g. with a mooring line failure).

8 “X”—to be considered; see Table 7 for details of typical accidental loads.

9 “Assoc.” implies the functional loads associated with the load condition under consideration.

10 Combined probability of occurrence, Pc, refers to the combination of independent environmental conditions and accidental events only. The occurrence probabilities refer to “yearly probability of occurrence.”

The design load cases shall be defined to analyze, as applicable, the effect on the flexible pipe of functional, environmental, and accidental loads. Reference API 17B for guidelines on the analysis techniques to be used for the loads given in Table 6.

5.1.3 Load Combinations and Conditions

The flexible pipe design shall be shown to meet the design requirements under the load combinations specified in this subsection. All loads, including loads specified in Table 7, which act on the flexible pipe, shall be evaluated. Variation of the loads in time and space, load effects from the flexible pipe system and its supports, as well as environmental and soil conditions, shall be analyzed.

The design load conditions that shall be analyzed are permanent operation (normal and extreme), abnormal temporary, and survival events. Load combinations shall be as defined in Table 6. Load combinations with a yearly probability of occurrence less than 10^{-4} can be ignored. Factory acceptance test (FAT) load combinations shall be defined by the manufacturer based on the FAT procedures. Different load combinations shall be considered for extreme, interference, and fatigue analyses.

Table 7—Typical Load Classes

Functional Loads	
1	Loads due to weight and buoyancy of pipe, contents, and attachments, both temporary and permanent
2	External pressure
3	External soil or rock reaction forces for trenched, buried, or rock-dumped pipes
4	Static reaction and deformation loads from supports and protection structures
5	Temporary installation or recovery loads, including applied tension and crushing loads, impact loads, and guidance-induced loads
6	Residual installation loads, which remain as permanent loads in the pipe structure during service
7	Loads and displacement due to pressure and tension-induced rotation
8	Testing pressures, including installation, commissioning, and maintenance pressures
9	Interaction effects of bundled or clamped pipes
10	Loads due to rigid or flexible pipe crossings, or spans
11	Loads due to positioning tolerances during installation
12	Loads from inspection and maintenance tools
13	Loads from multiphase flow slugging, where applicable
14	Loads from restraint due to packaging (e.g. FAT testing)
15	Internal pressure as specified in 4.3.2
16	Loads from pressure and temperature variations (including oil shrinkage effect)
17	Loads from reeling and handling of offloading hoses
Environmental Loads	
1	Loads caused directly or indirectly (e.g. VIV) by all environmental parameters specified in Table 4
2	Second-order slow drift motions and/or vortex-induced motions of the floating facility or subsurface equipment to which the flexible riser is attached, where applicable
Accidental Loads	
Loads and motions caused directly or indirectly by accidental occurrences involving external loads acting on the pipe, including the following:	
1	Dropped objects
2	Trawl board impact
3	Internal overpressure
4	Compartment damage or unintended flooding of vessel compartment
5	Failure of thrusters
6	Dynamic positioning system failure
7	Anchor line failure
8	Failure of turret drive system
9	Failure of relevant ancillary equipment that is likely to impact on the configuration of the pipe (e.g. buoyancy or ballast module)
10	Internal pressure differential across a hydrate plug, where applicable
11	Interference between flexible pipe and other structures

Design checks shall be carried out for any temporary conditions, which may include testing (FAT, EFAT, OLT, SIT), installation, abandonment, retrieval, handling, and storage, specified by the purchaser or the manufacturer, subject to the design criteria as specified in Table 8.

The occurrence probabilities for each load in each load combination shall be defined in the design premise (see 8.3), e.g. for combined wave and current load case the probabilities of each are to be defined. The probability of specific load classes or subclasses may be specified by the purchaser based on project-specific conditions. The probabilities of accidental and installation-related events should be specified by the purchaser (Tables 6 and 7). If the purchaser does not specify probabilities, the manufacturer shall propose the probabilities that are used for the individual events in the design premise.

The design load cases to be analyzed shall be derived from load combinations in Table 6.

5.1.4 Design Load Effects

Design loads give rise to tension/compression, bending, and torsion, which shall be considered in pipe design.

In the pipe design, the manufacturer shall account for the effects of internal and external pressures. The manufacturer shall specify the water depth at which the design internal pressure is given. This shall also be specified in the pipe markings (see 10.1).

Hydrodynamic load effects shall be determined by validated and documented methods that account for the kinematics of the seawater and the interaction effects of the different environmental phenomena. See API 17B for guidelines on analysis methods.

NOTE For guidance on seawater intake hoses refer to API 17B.

For fatigue analysis, the distribution of loads over the service life of the pipe 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. Mean loads and cycling load ranges (e.g. stresses and strains) shall be calculated to determine the fatigue performance. Mean strains (during FAT and installation and operation) shall be calculated to determine creep damage for nonmetallic reinforcement components.

Any accidental loads or combinations thereof can damage or render unfit for service a flexible pipe. Load cases that include accidental loads (e.g. increased offsets due to anchor-line or thruster failures) and do not violate the requirements of Table 8, define a limit on the safe occurrence of the accidental loads. Some accidental loads (e.g. fire and explosion) might not be easily analyzed in terms of the requirements in Table 8. In such cases, testing shall be used to define safe working times or other limits associated with the accidental load.

Design load cases shall consider seawater or transported fluid ingress into the pipe body and end fitting unless the purchaser and manufacturer agree that this is not applicable.

5.2 Pipe Design Methodology

Initially, and whenever revisions occur, the pipe-design methodology shall be verified by an IVA. The documentation submitted for verification of the design methodology shall include the following as a minimum:

— theoretical basis, including calculation procedures for the pipe design parameters;

— calculation method for all major load-bearing layers and components, for interaction between metallic and elastomer components, and for load sharing and transfer between different layers and components, in particular at and adjacent to the end fitting;

Table 8—Flexible Pipe Layer Design Criteria

Layer	Primary Pipe Failure Mode	Design Criteria	Storage Conditions	Operating Conditions			Non-operating Conditions			Survival
				Permanent		Abnormal	Temporary			
			Storage Bend Radius	Normal	Extreme		Normal		Extreme	
							Installation	Test [1]		
Pipe body	Collapse [2, 3]	Load [4]	N/A	(0.67) for D_{max} <= 300 m $\{[(D_{max} - 300)/600] \times 018 + 0.67\}$ for 300 m $< D_{max} <$ 900 m (0.85) for D_{max} >= 900 m						
Elastomer liner	Rupture	Thinning [5]	N/A	The maximum allowable reduction in wall thickness over the service life below the minimum design value, shall be 30 % under all load combinations.						
		Strain	The maximum allowable strain shall be 50 % of the elongation at break of the aged elastomer material at operating temperatures.							
Reinforcement layers [6]	Overstress	Stress	0.85	0.55	0.85	0.85	0.67	0.91	0.85	0.97 [8]
Hoop wires and rings	Breakage	Stress	0.67	0.55 [7]	0.85	0.85	0.67	0.91	0.85	0.97 [8]
Other elastomer layers	Rupture	Strain	The maximum allowable strain shall be 50 % of the elongation at break of the aged elastomer material at operating temperatures.							

1 FAT, EFAT, and post-installation test included.

2 The collapse resistance shall account for tension and all sources of ovalization, that is, from manufacture, test, installation, and operation (see 5.3.1). Maximum permissible ovalization criteria (under load and in unloaded condition) are to be defined by the manufacturer. Guidance can be found in API 17B. D_{max} denotes the maximum water depth, including tidal and wave effects.

3 For rough bore pipe, the stress can reach the material yield strength in one of the carcass or reinforcement layers, provided that the allowable utilization is not exceeded in the other.

4 The definition of permissible utilization is provided in 5.3.1.

5 Thinning includes erosion, elastic, plastic, and creep-induced reduction in thickness.

6 End-of-service-life creep effect shall be accounted for nonmetallic reinforcement layers.

7 For reeling applications it is allowed to increase the utilization to 0.67.

8 A margin of 3 % accounts for the allowable variation in utilization due to manufacturing tolerances (see 5.2).

— verification of theoretical basis with testing. The verification shall include weight, buoyancy, stiffness, and the capacity of all pipe structural layers. Simplified conservative analysis methods for checking of noncritical layers, such as breaker layers, are acceptable if the method does not influence the reliability of the calculation of loads in the other layers;

— basis for stress concentration factors used for the steel cable materials, including stress concentrations at and within the end-fitting interface, at clamped accessories, and due to contact with rigid surfaces, and manufacturing tolerances;

— manufacturing tolerances, manufacturing-induced stresses or strains, welds, and other effects which influence structural capacity;

— verification of the service life methodology, subject to the requirements of 5.3.4;

— documentation of the methodologies for evaluating combined load cases (as specified in 5.1.3), including such considerations as simultaneous pressure and bending;

— qualification of materials in accordance with Table 11, Table 12, and Table 13 for the pipe, and in accordance with 6.1.5 for the end fitting.

Initially and whenever revisions occur, the pipe design methodology shall be verified by an IVA, reviewing and verifying all aspects specified above. The IVA shall establish the range of applicability for each design methodology. The IVA shall verify that the manufacturing process is controlled such that the design requirements are met within the range of applicability of the design methodology. The IVA shall issue a certificate and a report describing the limits and constraints of the design methodology. The design methodology verification report shall be available for review by the purchaser.

The design methodology shall account for the effects of wear, corrosion, manufacturing processes, dimensional changes, creep, and aging (due to mechanical, chemical, and thermal degradation) in all layers, unless it has been documented that the pipe design does not suffer from such effects.

The utilization levels of Table 8 are based on nominal dimensions and end-of-life conditions. It shall be shown that variations in dimensions within manufacturing tolerances do not change utilization values by more than 3 % above the values specified in Table 8.

For a new pipe design the manufacturer shall perform a sufficient number of prototype tests to verify the design methodology. The prototype tests shall verify correlation with the design methodology and fitness-for-purpose for those design parameters which are outside the previously validated envelope. Qualification testing program and clear acceptance criteria shall be agreed upon between the manufacturer and purchaser. See API 17B for guidelines on the tests which should be performed and recommendations on the test procedures.

If the pipe is designed to be collapsible, then it shall be shown by the testing that the pipe can withstand the required number of collapse cycles specified by purchaser. The specific prototype tests should be agreed upon by the purchaser and manufacturer.

The methodology shall account for load, stress, and strain in the pipe layers and at the end fitting, fatigue of the pipe components, and the potential for voids to be generated in the pipe wall. The methodology shall be based on the results of prototype tests.

5.3 Pipe Structure Design

5.3.1 Design Criteria

The pipe layers shall be designed to the criteria specified in Table 8, subject to the requirements of 5.3.1.

The methodology shall define the diameter and maximum elongation of each layer.

The utilization for the internal carcass/embedded wire or ring shall be calculated as specified in 5.3.2.3, taking account of tension effects, loads from reeling, and the three water-depth ranges defined in Table 8. The manufacturer shall evaluate buckling failure modes in the carcass/embedded wire or ring, and shall confirm by analysis that the layer meets the design requirements. The methodologies for separate and combined tension-induced and hydrostatic collapse calculations of the carcass shall be documented and validated.

The utilization for cables of reinforcing layers shall be calculated as

utilization equals load divided by structural capacity

if load is the calculated load in the actual layer. The load shall be calculated using the design methodology specified in 5.2, subject to the design requirements of 5.3.2. The calculated value shall include dynamic loads and be based on average stress in the layer. The average load is to be calculated based on distributing the total layer load uniformly over all wires in the layer. The structural capacity shall be either the yield strength of the solid wire or stranded cable material sample, or 0.9 ×the ultimate tensile strength of the solid wire or stranded cable material sample, where tensile testing will accurately identify only the ultimate tensile strength. 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.

The storage MBR shall be calculated as the minimum bend radius that satisfies the requirement of Table 8 after accounting creep, where applicable. For pipes with interlocking carcass:

a) the bend radius required to cause locking in the interlocked layers shall be calculated, and

b) the storage MBR shall be at least 1.1× the MBR to cause locking.

The operating MBR shall be calculated as the minimum bend radius that satisfies all the requirements of Table 8.

In addition, for pipes with interlocking carcass:

— the operating MBR for static applications (all loading conditions) shall be a minimum of 1.0 times the storage MBR,

— the operating MBR for dynamic applications (all loading conditions) shall be a minimum of 1.65 times the MBR to cause locking.

— the safety factor on the operating MBR may be reduced from 1.65 to 1.375 for abnormal operation and normal operation with accidental loads.

Metallic fatigue life calculations shall be performed in accordance with the requirements of 5.3.4. The predicted fatigue life shall be at least 10× the service life. Corrosion analysis (as specified in 5.3.4) shall show that the material loss from corrosion does not cause utilization factors to exceed the criteria of 5.3 under all load combinations.

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

Creep damage calculation shall be performed on nonmetallic reinforcement components in accordance with the requirements of 5.1.4. The predicted creep life due to FAT, installation, and operation shall be at least 10× the service life.

The manufacturer shall evaluate relevant buckling, e.g. external water pressure. The manufacturer shall confirm by analysis and validate by testing that the layers meet the design requirements. Collapse calculations for the hoop reinforcement can account for the support provided by the other layers. The buckling load utilization shall be calculated as the applied load divided by the resistance. The methodology shall be documented and based on the minimum value obtained using an IVA-validated design methodology, taking into account all sources of ovalization (i.e. from manufacture, test, installation, operation) and loading in pipe's axial and radial directions.

5.3.2 Design Requirements for Pipe Layers

5.3.2.1 Liner

As a minimum, the liner shall be analyzed for the following load cases:

— most critical combination of internal pressure, temperature, operating MBR, and elastomer condition;

— hydrotest pressure at ambient temperature and storage MBR.

The analysis should include relevant cyclic loading effects such as hysteresis, relaxation, shrinkage, loss of plasticizer, and diffusion and absorption of fluids into the elastomer matrix. As a minimum, the following shall be included:

— pressure and temperature from the fluids inside the pipe;

— contact pressure from the carcass;

— strain due to pipe bending, axial elongation and compression, torsion, radial expansion, and compression.

The methodology used for calculating the wall thickness of the liner, its strength and fatigue resistance shall be validated by documented tests and/or field experience, and shall conform to the following minimum requirements.

— The analysis shall account for thinning and wear of the elastomer layer due to bending to the operating MBR (storage MBR for hydrotest), stress concentrations due to thickness variations, effect of deplasticization, swelling, and aging on material properties, manufacturing tolerances, and termination of the layer in the end fitting.

— The analysis shall verify the minimum level of coverage that the liner provides the reinforcing layer to account for the potential for the liner to extrude between the reinforcing layer cables under design loads.

For plastic liners the design requirements of liner materials specified in API 17J shall be met.

5.3.2.2 Cover

The design of the cover shall account for the effect of pipe bending, axial elongation and compression, torque loads, external pressure, installation loads, abrasion, and local loads from ancillary components.

5.3.2.3 Internal Carcass

The design of the internal carcass shall account for the following:

— collapse with minimum specified internal pressure, maximum external pressure, and maximum ovality;

[The external pressure shall be the full external pressure acting on the outside of the cover.]

— crack growth along the carcass strip due to bending-induced stresses in interlocked spirals;

[The carcass design shall be such that crack growth shall not occur.]

— loads induced by thermal expansion and contraction and/or swelling of the liner;

— erosion, erosion/corrosion, and wear;

— corrosion, including stress corrosion cracking;

— radial compression induced by tension in the axial reinforcement layers;

— collapse with maximum gas absorption in the elastomer layer, minimum internal pressure, and maximum ovality at occurring temperature.

5.3.2.4 Reinforcing Layers

The metallic materials of the reinforcing layers shall be designed for the required axial and hoop strength. The design shall account for any requirements for torsional properties and control of gaps between cables.

The complete pipe structure shall be designed such that the torsional balance and compression strength characteristics of the pipe meet the functional requirements.

5.3.2.5 Additional Layers

Thermal insulation layers shall be designed in accordance with the requirements of 5.4.3.

Breaker layers shall be demonstrated not to contribute to delamination of elastomer layers in their immediate vicinity following the test specified in 6.2.3.2 (applicable for live crude and gas service only).

Additional external protection layers, whether elastomer or metallic, shall be designed to prevent external damage or wear occurring in the cover, based on the design conditions specified by the purchaser.

5.3.3 End Fitting

The end fittings shall be designed for reliable termination of all pipe layers, such that leakage, structural deformation, or pull-out of cables or bonded layers, does not occur for the service life of the pipe, taking account of all relevant factors including corrosion, shrinkage, creep, aging, pressure effects, swelling, and temperature. The design methodology for end fittings (including integrated end fittings) shall be documented and shall be verified by documented tests and analyses. The methodology shall account for manufacturing tolerances. The design shall account for support loads from any ancillary components attached to the end fitting. The thickness of weld overlay material may be included as part of the wall thickness in end-fitting analysis. This requires that the overlay weld material strength is documented to be equal to or higher than the specified end-fitting base material strength. The connector requirements for both end fittings in the flexible pipe shall be specified. This shall include, as a minimum, connector type, welding specification, seal type, and sizes. The design shall also account for temporary or permanent hangoff loads into the end fitting, such as J-tube/I-tube hangoff, or hangoff during vertical lay operations, where applicable.

The design of the end fitting shall ensure sealing of both the liner and the cover at the end fitting. The design of the end-fitting sealing mechanism shall ensure that the combined strain induced by the in-service pull-out forces and installation of the end-fitting seal ring does not result in failure of the layer over the service life.

Any difference between the inner diameter of the end-fitting bore and the inner diameter of the flexible pipe shall be clearly documented and conveyed to the purchaser for sizing and design of pigs.

In the design of the end fitting, axial movements of the carcass relative to the end fitting shall be mechanically restrained.

Accounting for all physically possible load combinations, the following design requirements shall apply for the pressure-containing parts of, and components subject to tensile loading in, the end fittings:

$$\sigma_t \leq n \times \sigma_y \tag{1}$$

$$\sigma_e \leq n \times \sigma_y \tag{2}$$

where

σ_t is the tensile hoop stress;

σ_e is the equivalent stress (von Mises or Tresca);

n is the permissible utilization factor, as specified in Table 9.

Accounting for all physically possible load combinations, the design requirements in Equation (3) shall apply for the end-fitting anchoring system:

$$F \leq n \times F_y \tag{3}$$

where

F is the design pulling force resulting from design tension and pressure;

F_y is the anchoring system capacity;

n is the permissible anchoring system load utilization factor as specified in Table 9.

Table 9—End-fitting Permissible Utilization Factors

Component [1]	Failure Mode	Design Criteria	Operating Conditions			Non-operating Conditions			Survival
			Permanent		Abnormal	Temporary			
			Normal	Extreme		Normal		Extreme	
						Installation	Test		
Pressure containing	Overstress	Stress	0.55	0.85	0.85	0.67	0.91	0.85	0.97
Reinforcement layer [2]	Rupture	Stress	0.55	0.85	0.85	0.67	0.91	0.85	0.97 [4]
Hoop wires and rings	Breakage	Stress	0.55 [3]	0.85	0.85	0.67	0.91	0.85	0.97 [4]
Reinforcement layer anchoring system	Pull-out Breakage	Load	0.55	0.85	0.85	0.67	0.91	0.85	0.97

[1] Design procedures shall consider any changes to resistance coming from the mounting process.

[2] End-of-service-life creep effect shall be accounted for nonmetallic reinforcement layers

[3] For reeling applications it is allowed to increase the utilization to 0.67.

[4] A margin of 3 % accounts for the allowable variation in utilization due to manufacturing tolerances (see 5.2).

The manufacturer shall calculate the burst pressure of the pipe body structure and of the end fitting. This calculation is done based on minimum guaranteed material properties. The manufacturer shall state if the end fitting has a lower calculated burst pressure than the pipe body.

The manufacturer shall have a validated methodology for the determination of the anchoring system capacity.

The manufacturer shall calculate the failure tension capacity of the pipe structure and the end-fitting anchoring system capacity. The manufacturer shall state if the anchoring system capacity of the end fitting is lower than the failure tension of the pipe body.

For dynamic applications, fatigue life calculations shall be performed in accordance with the requirements of 5.3.4. The predicted fatigue life of the end fitting shall be at least 10 times the service life.

Selection of end-fitting materials shall be in accordance with the requirements of Section 6.

5.3.4 Service Life Analysis

5.3.4.1 Service Life—Static and Dynamic Applications

The service life analysis of flexible pipes shall document the properties of the pipe materials for the specified service life, in accordance with the requirements of Section 6. The minimum strength for all materials and minimum elongation at break for elastomer materials, during the service life of the pipe, shall be used in the design calculations. Materials shall be demonstrated to meet the design requirements of 5.3.2 over the service life. The analysis shall include as a minimum the following:

— creep, aging, dimensional changes (shrinkage, swelling), and strain to failure in the operating environment;

— wear, corrosion, and erosion of all applicable components;

— steel components in flexible pipes can be sensitive in fatigue to low levels of H_2S, and thus the effect of H_2S shall be evaluated;

— fatigue damage due to operating cycles (start-up/shutdown);

— seawater or transported fluid ingress into the pipe body or end fitting (where applicable).

5.3.4.2 Service Life—Dynamic Applications Only

For dynamic applications, the requirements of 5.3.4.3 shall apply. In addition, a fatigue analysis shall be performed for the cables of the reinforcing layers, hoop wires or rings (where applicable), which shall take account of all mechanical and dynamic effects that can introduce failure modes into the pipe in the dynamic application. As a minimum, the effects of shrinkage, residual wires stress, wear, fatigue, fretting, material degradation, including corrosion shall be considered.

If welds on hoop wire cannot be avoided in the fatigue-critical areas, then these welds shall be validated for the fatigue loads expected at the locations of the welds. Such validation can be achieved by testing of welded formed wire or ring samples to confirm the fatigue performance assumed in the design, or by developing S–N curves for welded hoop wires or rings.

Service life shall consider, subject to the requirements of 5.3.1 and 5.3.3:

— aging of elastomer layers in accordance with the requirements of 6.2.3.4;

— fatigue of elastomer layers, reinforcement layers, hoop wires, and rings, as per 5.3.4.3.

Service life shall be determined as follows, subject to the requirements of 5.3.1:

— in accordance with assessment for static applications under 5.3.4.1;

— assessment of service life for cables of reinforcing layers based on data from 6.2.4.4.

5.3.4.3 Fatigue Analysis

For dynamic applications the analysis of load conditions shall show that the extreme stresses in the cables of the reinforcing layers are below the endurance limit. Otherwise, fatigue damage calculations should be performed. Fatigue damage calculations shall be based on Palmgren-Miner linear damage theory using design S–N curves, which have been validated for the reinforcing materials used, under the applicable service environment that shall include likely corrosive conditions. The fatigue life analysis shall also confirm that the liner and cover maintain integrity under the calculated alternating strains in the applicable service environment. Fatigue life analysis shall also confirm adequate fatigue resistance of the end-fitting body and transition between the end fitting and BFP body (such as integrated bend stiffener, anchoring structure).

For dynamic applications, rubber fatigue shall be considered. The manufacturer should either base the fatigue check on the calculation of rubber strain range and check against manufacturer-established E–N curves, or use an alternative rubber-fatigue design methodology or experience-based methodology, approved by the IVA.

The fatigue life shall be at least 10 times the specified service life.

5.4 System Design Requirements

5.4.1 General

The design of the flexible pipe shall account for all applicable system requirements specified in 4.5, as listed in Table 10, and in accordance with the additional requirements specified in 5.4.2 to 5.4.9. The design shall meet all interface requirements specified by the purchaser or by the manufacturer.

The reverse end cap effect shall be included in the pipe load analysis. Upheaval buckling, upheaval creep, and termination load capacity of trenched, buried, or rock-dumped pipes, shall be checked for pressure and temperature-induced axial elongation and forces. The effect of pipe-bending stiffness variations, due to time, temperature, and pressure on the pipe loads, should be analyzed.

For dynamic riser applications, interference/clashing with other components of the system, including risers, mooring lines, and rigid surfaces such as pontoons, vessels, or platforms, shall be checked in the design.

If applicable, the elastomer/steel friction coefficient for the cover material shall be documented for design of the pipe for installation tensioner compression forces, and for design of devices to be clamped to the pipe.

The lateral and longitudinal elastomer/soil friction coefficients shall be documented for the cover for on-bottom stability design.

5.4.2 Corrosion Protection

5.4.2.1 Galvanic Corrosion

Selection of materials shall consider the effect of galvanic corrosion, where this could increase utilization factors above allowable limits. Where there is the possibility of galvanic corrosion occurring, dissimilar metals shall be isolated from one another with insulation or a coating, or alternatively, a sufficient corrosion allowance may be defined.

Table 10—System-related Pipe Design Requirements

General Requirements	Flowline Requirements	Riser Requirements	Loading and Discharge Hose Requirements
Corrosion protection	Flowline routing	Riser configuration	Hose installation
Thermal insulation	Guides and supports	Connection systems	Hose configuration
Gas venting	Protection requirements	Pipe attachments	Connection systems
Pigging and TFL requirements	On-bottom stability	Vessel data	Guides and supports
Fire resistance	Global buckling	Interference requirements	Vessel data
Piggyback lines	Crossover requirements	Flowrate for seawater intake hoses	Operation procedures
Connectors			Accidental surge pressure
Interface definitions			
Inspection and condition monitoring			Handling
Installation requirements			Reeling
Exothermal chemical reaction cleaning			
Gas absorption and rapid gas decompression (RGD)			
Erosion			
Abrasion and impact protection			
Shipping, storage, and handling			
Pipe attachments			
Expected pressure and temperature variations versus time			
Expected differential pressure versus time			

5.4.2.2 Surface Treatment

All external steel surfaces shall be prepared and coated in accordance with internationally recognized standards for corrosion protection in all environmental conditions specified in Section 4, unless the material is documented to be corrosion-resistant in the specified environment.

5.4.2.3 Corrosion Allowance

Requirements for internal and external corrosion allowances shall be evaluated in accordance with the location, conditions of installation, and the requirements specified in Section 4. The manufacturer shall document this evaluation and its effect on the pipe components.

Corrosion at the end fitting shall not cause damage to the anchoring and sealing systems.

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.

5.4.2.4 Cathodic Protection

Design of cathodic protection systems shall be in accordance with the requirements of 4.5.1.3. If the cathodic protection system is specified to protect the reinforcing layers, the anodes electrically connected to the end fitting shall be sized accordingly, and there shall be electrical continuity between the cables of the reinforcing layers and the end fitting. The voltage drop to the adjacent anodes shall be confirmed to be acceptable. The cathodic protection system design methodology shall be documented. See ISO 15589-2 or DNV RP B401 and DNV RP F103 for guidelines on the design of cathodic protection systems. Cathodic protection systems shall be designed to facilitate any requirements for electrical isolation of offloading and discharge pipes from support structures.

If a component of the flexible pipe system is reliant on the cathodic protection system of an adjacent structure, then the manufacturer shall have documented justification through calculations in the design report that this adjacent cathodic protection system is both compatible with and has sufficient capacity to give protection for the specified service life. Both the maximum and minimum current conditions shall be checked and particular attention shall be paid to hydrogen-induced cracking (HIC) when using high-strength steel.

5.4.3 Thermal Insulation

The materials used for thermal insulation layers shall be selected such that the overall heat transfer coefficient and cooldown times do not degrade below the levels specified in accordance with 4.5.1.4 for the specified service life. The determination of an acceptable cooldown time shall account for the heat transfer characteristics of the end fitting.

Conditions experienced during storage, transportation, handling, installation, and operation shall be analyzed, and where necessary, performance demonstrated by installation simulation tests. The manufacturer shall verify and document that permanent deformation of the insulation layers, due to crushing caused by items including tensioners, reels, sheaves, rollers, self-weight and impact loads, does not change the heat transfer coefficient or cooldown time, as required beyond the specified requirements.

5.4.4 Gas Venting

The gas-venting system shall be designed in accordance with the requirements of 4.5.1.5 and the following:

— safe removal of accumulated fluid components,

— no uncontrolled pressure buildup outside the pipe if the pipe is located within an enclosed space,

— chemical resistance of all parts exposed to the permeated gas.

The design of all layers in the pipe shall allow for permeated gas to be vented.

5.4.5 Pigging and TFL Operations

The flexible pipe shall be designed for the pigging if required by the purchaser, TFL, workover, and other tool requirements specified in 4.5.1.6. The selection of dimensional tolerances, including ovality, shall be in accordance with the specified requirements. See API 17C for guidelines on TFL systems.

The innermost layer (carcass or liner) selected for the pipe design shall be compatible with the specified requirements, and the manufacturer shall have performed documented tests to demonstrate compatibility.

The pipe design should result in a smooth interface between the innermost layer and the end fitting. Any variation, steep or constant, in wall thickness due to corrosion shall not influence pigging operations. End fitting designs shall be such that a variation in wall thickness as a result of corrosion shall not result in damage to the internal carcass or liner during pigging operations.

5.4.6 Fire Resistance

Fire resistance of flexible pipes is measured by testing the time a pipe and/or end fittings can be exposed to fire without loss of pressure. Fire-protective insulation may be applied to flexible pipe bodies and end fittings to slow the degradation due to heat. However, the pipes cannot be rendered fireproof. Flexible pipes exposed to fire shall be considered unfit for further service until detailed examination can demonstrate otherwise.

Fire-resistance requirements specified by the purchaser should consider the following:

- fire temperature, source, and surrounding material;
- need to extinguish or cool the pipe structure;
- fire extinction method;
- time required to extinguish;
- transported medium;
- heated steel in contact with elastomeric material in the flexible pipe;
- pipe abandonment facility and its fire protection capability;
- pipe function;
- flash point of transported medium in the event of a leak;
- depressurization time.

If fire resistance is required in accordance with 4.5.1.7, the pipe shall be tested in accordance with Lloyds or DNV GL IMO Resolution A 753 (18), or API 16C, unless previous testing of the design has been performed and documented.

5.4.7 Routing

Pipe crossing on the seabed shall be acceptable as long as appropriate protection measures are taken. These can include the following:

- separating the pipes with a mattress,
- entrenching one of the pipes,
- demonstrating with calculations that the pipes can withstand the crossing loads and the outer covers can withstand any abrasive damage.

5.4.8 On-bottom Stability

On-bottom stability analysis shall demonstrate that under extreme functional and environmental loading conditions pipe movements do not exceed limits specified by the purchaser. The functional and environmental loading conditions shall account for the following as a minimum:

- internal pressure;
- internal fluid temperature;

— water depth and wave loading if applicable at pipe depth;

— current loading at pipe depth;

— seabed characteristics.

If the purchaser does not establish limits, then the manufacturer shall submit a criterion.

NOTE See DNV RP F109 for guidance on on-bottom stability analysis.

5.4.9 Seawater Intake Hoses

Seawater intake hose systems can be seen as a particular application of bonded risers. The flexible pipe shall be analyzed in accordance with the load cases defined in the design premise. All components of the system shall be designed to ensure that the specified service life requirement is met. The analysis should take account of pipe stability, including internal flow-structure interactions (e.g. changes of natural frequencies as a function of flow rate) as applicable.

6 Materials

6.1 Material Requirements

6.1.1 General

The requirements of 6.1 shall only apply to elastomer materials, including additives, flat metal strips for carcasses, textiles, and fabrics, as used in breaker layers, metallic and nonmetallic reinforcement cables, and finished or semi-finished end-fitting components, as delivered to the pipe manufacturer by suppliers, and subject to manufacturing processes as employed by the manufacturer.

NOTE Section 6 does not cover the use of composite materials for reinforcement and carcass layers.

The manufacturer shall have on file the records of tests demonstrating that the materials selected for a specific application meet the functional requirements specified in Section 4 for the service life for both operation and installation conditions. The documented test records shall conform to the requirements of 6.2. If suitable qualification records do not exist, the manufacturer should conduct testing relevant to the application according to 6.2.

All materials including material for breaker layers and other manufacturing aids used in the flexible pipe construction shall be compatible with permeated gases and liquids at design temperatures. All materials exposed to seawater shall be documented to be compatible with seawater. The manufacturer shall document that all corrosion-protection coatings used in the manufacture of the pipe are compatible with all other structural or pressure-sealing materials in the pipe. In particular water osmosis shall be considered.

6.1.2 Elastomer Materials

6.1.2.1 General

The manufacturer shall utilize documented design standards, based on tests as specified in Table 11, that define the pre-qualified range and combination of exposure conditions for each of the vulcanized elastomers used in the liner, embedding compound, insulation layer, cover, and abrasion layers.

The validity of an elastomer qualification applies only for the specific compound with its constituents. The manufacturer shall have documented procedures for testing and qualifying new suppliers of major constituents to ensure that specific compound properties are maintained within the manufacturer's specifications.

6.1.2.2 Liner

The manufacturer shall document the mechanical, thermal, fluid compatibility, and permeability properties of the material for the liner, as specified in Table 11, for a range of temperatures and pressures that shall include the design values.

Table 11—Property Requirements Tests for Elastomer Materials

Characteristic	Tests[a]	Liner	Embedding Compound[b]	Cover and Abrasion Layer	Insulation Layer[c]
Mechanical/ physical properties	Tensile strength/elongation	X	X	X	X
	Stress relaxation properties	X	—	X	—
	Hardness	X	X	X	—
	Compression set	X	X	X	X
	Hydrostatic pressure resistance	—	—	—	X
	Abrasion resistance[d]	X	—	X	—
	Tearing resistance	X	X	X	—
	Void formation	X	X	X	—
	Adhesion	X	X	X	X
	Density	X	X	X	X
Thermal properties	Coefficient of thermal conductivity	X	X	X	X
	Brittleness (or stiffening at low) temperature	X	X	X	
Permeation characteristics	Fluid permeability	X	X	X	X
	Blistering resistance[e]	X	—	—	—
Compatibility and aging	Fluid compatibility[f]	X	X	X	X
	Aging[g]	X	X	X	—
	Ozone resistance	—	—	X	—
	Swelling	X	—	X	—
	Water absorption	X	—	X	X

NOTE There are no property requirements for manufacturing aid materials.

[a] Test procedures are specified in Table 14
[b] The requirements for the embedding compound shall also cover the elastomer in breaker layers.
[c] The property requirements specified for the insulation layer apply to the use of both elastomers and non-elastomers.
[d] The abrasion resistance test is intended for pipes without an internal carcass, and for cover and abrasion layers.
[e] The requirement for blistering resistance tests applies only to pipes intended for live crude and gas service.
[f] Additional adhesion testing for application specific conditions (e.g. seawater ingress and transported fluid) agreed upon between the manufacturer and the purchaser
[g] Either the brittleness or the low temperature stiffening test shall be performed.

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

If the conveyed fluid contains gas, the elastomer shall be shown, by testing, to not blister or degrade during rapid depressurization from the maximum pressure and temperature conditions. Refer to 6.2.3.2, which specifies a decompression rate etc. The effect of aging and swelling on permeability shall be analyzed. Manufacturer shall specify the criteria to be applied to the elastomer for assessment of serviceability (embrittlement, creep, shrinkage, swelling, plastic deformation, etc.) and quantify its application, using results of testing in accordance with 6.1.2.2.

The RGD testing shall take account of permeation rate and sample size to ensure saturation before the first cycle. It should be shown by diffusion calculations that at least 90 % saturation of the liner material is reached before the first decompression cycle. A holding period to ensure saturation shall be calculated.

Chemicals that affect the elastomer shall be included in the RGD testing of relevant properties according to service conditions. This shall be accomplished by aging the specimens in fluids (see 6.2.3.4) that include the chemicals before performing RGD testing.

6.1.2.3 Breaker Layers

The manufacturer shall document the properties specified in Table 11 for the elastomer material of the breaker layer.

6.1.2.4 Reinforcing Layer

The manufacturer shall document the properties specified in Table 11 for the elastomer material in the reinforcing layer (embedding compound).

6.1.2.5 Cover

The manufacturer shall document the properties specified in Table 11 for the cover material. For debonding acceptance criteria, see 7.8.3.

A documented evaluation shall be performed by the manufacturer, to confirm compatibility of the cover with all permeated fluids, ancillary components and all external environmental conditions specified in 4.4.

6.1.2.6 Insulation Layer

For the insulation layer material, the manufacturer shall document the relevant properties specified in Table 11. The thermal conductivity of the layer shall be documented for the design and operating temperatures and pressures. Degradation of thermal performance over the specified service life, due to pressure, temperature, permeated gas and seawater where applicable, shall be analyzed. Creep in the insulation material shall not result in loss of thermal insulation, such that the overall thermal insulation of the pipe is less than the design requirements.

The manufacturer shall document and verify with tests that the compressive strength of the insulation material is sufficient to withstand all expected compressive loads, within the design requirements of 5.4.3.

ASTM C335 may be used to test the overall heat transfer properties of the insulation layer.

6.1.3 Metallic Materials

6.1.3.1 General

For the specified application, the manufacturer shall, for each of the characteristics listed in Table 12, confirm by testing the suitability of the selected material and weldments, if applicable. Metallic material selection shall consider corrosive attack appropriate to the environment that the layer will be exposed to over the specified service life of the pipe. Materials for sour-service applications shall be tested in accordance with 6.2.4.2. All metallic components designed for, or that can be exposed to, cathodic protection shall be made of materials that are resistant against hydrogen embrittlement in the applicable environment.

6.1.3.2 Carcass

The manufacturer shall document the properties and characteristics specified for the carcass in Table 12. For the specified application, the manufacturer shall evaluate, for each of the listed characteristics, the suitability of the selected carcass material, and shall have available for review by the purchaser documented tests to confirm the suitability of the material for the application, together with the criteria for acceptance.

Table 12—Property Requirements Tests for Metallic Cables and Strip Materials and Weldments

Properties/Characteristics	Parameter	Carcass	Reinforcing Layers
Alloy properties	Chemical composition	X	X
	Microstructure	X	X
Mechanical properties	Yield strength	X	X
	Ultimate strength	X	X
	Elongation	X	X
	Fatigue resistance	—	X
	Erosion resistance	X	—
Material characteristics	SSC and HIC resistance [a]	—	X
	Corrosion resistance	X	X [c]
	Cracking resistance under cathodic protection	—	X
	Chemical resistance	X	X [c]
	Wear resistance [b]	—	X
NOTE Test procedures are specified in Table 14.			

[a] SSC and HIC Resistance tests apply to sour-service pipes only, subject to 5.3.4.2.3.

[b] To be confirmed by inspection of cables in fatigue test pipes. No cable wires shall be worn or broken.

[c] The material is encapsulated in the design embedding compound. Small-scale test shall be performed on the specimen's representative of the hose's construction at the saturation level based on diffusion calculations performed by the manufacturer. Saturation level shall be measured by mass uptake and achieved by convergence. Saturation can be accelerated by elevating temperature.

If the carcass is to be exposed to tools passing through the pipe, including pigs, TFL, and workover equipment, the wear rate from all expected occurrences shall be calculated or experimentally determined. Additional sacrificial material shall be included in pipes that are expected to experience high wear or abrasion rates. The amount of additional material shall be determined by analysis using wear-rate data and expected occurrence rates.

The material selection for the carcass shall account for the installation conditions, in particular if the pipe is to be temporarily filled with seawater.

6.1.3.3 Reinforcing Layer

The manufacturer shall document the properties and characteristics specified for the cables of the reinforcing layers in Table 12 and Table 13, subject to the requirements of 6.1.3.3.

For the specified application, the manufacturer shall document the sensitivity to corrosion (uniform and pitting) or cracking (SSC, HIC, and fretting) of the rubberized carbon-steel materials selected for the pressure and tensile cables, and shall have documented test records that confirm the suitability of the material for the particular application.

6.1.4 Nonmetallic Reinforcement Materials

For the specified application, the manufacturer shall, for each of the characteristics listed in Table 13, confirm by testing the suitability of the selected material. Nonmetallic material selection shall consider degradation appropriate to the environment that the layer will be exposed to over the specified service life of the pipe. Materials for sour-service applications shall be tested for aging in a representative environment followed by the mechanical/physical tests defined by Table 13.

Table 13—Property Requirements Tests for Nonmetallic Reinforcement Materials

Characteristic	Tests
Mechanical/ physical properties	Tensile strength/elongation
	Creep characterization and time to rupture
	Adhesion
	Fatigue
Thermal properties	Coefficient of thermal conductivity
	Brittleness (or glass transition) temperature
Compatibility and aging [a]	Fluid compatibility [b]
	Aging
	Water absorption [b]

[a] The material is encapsulated in the design embedding compound.

[b] Test shall be performed at the saturation level based on diffusion calculations performed by the manufacturer. Saturation level shall be measured by mass uptake and achieved by convergence. Saturation can be accelerated by elevating temperature.

6.1.5 End Fitting

6.1.5.1 Metallic Materials

End-fitting metallic components for primary pressure-containing parts shall be wrought or forged in accordance with the requirements of ASTM A668, ASTM A29, ASTM A182 Grade F51 (duplex steel), ASTM 694, ASTM A105, API 5L pipe, ASTM A516, ASTM A537, EN 10083, EN 10028, and EN 10025 plates, or the requirements for connectors specified in API 6A.

For sour service applications, metallic materials shall conform to the requirements of NACE MR0175.

NOTE For the purposes of this provision, ISO 15156 is equivalent to NACE MR0175

The manufacturer shall document the chemical composition, manufacturing method, heat treatment, and the tensile, hardness, and Charpy-impact properties for the metallic materials in all primary end-fitting components. The chemical composition should be selected to ensure that the components meet the property requirements for the specified service after all manufacturing processes, including welding and weld heat treatments.

The end fitting shall be resistant to corrosion, either by way of material selection or by means of the combination of a suitable coating and cathodic protection. The material for the end-fitting internal surfaces shall be resistant to erosion due to solids entrained in the conveyed fluid.

For applications requiring weld overlay, all surfaces exposed to the conveyed fluid shall be documented by tests to be corrosion resistant.

6.1.5.2 Epoxy Material

If epoxy is used, the epoxy filler material used to embed the cables of the reinforcing layers shall be documented to withstand the temperatures experienced by the end fitting, during manufacture and service, for the specified service life. Consideration shall be given to the maximum temperatures that the end fitting experiences in enclosed spaces, such as underneath fire insulation and bend stiffeners.

The manufacturer shall document the compressive strength or shear strength of the epoxy at a temperature between 20 °C and 25 °C (68 °F and 77 °F), and at design minimum and maximum temperatures. Glass-transition temperature, fluid compatibility for predicted environment due to permeation, and aging characteristics of the epoxy shall be documented. The epoxy used in testing shall be mixed and cured according to the supplier's specifications.

6.2 Testing Requirements

6.2.1 General

6.2.1.1 Test Requirements

The physical, mechanical, chemical, and performance characteristics of all materials in the flexible pipe, as specified in Table 11, Table 12, and Table 13, shall be verified by the manufacturer through a documented test program. The program shall confirm the adequacy of each material based on test results and analysis that shall demonstrate the suitability of the material for the specified service life of the flexible pipe. Test procedures listed in Table 14, Table 15, and Table 16 shall be used to determine the properties specified in Table 11, Table 12, and Table 13. If the test method is not specified in Section 6, guidance may be obtained from API 17A or the manufacturer may use their own methods, subject to the requirements of 6.2.1.4.

The qualification of materials by testing shall consider all processes (and their variation) adopted to produce the pipe, which can impair the properties and characteristics required by the design. For any product purchased, documented test results shall be available showing acceptable performance in conditions equal to or more severe than those specified by the purchaser.

If qualification tests cannot be carried out on processed materials, the manufacturer shall justify in the documented qualification program why the selected material provides equivalent characterization as the processed material. Use of non-processed materials shall be subject to IVA or purchaser approval.

6.2.1.2 Test Data

Test data shall be kept on file for 20 years after delivery to the purchaser, or the service life, whichever is greater.

6.2.1.3 Applicability

Only primary component materials with identical specified chemistry and material manufacturing process (e.g. heat treatment and cold forming, etc.), and from the same supplier as used in the qualification testing or from a supplier who has satisfied the quality assurance requirements of 6.3, shall be regarded as qualified.

NOTE Documented operational experience may be accepted as verification of long-term properties in environments which are equal to or less severe than the documented experience.

The severity of the environment for metallic components shall be determined by temperatures, stresses, contact pressures, corrosive environments, pH, chloride content, injected chemicals, concentrations of H_2S and CO_2, and other conditions deemed by the manufacturer or purchaser to be detrimental. The environmental factors considered for elastomers shall include temperatures, strains, pressures, concentrations of water, aromatics, alcohols, H_2S and CO_2, UV exposure, ozone exposure, acidic conditions (lower pH or higher TAN), and other conditions deemed by the manufacturer or purchaser to be detrimental.

6.2.1.4 Test Methods

The test methods shall be as specified in 6.2. Where test methods are not specified, the manufacturer may use their own methods/criteria or alternative methods developed by the raw material supplier. In such cases, the methods and/or criteria shall be documented and the results correlated with the specific material applications. Where test methods are specified but alternative methods are preferred to be followed, the manufacturer shall justify in the documented qualification program why the alternative methods used provide equivalent or better characterization than the specified test methods. Nonstandard test methods shall be verified by an IVA or approved by the purchaser.

6.2.2 Elastomer Materials

Samples used for qualification testing shall be taken from vulcanized material. Tests shall be performed to determine the properties of unaged material and aged material in certain tests covered by this specification as per section 6.1.2.6 and 6.2.3.4.

In the qualification program, the manufacturer shall test and document the properties specified in Table 11 for the elastomer layers and insulation layer materials. The test procedures specified in Table 14 should be used. If no specification test procedure is available, the manufacturer shall document the test procedure.

If PVC is used as the insulation material, a heat stability test shall be performed at or above the maximum design temperature for a period of at least 30 days.

6.2.3 Elastomer Test Procedures

6.2.3.1 Fluid Permeability

For fluid permeability tests the following conditions shall apply, as a minimum.

- **Sample:** Sample shall be taken from a vulcanized elastomer layer.
- **Temperature:** Perform sufficient tests to allow for linear interpolation.
- **Pressure:** As with temperature.

The test shall be performed as per ISO 6179 and/or ISO 2782.

The procedure for the fluid permeability test may be to pressurize one side of the specimen and measure fluid flow at the other side when steady-state flow conditions are reached. Alternatively, the test may be performed with the same absolute pressure on both sides using the partial pressure as the driving force.

The fluid permeability test shall also measure the diffusivity and solubility parameters of the elastomer.

6.2.3.2 Blistering Resistance

The requirements of 6.2.3.2 apply to pipes intended for live crude and gas service only.

A full-scale prototype test shall be carried out to verify the integrity of the pipe with respect to blistering resistance. See to API 17B for guidelines on test procedures.

As an alternative, small-scale blistering resistance tests which reflect the design requirements, relating in particular to fluid conditions, pressure, temperature, number of decompressions and decompression rate may be performed. The IVA shall confirm the suitability of the small-scale blistering samples in the design methodology report. A minimum of five samples shall be tested. As a minimum, the following conditions shall apply.

Table 14—Test Procedures for Elastomer Materials

Characteristic	Tests	Test Procedure [a] ISO or Section Number [b]	Test Procedure [a] ASTM [b]	Comments
Mechanical/ physical properties	Tensile strength/elongation	ISO 37	ASTM D412	ISO 37 Type 1 or ASTM D412 Die C specimen types shall be used.
	Stress relaxation properties	—	ASTM E328	Swaged end fitting only. Strain controlled method shall be used.
	Hardness	ISO 7619-1 or ISO 48	ASTM D2240	
	Compression set	ISO 815-1	ASTM D395	Swaged end fittings only. ISO 815-1 TYPE A or ASTM D395 TYPE 1 test piece shall be used.
	Hydrostatic pressure resistance	ISO 1856-C or ISO 3386-1	—	Insulation or floatation material only.
	Fatigue resistance		ASTM D4482	Manufacturer’s validated methodology can be used instead of ASTM D4482.
	Abrasion resistance	ISO 4649	—	Not required for liner material used with an internal steel stripwound carcass. Testing method should be defined by the manufacturer.
	Tearing resistance	ISO 34-1	ASTM D624	or ISO 34-2. ISO 34-1 Method A = ASTM D624 4.2.4.; ISO 34-1 Method B = ASTM D624 4.2.3.; ISO 34-1 Method C = ASTM D624 4.2.2. Type B; Testing method should be defined by the manufacturer.
	Void formation	6.2.3.5	—	—
	Adhesion – between elastomer layers	ISO 36	ASTM D413	
	Adhesion – between cables and elastomers	ISO 4647/ ISO 36	ASTM D4776 / ASTM D413	Modified for wire.
	Density	ISO 2781	—	—
Thermal properties	Coefficient of thermal conductivity	—	ASTM C177	—
	Brittleness temperature	ISO 812	ASTM D746	—
	Low-temperature stiffening test	ISO 1432	ASTM D1053	To test low temperature behavior with the Gehman or DSC test.
Permeation characteristics	Fluid permeability	6.2.3.1 ISO 6179 and/or ISO 2782		As a minimum to CH_4, CO_2, H_2S, and methanol, where present, at design temperature and pressure.
	Blistering resistance	6.2.3.2		At design conditions; gas service pipes only.
Compatibility and aging	Fluid compatibility [c,d]	6.2.3.3		—
	Aging [d]	6.2.3.4		For guidelines refer to ISO 188 for aging in air, ISO 1817 for aging in fluids.
	Ozone resistance	ISO 1431-1		Minimum test requirements: 50 pphm ozone conc., 40 +/-2 °C, 20 % strain, 72 h test period
	Swelling	ISO 1817		—
	Water absorption [c, e]	ISO 62	ASTM D570	

NOTE The test requirements are specified in Table 11.

a The test procedures apply to elastomer layer materials and insulation layer materials, both elastomer and non-elastomer.

b For the purposes of the requirements for the listed test, the ASTM reference(s) listed is/are equivalent to the associated ISO Specification, where one is given. Example: For the purposes of the procedure for the low temperature stiffening test, ASTM D1053 is the equivalent of ISO 1432.

c Test shall be performed at the saturation level based on diffusion calculations performed by the manufacturer. Saturation level shall be measured by mass uptake and achieved by convergence. Saturation can be accelerated by elevating temperature.

d Add adhesion testing for application specific conditions (e.g. seawater ingress and transported fluid) agreed upon between the manufacturer and the purchaser. Adhesion tests to be performed according to ASTM D413.

e Test specimen size can differ as per manufacturer's specifications.

— **Fluid mixture:** Gas components of specified environment as documented in test procedure with a minimum of 5 % CO_2.

— **Soak time:** Sufficient to ensure saturation. First saturation cycle to be a minimum of 72 h depending on the sample dimensions. It should be shown by diffusion calculations that at least 90 % saturation of the liner material is reached before the first decompression cycle.

— **Test cycles:** If available, use expected number of decompressions or else use 20 cycles as a minimum.

— **Decompression rate:** If available, use expected decompression rate or else use minimum 7 MPa (70 bar) per minute.

— **Thickness:** Liner wall thickness, as a minimum.

— **Temperature:** Expected decompression temperature.

— **Pressure:** Design pressure, as a minimum.

— **Procedure:** After tenth and twentieth depressurization cycles, the sample shall be examined at a magnification of 20× for signs of blistering, swelling, cracks, and slitting.

The acceptance criteria shall be that no blister formation, slitting, or leakage path is observed. If slitting is observed, the cause shall be determined and shown not to be detrimental to pipe performance. Voids smaller than what can be observed at 1× magnification are acceptable, as long as the voids are not increasing in size between decompressions.

6.2.3.3 Fluid Compatibility

The manufacturer shall evaluate all constituent components of the environment to which the elastomer is exposed, and perform tests on those components that are considered to possibly have adverse effects on the elastomer. The criteria for acceptance shall be verified by an IVA.

Fluid compatibility tests shall be performed in accordance with the manufacturer's or material supplier's documented procedures. Laboratory tests with vulcanized samples may be used to determine gross incompatibility. Tests shall be based on the design temperature, pressure, and strain. As a minimum, tensile strength, elongation at break, visual appearance, swelling, weight, and volume change shall be measured/evaluated in the test.

For sour service applications, the effects of H_2S at the design pressure and temperature shall be evaluated. Additional curing of the elastomers by the H_2S or other fluid components over the service life of the pipe shall be evaluated based on small-scale material tests. The aged material shall be shown to meet the specified design requirements at the end of the service life.

The effect on the elastomer of sulfur liberated by H_2S and reacting with steel components shall be evaluated in the test program.

6.2.3.4 Aging

The manufacturer shall have verified aging models for each elastomer in the flexible pipe, where applicable. The models shall be based on laboratory testing of new and aged materials and field experience, and shall predict the aging or deterioration of the elastomer under the influence of relevant environmental and load conditions. The aging models may include accumulated damage concepts based on blocks of time or operational cycles of temperature/pressure under different exposure conditions. Aging may be determined by either change in specified mechanical properties or in specified physicochemical characteristics, which includes reduction in the plasticizer content of the material and uptake of constituents from the fluid environment.

The fluid used in aging resistance tests should be representative of the specified internal fluid. Materials that are tensile- or compressive-loaded in service should be tested with similar stresses induced.

6.2.3.5 Void Formation

The manufacturer shall document the evaluation of void formation due to gas permeation and due to the gases generated by the curing process and any gases entrapped by the calenderizing or winding processes.

The acceptance criteria shall be that no visible voids shall form.

6.2.4 Metallic Reinforcement Materials

6.2.4.1 Test Requirements

At a minimum, the qualification test requirements for carcass and reinforcing layer materials shall include the tests specified in Table 15.

Table 15—Test Procedures for Metallic Materials (Carcass Strip, Reinforcement Cables) and Weldments

Tests	Test Procedure	Comments
Chemical composition	ASTM A751	or ISO 16120-1
Yield strength/elongation	ISO 6892 [b]	—
Ultimate strength/elongation	ISO 6892 [b]	—
SSC and HIC [a]	6.2.4.2	To specified environments; reinforcement armor only
Erosion resistance	6.2.4.3	Carcass only
Fatigue resistance	6.2.4.4	Reinforcement armor in dynamic applications only
Chemical resistance		To specified environments
NOTE The test requirements are specified in Table 12		
[a] SSC and HIC resistance tests apply to sour-service pipes only, in accordance with 5.3.4.1. [b] For the purposes of this provision, ASTM A370 is equivalent to ISO 6892.		

6.2.4.2 SSC and HIC testing

For sour service static applications, the threshold limits of the rubberized steel cables in respect to HIC and SSC shall be determined as specified by 6.2.4.2.a and 6.2.4.2.b, according to the manufacturer's documented criteria.

a) To determine the resistance of the rubberized steel cable material to HIC and SSC, the cables shall be submitted to the NACE TM0177 (SSC) tests at a constant pH between 3.5 and 3.8. The threshold level for the occurrence of SSC shall be determined by loading multiple tensile specimens at increasing stress levels which gives a fail/no fail test result from a tensile load test.

b) The manufacturer shall additionally demonstrate through analysis and testing (duration 720 h) the SSC performance at the actual service condition of the rubberized steel cable material. The actual service condition consists of the equivalent partial pressure of H_2S, CO_2 and CH_4 in the pipe bore, in aqueous solution at ambient temperature, design pressure, and design stress levels. The CH_4 may be replaced with another inert gas.

For dynamic applications, the reinforcing layer metallic materials shall be subjected to the qualification testing specified in 6.2.4.4a, for the specific application. S–N data shall clearly define the endurance limit, if this exists, for the material under the design conditions, and shall be documented, or generated, for the conditions in 6.2.4.4a.

6.2.4.3 Erosion Resistance

The manufacturer shall demonstrate, either with tests or analytical data based on tests, that the innermost layer has sufficient erosion resistance to meet the design requirements for the specified service life. Reference API 17B for recommendations on erosion tests.

6.2.4.4 Fatigue Resistance

For dynamic applications, rubberized steel cables (with embedding compound) shall be subjected to the testing given in 6.2.4.4a and 6.2.4.4b, and evaluation, or equivalent documentation provided. The maximum thickness of the rubber coating on the steel cables shall be not greater than the minimum design thickness of the embedding compound in the pipe construction. Reference API 17B for recommendations on fatigue testing and interpretation. The design S–N curves, used in the fatigue analysis of the reinforcement layers, wires, and rings, shall be based on fatigue test data with a statistically significant lower bound design curve that provides 97.5 % probability of survival. The effects of mean stresses shall be considered. The S–N curves shall be either developed or corrected for these mean stress conditions. S–N data shall be documented, justified, or generated for the following testing environments:

a) exposed to air, at atmospheric pressure, and ambient temperature with wires rubberized, and tested to the manufacturer's specifications;

b) exposed to the predicted environment at the surface of the reinforcement layers, wires, and rings, inclusive of H_2S and CO_2 levels for relevant transported fluids at atmospheric pressure and ambient temperature;

c) consideration should be given to the effects of cathodic protection systems on S–N performance.

NOTE Refer to ASTM E739 (latest revision) for recommendations on the number of samples and statistical analysis to be used to generate S–N data.

6.2.5 Nonmetallic Reinforcement Materials

6.2.5.1 General

As a minimum, the qualification test requirements for nonmetallic reinforcing layer materials shall include the tests specified in Table 16.

Table 16—Test Procedures for Nonmetallic Reinforcement Materials

Tests [a]	Test Procedure	Comments
Tensile properties	ISO 2062	—
Fatigue resistance [b]	6.2.5.1	Dynamic applications only
Adhesion	ISO 4647/ISO 36/ASTM D4776/ASTM D413	
Creep resistance [b]	6.2.5.2	Both static and dynamic applications
Chemical resistance		To specified environments
Thermal shrinkage	ASTM D4974	
Sour service		Test procedure shall be defined by the manufacturer and approved by the purchaser
Water absorption	ISO 62 / ASTM D570	Test specimen size can differ as per manufacturer's specifications

NOTE The test requirements are specified in Table 13.

[a] The tests should be performed to the predicted environment

[b] The tests shall be performed as per the manufacturer's validated methodology. Refer to ASTM E739 (latest revision) for the number of samples and statistical analysis.

6.2.5.2 Fatigue Resistance

For dynamic applications, the fatigue resistance of the reinforcing layer materials shall be established by fatigue (S–N) testing that accounts for mean loads.

6.2.5.3 Creep Resistance

The creep resistance of the reinforcing layer materials shall be determined by establishing time to rupture (stress–time) curves and creep rates.

6.2.6 End Fitting

6.2.6.1 Metallic Materials

The combination of temperature variations (maximum and minimum, design temperatures), pressure variations, and the ability of the end-fitting design to withstand the combined loading, shall be documented. The number of cycles shall be realistic with respect to operational conditions. The test fluid should reflect service conditions (see 4.3.4). The test should be performed according to the methodology specified in API 17B, Annex A or Annex C as applicable.

Test samples used in the qualification of metallic materials for end-fitting components shall be in accordance with 6.2.6.1a and 6.2.6.1b. The qualification program shall test and document the following properties and characteristics of the metallic materials for the primary end-fitting components:

— **chemical composition:** ASTM A751,

— **shear strength:**

— **tensile properties:** ISO 6892.

NOTE 1 For the purpose of this provision, ASTM A370 is equivalent to ISO 6892.

— **Charpy impact:** 6.2.6,

— **hardness:** 6.2.6,

— **SSC and HIC resistance:** 6.2.4.2.

The requirements in 6.2.4.2 apply to pipes intended for sour service only. If duplex stainless steel end fittings are specified, they shall be tested for pitting resistance in accordance with ASTM G48-03, Method A.

a) The mechanical properties of forgings shall be determined from test samples that represent the actual component, including being from the same heat and heat treatment batch, and having the same forging ratio. The location of test samples shall represent the heaviest thickness, and shall be taken in $^1/_4\, t$ position from the outer diameter (OD), where t is the thickness of the component.

b) If end-fitting components of different dimensions are in the same lot, it is sufficient to test the largest dimensions only, provided the strength requirement is the same in all dimensions.

Charpy V-notch impact testing shall be carried out in accordance with ISO 148-1 for carbon or low-alloy steel forgings. Full-sized Charpy V-notch specimens as defined in ISO 148-1 shall be used whenever possible. The notch shall be perpendicular to the surface. The test temperature shall be −20 °C (−4 °F) or the design minimum temperature if lower than −20 °C (−4 °F). Energy values shall be in accordance with the manufacturer's specifications, which shall specify minimum single impact energy values and minimum average of three values, acceptable specimen sizes to be 10 mm × 10 mm (0.4 in. × 0.4 in.), 10 mm × 7.5 mm (0.4 in. × 0.3 in.) and 10 mm × 5 mm (0.4 in. × 0.2 in.).

NOTE 2 For the purpose of this provision, ASTM A370 is equivalent to ISO 6892.

Impact testing is only required for steel materials with thickness above 6 mm (0.24 in.) and minimum design temperature less than 0 °C (32 °F) or, if specified, by the purchaser.

The hardness tests of carbon steel forgings and corrosion-resistant weld overlays shall be performed in accordance with ISO 6506-1, ISO 6508-1 or ASTM E92. The results shall be to the manufacturer's specifications, which shall distinguish between sour and sweet service applications. For sour service, hardness values shall be in accordance with NACE MR0175.

NOTE 3 For the purpose of this provision, ASTM E10 is equivalent to ISO 6506-1.

NOTE 4 For the purpose of this provision, ASTM E18 is equivalent to ISO 6508-1.

NOTE 5 For the purpose of this provision, ISO 15156 is equivalent to NACE MR0175.

6.2.6.2 Epoxy Material

Epoxy samples for testing shall be molded and cured under the same temperature and humidity conditions as when filling the end fitting. The qualification test requirements for the cured epoxy shall be as follows:

— **compressive strength:** ASTM D695,

— **shear strength:** API 17B,

— **glass transition temperature:** ASTM E1356,

— **fluid compatibility for the predicted environment due to permeation:** 6.2.3.3,

— **aging test:** 6.2.3.4,

— **degree of cure:** DSC to ASTM D5028.

6.3 Quality Assurance Requirements

6.3.1 General

All base materials used in flexible pipe 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, base metallic materials shall be certified to ISO 10474 3.1 (EN 10204 3.1). Base materials shall be tested in accordance with the requirements of Table 17 of this specification. 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 supplier shall be available for review by the purchaser.

For the liner, elastomers shall be 100 % virgin material containing no regrind or other previously processed materials.

Table 17—Minimum Quality Control Test Requirements—Raw Material

Material	Test	Frequency	Comments
Elastomers [a]	Composition	One per batch	Purity or weight percent of all additives
Metallic cables and strips	Chemical composition	One per batch	All metals
	Tensile test	One per coil [b]	All cables
	Dimensions	Two per coil	All cables; Start and end of coil; ASTM A480 procedures
Nonmetallic reinforcement	Tensile test	Two per shipment	
	Dimensions	Two per shipment	
	Twist	Two per shipment	If applicable. ISO 2061 procedures.
End fittings	Chemical composition	One per heat [c]	Body material and connector
	Tensile test	Two per heat	Body material and connector
	Charpy V-notch	One set per heat	Body material and connector; subject to 6.2.6.1
	Hardness test	One per heat	Body material and connector; subject to 6.2.6.1
	Radiography	One	Welded neck and welded seams only
	100 % Ultrasonic	Each	Body material and connector
Epoxy	Compression or shear strength	One per end fitting	Refer to 7.7.4, or shear test as specified in 6.2.6.2.

[a] Elastomer in the context of this table refers to the material prior to curing.
[b][a] A coil is an order lot of cable not greater than 3 000 kg (6 614 lb) and from the same forming process and heat treatment batch.
[c][b] "Per heat" refers to heat treatment batch.
[c] Elastomer in the context of this table refers to the material prior to curing.

Requirements and criteria for surface condition of cables, wires, and carcasses shall be established and documented by the manufacturer. As a minimum, the metallic materials shall have a surface finish free from defects that exceeds the acceptance criteria set by the manufacturer and are documented in the manufacturing quality plan or fabrication specification.

6.3.2 Documentation Requirements

The manufacturer's written specifications for compound ingredients and metallic materials shall include, as applicable, the requirements of Table 18. The heat treatment procedure shall include cycle time and temperature with tolerances, heat treatment equipment, and cooling media.

Table 18—Requirements of Material Specifications

Requirements	Metallic Material	Nonmetallic Material	Compound Ingredients
Material composition/chemistry requirements, with tolerances	X	X	X
Generic base elastomer (ASTM D1418)	—	—	X
Physical and mechanical property requirements	X	X	X
Allowable melting and forming practices	X	—	—
Heat treatment procedures	X	—	—
Storage and age control requirements	X	X	X
NDE requirements	X	—	—
Acceptance and/or rejection criteria	X	X	X
Certification and records requirements	X	X	X
Marking, packaging, handling, and traceability requirements	X	X	X
NOTE Some of the requirements might not be applicable to all compound ingredients.			

The specification for end-fitting epoxy material shall include, as a minimum, trademark, grade, and color of resin and hardener, mixing ratio, pot life, molding temperature, and curing temperature and time.

6.3.3 Storage

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

All hydroscopic raw elastomer material shall be suitably packaged and handled to avoid moisture absorption. Damaged packages shall be evaluated to determine if the damage has resulted in contamination of the material. Contaminated material shall be rejected.

6.3.4 Traceability

Raw materials shall be traceable and suitably marked for easy identification. In the case of elastomer materials, the type of elastomer and the supplier's name and designation shall be identified. The marking of primary end-fitting metallic components shall ensure traceability to the base material.

Compound material shall be suitably marked per batch for easy identification. This identification is to be carried through to the finished pipe product so as to ensure traceability of the compound used in the production.

7 Manufacturing Requirements

7.1 Quality Assurance Requirements

7.1.1 General

Manufacturing operations shall be performed in accordance with the manufacturer's written fabrication specifications and manufacturing quality plan, which shall conform to the requirements of Section 7. Processes requiring validation, including curing, welding, heat treatment, and coating, shall be performed in accordance with the requirements of 7.9. The manufacturer shall maintain documentation of the validation qualification of processes that require it, for review by the purchaser or a mutually agreed upon IVA.

Nondestructive examination (NDE) shall be performed in accordance with the requirements of ISO, ASTM, or equivalent standards.

Quality assurance requirements for materials to be used in the pipe manufacture shall be as specified in 6.3.

7.1.2 Process Control

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 pipe. All manufacturing nonconformance reports and actions adopted to correct it shall be available for review by the purchaser and included in the as-built documentation; see 8.7. Process control shall be performed as a minimum for the following manufacturing processes.

- **Carcass:** preparation and winding of flat steel strip, welding of flat steel strip sections, pre-forming, cold forming of carcass, reeling of interlocked carcass.
- **Elastomer layers:** mixing of raw materials, winding of elastomer layers, curing of pipe, and reeling of pipe.
- **Calendering:** cylinder temperatures, cylinder relative speeds, and duration of calendering.
- **Reinforcing layers:** preparation of steel cables, feeding of pipe, and winding of reinforcement.
- **End fittings:** mounting process, preparation, and resin injection, where applicable.

For each manufacturing condition that is outside the qualified manufacturing procedure, qualified engineering personnel shall assess and justify corrective actions and define objective acceptance criteria.

During manufacture, the manufacturer shall take measures to ensure that all measurements are within the manufacturer's tolerances.

7.1.3 Handling During Manufacture

The manufacturer shall have documented procedures for the handling of intermediate and finished products during manufacture, packing, and storage. The procedures ensure that any anomalies resulting from pipe abrasion, mechanical damage, torsion, bending, and crushing, when winding /unwinding pipe on reels and carousels, or during end-fitting assembly and when removing pipe from mandrel, do not exceed manufacturing tolerances.

The condition of all reels, carousels, guides, and rollers, shall be such that they do not induce any damage to the BFP.

The manufacturer shall ensure that contamination of the pipe and end fitting due to foreign material is avoided.

The manufacturer shall use documented procedures for the handling of flat or shaped wire carcass from supplier's shipping reel to the manufacturer's reel, bobbin or mandrel.

7.2 Carcass

7.2.1 General

Carcass profile conformance to the manufacturer's acceptance criteria shall be documented at the start and end of each production. The occurrence of sharp edges in the formed carcass layer shall be prevented.

For carcass layers made up in sections, or when two sections of carcass are joined, for example, in case of repairs, the join-up procedures for the sections shall be validated for all loads expected at the locations of these connections, and documented. The manufacturer shall ensure that the minimum distance between carcass join-up welds shall be specified in the manufacturing quality plan. Carcass join-up welds should be avoided in high-bending regions and dynamic locations (e.g. bend-stiffener region, touchdown area, etc.).

The manufacturer's procedures shall include a plan for inspection and refurbishment of forming tools and rollers.

7.2.2 Inspection and Acceptance Criteria

The axial tension in the carcass shall be such that the adjacent profiles are in their neutral position, at approximately 50 % of their possible movement. The external surface of the as-formed carcass shall be visually examined for flaws, including dents, cracks, scratches, shavings, gouges, wire deformation or lamination, corrosion, lack of interlock, discolored areas (blurring, scorching, staining, etc., except at welds), distorted or buckled strip profile, and significant scoring. Acceptance criteria for flaws shall be documented by the manufacturer. Unacceptable flaws shall include corrosion, wire lamination, cracks, lack of interlock, twist, and excessive slope. Carcass profiles shall be additionally inspected for lack of interlock at the start and completion of each production run. The carcass profile interlocking shall be checked for sufficient freedom of movement to prevent alternating stresses above allowable values. The manufacturer should have acceptance criteria for the allowable freedom of movement.

The outside diameter, full axial travel, slope, and ovality, shall be measured and interlock checked at the start of the production run. Subsequent to this, these parameters shall be controlled (measured or checked) at least every 5 m (16.4 ft) for the first 50 m (164 m) and subsequently at intervals demonstrated by the manufacturer to be acceptable. The manufacturer shall record process data at intervals, agreed upon with the purchaser, throughout the process. All results shall be recorded and shall be to the manufacturer's specifications, which shall conform to the tolerance requirements of 7.10.

For carcass sections that are not manufactured on a mandrel, the internal diameter shall be measured at both ends of the manufactured carcass, and shall be within the tolerances specified in 7.10. For carcass formed over another pipe layer, the outer diameter shall be measured at least every 5 m (16.4 ft) if it is not possible to measure the inner diameter.

7.3 Preparation of Compound and Calendering

7.3.1 General

Preparation of compound materials and calendering shall be performed in accordance with the manufacturer's documented procedures.

7.3.2 Preparation of Compound

During preparation, the following process parameters shall be monitored and recorded, and shall conform to the manufacturer's specifications:

— sequence of mixing,

— rate and duration of mixing,

— timing of addition of curing agent,

— degree of vulcanization after mixing.

7.3.3 Calendering

During calendering, the following process parameters shall be monitored and recorded, and shall conform to the manufacturer's specifications:

— cylinder temperatures,

— cylinder relative speeds,

— velocity of calendering.

7.3.4 Inspection and Acceptance Criteria

A visual examination of the calenderized layer external surface shall be performed to identify flaws, including bubbles/voids, inclusions, discoloring, surface irregularities, notches, and indentations. All flaws shall be in accordance with the manufacturer-specified acceptance criteria.

7.3.5 Test Requirements

Minimum test and inspection requirements shall be as specified in Table 19 and all results shall be in accordance with the manufacturer's specifications and procedures, and recorded on material test certificates.

Table 19—Minimum Material Quality Control Test Requirements—Compound

Material	Test	Frequency	Comments
—	Composition	One per mixer load	Measure weight of all additives to be placed in the mixer
Compound	Density/specific weight	One per mixer load	ISO 2781
—	Rheology and degree of cure	One per mixer load	ISO 6502 [a]
—	Hardness	One per ten mixer loads or less	ISO 7619-1 or ISO 48
—	Tensile test	One per ten mixer loads or less	ISO 37 [b]

NOTE If metal bonding promoters are included in the compound, one hardness test, one tensile test, and one elongation at break test for each mixer load may be substituted for the rheology test.

[a] For the purpose of this provision, ISO 6502 is equivalent to ASTM D2084 and ASTM D5289.

[b] For the purpose of this provision, ISO 37 is equivalent to ASTM D412.

7.4 Elastomer Winding

7.4.1 General

Winding of elastomer materials shall be performed in accordance with the manufacturer's documented procedures. The procedures shall include requirements for the condition of the elastomer sheet prior to winding, and for the condition of the finished layer, such that the layer and underlying or overlying layers meet the manufacturer's specifications.

The manufacturer should ensure that all windings are onto a clean and dry underlying layer.

During winding, the following process parameters shall be monitored and recorded, and shall conform to the manufacturer's specifications and procedures:

— feed rate of the winding appliance,

— rate of travel.

7.4.2 Inspection and Acceptance Criteria

7.4.2.1 Visual Examination

The manufacturer's specifications and procedures shall document acceptance criteria for flaws as a function of category (individual or cluster), size, position in material thickness, distance between flaws, and number. A visual examination of the elastomer layer external surface shall be performed to identify flaws, including bubbles, inclusions, discoloring, surface irregularities, tool scratches, notches, and indentations. All flaws shall be in accordance with the manufacturer-specified acceptance criteria.

The maximum dimensions of each flaw or combination of flaws shall be such that the total remaining thickness of the layer, after curing, shall be at least equal to the minimum design thickness.

7.4.2.2 Dimensional Measurements

Diameter measurements of the wound layers shall be recorded at least every 5 m (16.4 ft) for the first 50 m (164 ft). Subsequent to this, the diameter shall be measured and recorded at intervals verified by the manufacturer to be acceptable.

7.5 Reinforcement Armor Layer

7.5.1 General

The manufacturer shall have documented procedures for the winding of the reinforcing layers onto the pipe, which shall ensure that the cables are laid to the design requirements. The procedures shall include requirements for the condition of the cables prior to winding and for the condition of the finished layer, such that the layer and underlying or overlying layers meet the manufacturer's specifications.

The procedures shall specify all parameters and allowable tolerances, which are to be monitored and recorded at intervals verified by the manufacturer to be acceptable. The recorded values shall conform to the manufacturer's specifications. As a minimum, diameter, pitch (or lay angle), and density of the cables over the pipe surface shall be measured.

No welding or joining of reinforcement armor cables shall be allowed. Overlapping of reinforcing cables shall be allowed provided the manufacturer has documented evidence to support the effectiveness of such a procedure, including minimum permissible overlap length.

7.5.2 Inspection and Acceptance Criteria

The outside diameter shall be measured and recorded at least every 5 m (16.4 ft) for the first 50 m (164 ft) and subsequently at intervals verified by the manufacturer to be acceptable. The results shall be within the tolerances specified in 7.10.

7.6 Insulation Layers

7.6.1 General

The manufacturer shall ensure that insulation layers are applied in accordance with documented procedures. The procedures shall document acceptance criteria for workmanship and defects.

7.6.2 Inspection and Acceptance Criteria

The external surface of the insulation layers shall be visually examined over the entire length for flaws, including damage, distortion, and folds. Identified flaws shall conform to the manufacturer's specifications.

The outside diameter shall be measured and recorded at least every 5 m (16.4 ft) for the first 50 m (164 ft) and subsequently at intervals verified by the manufacturer to be acceptable. The results shall be within the tolerances specified in 7.10.

7.7 End Fitting

7.7.1 General

All operations in the manufacture, machining, assembly, and inspection of end fittings shall be performed in accordance with the manufacturer's specifications and procedures, which shall meet the requirements of 7.7.

7.7.2 Assembly

Before mounting the end fitting on to the pipe, all exposed surfaces shall be cleaned, dried, and visually inspected, and confirmed to be in accordance with the requirements of the manufacturer's specifications and procedures.

Control features shall be established and documented to ensure that overheating of epoxy or elastomer layers is prevented during welding operations.

Prior to mixing the epoxy resin, all equipment required for the filling operation shall be checked for proper functioning. The mixing and curing of epoxy resin shall be in accordance with the supplier's specifications. Filling shall be carried out in such a way that unacceptable voids do not occur. Any resin cure process that requires the heating of the end fitting shall be carried out with proper temperature control.

7.7.3 Inspection and Acceptance Criteria

For the end-fitting assembly, hold points shall be included where visual examination, dimensional control and component identification are performed. Results from all inspections shall be documented.

For components requiring a specific tightening force or torque, including swaging machines, it shall be verified using suitable and calibrated equipment that the specified value has been obtained.

The manufacturer shall use a validated and documented procedure to verify that sufficient epoxy resin has been injected into the end fitting such that no voids are left in the end fitting which would affect its functional performance. Control of resin injection shall include, as a minimum, resin composition, mixing process, injection duration, and curing time. The volume injected shall be checked.

7.7.4 Test Requirements

Minimum test and inspection requirements for primary end-fitting components shall be as follows and all results shall be in accordance with the manufacturer's specifications and procedures:

— **all surfaces:** 100 % visual examination,

— **carbon and low alloy steel surfaces:** 100 % magnetic particle or liquid-penetrant inspection when geometry prevents magnetic particle inspection (MPI),

— **weld overlay surfaces:** 100 % liquid penetrant, thickness (can be achieved by measuring the dimensions before and after weld overlay),

— **end-fitting bodies:** 100 % ultrasonic test,

— **circumferential butt welds:** 100 % radiographic test,

— **longitudinal seam weld inspection:** 100 % radiographic test,

— **coating:**

  — paint and epoxies—thickness (and adhesion during qualification);

  — electrochemical deposition coatings—chemical composition, metallography of the interaction between base material and coating, liquid penetrant.

On completion of epoxy resin injection, a minimum of three samples shall be taken from the same mix as used for the end fitting. Results from compression strength tests shall be carried out in accordance with ASTM D695 procedures, or for shear strength tests, per ASTM D3410. The compression strength shall be within the range specified by the manufacturer for the cured epoxy. See API 17B for guidelines on epoxy shear strength test.

7.7.5 Connectors

All end-fitting connectors and components shall conform to API 6A, API 17D, other recognized industry standards, or as specified by the purchaser, and shall meet the requirements specified in 4.5.1.9. If the end-fitting connectors or components are not in accordance with a recognized industry standard, then equipment-specific requirements in the Other End Connections section of API 6A shall apply.

7.8 Curing Process

7.8.1 General

All operations in the curing process shall be performed in accordance with the manufacturer's documented procedures (see 7.9.4).

7.8.2 Handling

The manufacturer shall have documented procedures for handling the pipe during construction.

The manufacturer shall use documented procedures for removing the pipe from mandrels after curing.

7.8.3 Inspection and Acceptance Criteria

7.8.3.1 Visual Inspection

Visually inspect in accordance with the manufacturer’s workmanship procedures and standards.

7.8.3.2 Dimensional Measurements

Diameter measurements of the vulcanized pipe shall be recorded at least every 5 m (16.4 ft). Measurements shall be taken after the cooling process. Measured results shall be within the manufacturer's specified requirements.

7.8.3.3 Test Requirements

The tests shall be performed on samples from materials taken from the first pipe and on samples representative of every tenth pipe thereafter. The tests may be performed on a test piece/coupon that accurately represents the pipe construction (reinforcing layer lay angles may be changed from the actual pipe reinforcing lay angle for convenience of manufacture and testing of the sample) and is subjected to the same curing regime as the pipe. The sample shall be stored at room temperature for a minimum of six hours prior to testing. The following tests shall be performed on the sample in accordance with the procedures specified in Table 14 (tests 7.8.3.3b through 7.8.3.3f should be performed for the material of the pipe liner and cover only):

a) adhesion between elastomer layers and between elastomer and reinforcement cables,

b) hardness of elastomer,

c) tensile strength of elastomer,

d) elongation at break of elastomer,

e) density of material,

f) swelling of material.

All test results shall be recorded and shall conform to the manufacturer's specifications.

The sample shall also be dissected and inspected for voids in accordance with manufacturer's procedures. The acceptance criterion shall be that no visible voids are present.

The adhesion test acceptance criteria are as follows:

— 6 N/mm for adhesion between composite plies or elastomer to elastomer contact faces,

— 4 N/mm for elastomer to elastomer contact faces (for the outer cover),

— 3 N/mm for elastomer to polyurethane contact faces,

— 10 N/mm for elastomer to metal at end fitting or integrated flange area (qualification purposes only).

7.9 Processes Requiring Validation

7.9.1 Welding

7.9.1.1 Qualification

All welding operations shall be performed by qualified welders in accordance with the manufacturer's approved procedures. Welding procedure specifications (WPS), welding procedure qualification records (WPQR), and welder qualifications shall be documented, and shall be available for review by the purchaser. Welding procedure validation shall be witnessed and approved, and records of welder qualification shall be reviewed by an IVA who is qualified to witness and approve the standards and criteria being used. For welding performed with automated processes, or for welds that serve only as manufacturing aids, the IVA of welder qualifications may be substituted by an American Society for Nondestructive Testing-qualified Level II inspector, or equivalent. Welders and welding procedures shall be qualified according to API 1104, ASME Section IX, ISO 13847, BS EN 15607, or the equivalent. Procedures shall include acceptance/rejection criteria.

The manufacturer shall have documented procedures for the storage, handling, and drying of welding consumables.

7.9.1.2 Carcass

Strip welds for carcass join-up shall be subjected to a visual examination. Results from all tests shall be documented and shall be within the manufacturer's specifications and procedures.

Weld metal for carcass join-up shall be ground smooth to prevent damage to adjoining elastomer layers.

Butt welds for joining carcass strips, and carcass join-up welds, shall be subjected to the following inspection requirements:

— **carcass strip:** 100 % visual examination.

— **carcass join-up:** 100 % visual examination and 100 % liquid penetrant inspection.

The 100 % visual examination shall be performed prior to the steel passing through the machine forming tools. The external surface of the weld shall also be examined for cracks after passing through the forming tools. Cracks shall not be allowed.

7.9.1.3 End Fitting

All circumferential butt and overlay welds shall be performed in accordance with validated and documented procedures. Inspection and test requirements shall be as specified in 7.7.4.

7.9.2 Heat Treatment

Reinforcement layers hoop wires and rings, and cold-worked or forged components, which require heat treatment in order to meet specified requirements for strength, formability, or NACE compliance, shall be heat treated in accordance with the manufacturer's specifications. The heat-treatment procedures and charts shall be maintained by the manufacturer or subcontractor for review by the purchaser.

7.9.3 Coating

Coatings applied to end-fitting components to limit corrosion due to internal or external environments shall be applied in accordance with qualified and documented procedures, which shall include acceptance and rejection criteria. Coating examples are painting, galvanizing, and electroless nickel coating.

7.9.4 Pipe Wall Lay-up

All curing process operations shall be performed in accordance with the manufacturer's qualified and documented procedures. As a minimum, the procedures shall specify:

— the applicable compound designations;

— the process equipment to be used;

— the process aids, consumable and/or auxiliary materials allowed;

— the process sequence;

— the allowable range for each required process variables or machine setting (speeds, temperatures, times, pressures, etc.);

— the specific process variable records (parameter and frequency) to be kept;

— acceptance/rejection criteria.

All curing process procedures shall be qualified by testing for each compound used, although a procedure may be qualified for more than one compound. Procedure qualification shall be based on the destructive examination of a qualification sample made using the written procedures, compound, and process equipment being qualified. Qualification samples shall have a minimum inside diameter of 76.2 mm (3 in.) and a minimum length of 0.5 m (1.6 ft) and shall be confirmed by the tests given in 7.8.3.3 to conform to requirements documented by the manufacturer. Qualification may be based on samples produced for other prototype or test purposes, such as burst or dynamic fatigue.

Qualification samples shall conform to all specified requirements. Each qualification sample shall be cut in half lengthwise and the half shells shall be cut radially into three approximately equal lengths. The carcass layer should be removed to expose the elastomer surface beneath it. When the sample pieces are inspected on all surfaces at 1× magnification, there shall be no evidence of lack of cure, lack of fusion between adjacent layers, blistering, voids, inclusions, or other flaws. Damage due to the dissection process should be ignored. Samples of the material shall meet the requirements of 7.8.3.3. Complete records of qualification sample preparation, testing, and findings shall be retained and be available for review by purchasers or their representatives.

7.10 Manufacturing Tolerances

The manufacturer shall document the tolerances to be used for each layer of the flexible pipe. These tolerances shall be verified in the design process to be acceptable, such that the functional requirements of the individual layers and pipe are unaffected by variations within the specified tolerances and utilizations remain in accordance with 5.2. As a minimum, tolerances shall be specified for the following parameters:

— **carcass:** external diameter, ovality, slope and gap;

— **elastomer layers:** vulcanized thickness and external diameter;

— **reinforcing layers:** external diameter and pitch (or lay angle);

— **cured pipe:** external diameter.

The tolerance for the length of the flexible pipe should be as specified by the purchaser.

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

The maximum gap between cables is one cable diameter.

7.11 Repairs

The manufacturer shall have documented validated procedures for performing repairs, and these procedures shall be available for review by the purchaser. The manufacturer shall document by additional tests and/or calculations that the repairs to the flexible pipe do not compromise the structural or long-term requirements of the pipe. The purchaser shall have the option of witnessing all repairs and shall be given appropriate notice of their timing by the manufacturer.

Repair of the liner is not permitted. Unacceptable defects found in this layer shall result in the withdrawal of the pipe.

Minor flaws in the cover layers are permitted. Repairs shall be performed in accordance with validated procedures. The purchaser shall be permitted to inspect all repairs carried out. Minor flaws are defined as slight unevenness, provided that changes in the pipe cover contour are not sharp and not over 3 mm (0.12 in.) deep or high at locations of ridges or indentations for submarine pipes, and 5 mm (0.2 in.) for pipes with integral buoyancy.

Carcass strip weld repairs are permitted prior to forming, provided a validated repair procedure is used and visual inspection confirms the weld repair is acceptable. Inspection requirements for repair welds shall be as specified in 7.9.1.

Procedures for repair of damage to surface protection coatings shall be available for review by the purchaser.

Weld repair shall conform to all the applicable guidelines of API 6A product specification level PSL-2 and PSL-3 unless PSL-4 is specified by the purchaser. No weld repairs are permitted for PSL-4.

8 Documentation

8.1 General

The minimum documentation that the manufacturer shall have available for the purchaser shall be as specified in Section 8. The documentation requirements for materials and manufacturing shall be as specified in the relevant subsections of this specification.

The manufacturer shall have available for the purchaser the following documents and should have them available at the specified times:

— **pipe datasheet:** prior to pipe manufacture,

— **design premise:** prior to pipe design,

— **design load report:** prior to manufacture,

— **design report:** prior to manufacture,

— **manufacturing quality plan:** prior to manufacture,

— **fabrication specification:** prior to manufacture,

— **FAT documents** with supplied pipe,

— **as-built documentation**: after supplied pipe,

— **operation manual:** prior to delivery.

— **qualification/validation test procedures:** prior to test run,

— **qualification/validation test reports:** before commencement of manufacture or before the delivery of (if production tests are required) the pipe.

The purchaser should specify the documentation to be delivered by the manufacturer or made available for review. Detailed information, e.g. carcass strip cross section, lay angle, diameter, thickness, number of cables needed for design and analysis verification purposes, should be provided to the purchaser upon request. The exclusion of any proprietary and confidential information in the delivered documentation shall be agreed upon between the purchaser and manufacturer.

8.2 Pipe Datasheet

Refer to Annex C.

8.3 Design Premise

The design premise shall contain the parameters specified in Table 20. If the manufacturer has made assumptions on any of the parameters in Table 20, then it shall be specified in the design premise that the values are assumed. The design premise shall include all technical requirements and recommendations contained in the purchaser specification.

Table 20—Documentation Requirements for the Design Premise

Parameter	Comments
Internal fluid parameters	All relevant internal fluid parameters, including as a minimum the parameters specified in Table 1.
External environment	All relevant external environment parameters, including as a minimum the parameters specified in Table 4.
System description	All relevant system parameters, including as a minimum the parameters specified in 4.5.
Service life	Including, where relevant, maintenance and replacement programs.
Design load case definition	All potential load cases for the flexible pipe system during manufacture, storage, transport, testing, installation, operation, and retrieval shall be addressed. A matrix showing the load cases to be checked for each component of the flexible pipe system shall be established, and shall conform to the requirements of Section 5.
Design accidental events	All accidental events and combinations of accidental and other loads (functional and environmental) shall be specified. The load cases shall be included in the load case matrix.
Design criteria	Required safety margins and definitions of structural capacity shall be specified for each layer of the pipe and components, and shall conform to the requirements of Section 5.
Analysis parameters	These shall include hydrodynamic coefficients, structural parameters, and seabed parameters; regular/irregular wave approach, extreme value; consideration of currents and relative wave-to-vessel headings for fatigue and interference analyses; and verification of critical analysis assumptions.
Software tools	All software tools intended for use for the identified analysis methodologies, including global pipe configuration tools and local component stress/strain/deflection tools. The verification and validation of each software tool shall be available for purchaser review.

8.4 Design Load Report

The design load report shall include results from analyses of load cases defined in the design premise. Calculated stresses and strains shall be reported for each design load case. The design load report may be incorporated into the design report.

For dynamic applications, this report shall describe the extreme, fatigue, and interference analyses (where applicable), and shall compare the results from those analyses with the relevant acceptance criteria.

8.5 Design Report

The design report shall contain a detailed description, including drawings, of each pipe component. The description shall include a layer-by-layer description of the pipe, materials, including references to material specifications, and properties.

Unless separate material specification documentation is issued, material specification and data shall be included in the design report. Material data shall include yield or tensile strengths and fatigue parameters for dynamic service (S–N curve slopes, intercepts and inflection points), and shall identify fluid components that may adversely affect the material.

Each component shall be documented to have sufficient structural capacity to sustain the design loads and stresses listed in the design load report, with the utilization factors specified in the design premise in accordance with Table 8 as a minimum.

The design report shall define or record the conditions, features, capacities, or properties listed below for the flexible pipes. The design report shall include schematic drawings of the layer-by-layer pipe structure and end fittings. Wherever mentioned, "permissible" means a maximum load to which the pipe can be subjected without any damage or restrictions for future use, including its service life. The cause, origin, and location of the predicted damage or restriction shall be included in the report. The report shall also include:

— diameters (internal and external);

— mass per meter (in air, empty and seawater-filled; and in seawater, empty and seawater-filled);

— internal and maximum differential design pressures;

— design temperatures;

— design water depth;

— MBR (storage and operating);

— axial stiffness (at specified pressure values);

— bending stiffness (at specified tension, pressure, and temperature values);

— torsional stiffness (at specified pressure values);

— adhesion requirement for each layer and any components that are not bonded shall be specified.

The design report shall define the following properties for the flexible pipe, if specified by the purchaser:

— permissible tension (as a function of bend radius and pressure);

— permissible axial compression;

— permissible crushing (radial), pipe empty and full of seawater;

— permissible twist (as a function of relevant parameters, if applicable);

— pressure- and temperature-induced axial and radial expansion or contraction;

— pressure- and temperature-induced twist;

— axial stiffness (in both tension and compression, and as a function of pressure and temperature);

— bending stiffness (as a function of tension, pressure, and temperature);

— torsional stiffness (as a function of twist direction, tension, pressure, and temperature);

— structural damping;

- results of the global, service life, and local analyses for the specified installation and service conditions;
- pipe hydrostatic collapse and buckling resistance for a straight pipe and a BFP at operating bend radius (OBR) at design water depth, considering the effects of the crushing loads from the specified installation methods, equipment, and conditions, where applicable;
- drawings (not including manufacturing drawings), specifications and properties of materials, data used in calculations, accurate dimensions regarding interfaces, and design calculations of end fittings, ancillary components, and accessories (fatigue included for items subjected to relevant dynamic loading);
- restrictions imposed by collapse and buckling resistance, such as:
  - requirement to install empty/full,
  - temporary storage requirements (onshore or on the seabed),
  - allowable linear decompression rate.

The IVA's certificate for the design methodology (see 5.2) shall be included in the design report.

8.6 Manufacturing Quality Plan

The manufacturing quality plan shall specify all quality control procedures, including process control, inspection points, manufacturing tolerances, and test procedures as per Section 7. The manufacturing quality plan may be included in the manufacturer's fabrication specification.

8.7 Fabrication Specification

All processing which converts or affects material properties, including welding and plastic deformation of metals, shall be documented in the manufacturer's specifications and procedures. The specifications and procedures shall include a statement of applicable scope, limits on critical process parameters, inspection and test methods and acceptance/rejection criteria. The manufacturer's specifications and procedures shall be approved by the designated personnel of engineering and manufacturing, shall be controlled documents, and shall be readily available to the process machine operator.

The manufacturer's fabrication specifications shall ensure that the pipe is in accordance with the design.

The manufacturer's fabrication specifications shall document the following as a minimum:

a) layer-by-layer and step-by-step description of the manufacturing procedures, including quality control, welding, heat treatment, type and extent of NDE and acceptance criteria, FAT procedures, fabrication method, and allowable repair procedures, for the complete flexible pipe (i.e. all layers, end fittings, and any other items forming an integral part of the final product);

b) procedures for processes requiring validation;

c) references to specifications and sources of all materials used in the manufacture of the flexible pipe, including the materials used for the manufacture of the layers and materials such as lubricants and corrosion-coating and breaker materials;

d) 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;

e) procedures for dimensional control of the layer termination processes (e.g. cutting of reinforcement layers) and of end-fitting assembly parts;

f) all processing that converts or affects material properties, including curing, welding, and plastic deformation of metal. The specification shall include a statement of applicable scope, limits on critical process parameters, inspection and test methods, and acceptance/rejection criteria.

8.8 As-built Documentation

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

— purchase order reference number;

— equipment descriptions;

— references to design specifications and drawings;

— material certificates for end-fitting, metallic, and nonmetallic reinforcements included in the flexible system;

[For elastomer materials, records of conformance for tests required in 7.3.5 and a summary report of tests required in 7.8.3.3.]

— dimension control measurements, including statistical parameters for continuous processes;

— FAT results;

— all reports of nonconformities identified during manufacture, repairs, and inspections performed after repairing, including the traceability of the affected region and its location with respect to the pipe end fitting or position in the accessory;

— WPSs and PQRs;

— WPQs;

— NDE operator qualifications and NDE test records;

— heat treatment records;

— pipe maximum and minimum OD and length between end fittings;

— drawings of ancillary components and accessories, indicating dimensions, SWL, weight, and summarized assembly instructions (e.g. specified bolt torques);

— drawings of ancillary components and accessories mounted on the flexible pipe prior to delivery, indicating dimensions, SWL, weight, and summarized assembly instructions (e.g. specified bolt torques).

The manufacturer shall keep on file for the service life of the pipe all documentation pertaining to the pipe manufacture, including manufacturing records, certificates, inspection, and factory acceptance test documentation.

8.9 Operation Manual

The operation manual shall be prepared for the system and shall address all maintenance tasks and restrictions, and emergency procedures, as specified by the manufacturer or purchaser. The manual shall include the following as a minimum:

— the pipe datasheets;

— interface requirements including flange details, gaskets, seals;

- field inspection requirements;
- repair procedures or manufacturer contact for repairs;
- handling, storage, winding/unwinding procedures, and limitations;
- gas-venting system description and permeation rate;

Warning—The maximum pipe retrieval rate should be determined to allow accumulated gas to safely escape from the BFP structure.

- allowable decompression/compression rates and possible restrictions in compression/decompression related to the type of structure or service—water, gas, or multiphase;
- restrictions on internal fluid components (including H_2S and CO_2), acids, bromides, amines, and inhibitors;
- pigging and TFL capabilities and relevant restrictions;
- allowable maximum loads and top angle (risers);
- maximum time with seawater or inhibited seawater in pipe and inhibitor requirements;
- maximum allowable axial pressure which can be applied across a hydrate blockage (or alternative) in the pipe when a carcass layer is included in the pipe design;
- reference for as-built documentation;
- procedures should the pipe be damaged in handling;
- procedures should re-use of the pipe be considered;
- reeling/unreeling procedures;
- detailed in-service inspection, monitoring, and maintenance/replacement plan, where relevant.

The operation manual shall include all flexible pipe and flexible pipe system limitations identified by the manufacturer regarding safety, including temperature limits and testing.

If specified by the purchaser, a separate installation manual shall be supplied and this shall document the installation procedures.

If specified by the purchaser, a separate repair manual shall be supplied, and this shall document repair procedures, including those applicable during installation. The procedures shall contain the list of required equipment, materials, qualified personnel, logistics, and facilities.

9 Factory Acceptance Tests (FATs)

9.1 General

The flexible pipe shall be subjected to FATs, including gauge, hydrostatic pressure, electrical continuity and electrical isolation, and vacuum and kerosene tests as applicable, to verify the manufacture of the pipe to the requirements of this specification. The purchaser shall have the option of witnessing all tests and shall be given appropriate notice of their timing by the manufacturer. The vacuum test and kerosene test shall be performed only on request of the purchaser.

The hydrostatic test shall be required for all pipes. The electrical continuity and electrical isolation tests shall be required for pipes that are cathodically protected. The gauge and electrical isolation tests are only applicable to rough bore structures. The vacuum test shall be performed for pipes without an internal carcass of 13 m (42.65 ft) and shorter. The kerosene test is only applicable to pipes of 13 m (42.65 ft) and shorter.

NOTE For test samples, not all FATs specified in Table 21 may be required.

The manufacturer's specifications shall specify the minimum time which shall elapse between the completion of the end-fitting mounting (including epoxy curing) or pipe curing and the start of the acceptance tests. The acceptance test program shall conform to this minimum time.

A report for each acceptance test shall be submitted to the purchaser. Current certification/ calibration certificates for all test equipment shall be included in the test report. All pressure-recording equipment shall be calibrated against a dead-weight tester at least every three months.

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 actions shall be included in the report.

Tests, as applicable (see Table 21), shall be conducted in the sequence listed in Section 9.

Table 21—Factory Acceptance Test

		1	2	3		4	5	6
		Gauge Test (9.2)	**Hydrostatic Pressure Test** (9.3)	**Electrical Isolation Test** (9.4)	**Electrical Continuity** (9.4)	**Kerosene Test** (9.5)	**Vacuum Test** (9.6)	**Tensile Test for SWI Pipe** (9.7)
Without cathodic protection	with carcass	X	X	N/A	N/A	N/A	N/A	N/A
	without carcass	N/A	X	N/A	On purchaser request	On purchaser request, but only max. 13 m (42.65 ft) each end	Max. 13 m (42.65 ft) each end	X
With cathodic protection	with carcass	X	X	X	X	N/A	N/A	N/A
	without carcass	N/A	X	N/A	On purchaser request	On purchaser request test on up to 13 m (42.65 ft) at one or each end	Max 13 m (42.65 ft) at one or each end	X

9.2 Gauge Test

9.2.1 Purpose

The purpose of the gauge test is to detect blockages and any gross deformations.

9.2.2 Procedure

The gauging pig shall be equipped with (a) disk(s) capable of detecting any unacceptable obstruction.

The minimum diameter of the gauging pig shall be 10 mm (0.4 in.) smaller than the nominal ID or at least 95 % of the ID for pipes with an ID less than 200 mm (7.87 in.). The gauging pig shall consist of two parallel plates not less than 100 mm (3.94 in.) from each other.

9.2.3 Acceptance Criteria

The pig shall pass through the bore of the flexible pipe undamaged. Minor scratches and scuffs are acceptable; dents are not acceptable.

9.3 Hydrostatic Pressure Test

9.3.1 Purpose

The purpose of the hydrostatic pressure test is to demonstrate that the pipe can hold pressure above a desired level, or to identify latent defects in the pipe.

9.3.2 Procedure

The hydrostatic test pressure shall be 1.5× the design pressure. Unless otherwise specified, potable water filtered to 100 µ shall be used as the test fluid for rough bore pipes. The maximum chloride content shall be less than 50 mg/l (equivalent to parts per million (ppm), a deprecated term) for rough bore pipes. If required to protect the internal carcass material, the water shall be chemically inhibited. A suitable dye may be added to assist in leakage detection.

Trapped air shall be removed from the pipe in accordance with the manufacturer's procedures.

The pressure shall be gradually increased, at a rate not greater than the rate specified in the manufacturer's test procedure, to a value no greater than 110 % of the nominal test pressure for nominal test pressure exceeding 10 bars, or to a value equal to 1 bar greater than the nominal test pressure for nominal test pressures below 10 bars.

The stabilization period should be at least two hours. If necessary, additional fluid can be added and the pressure shall be cycled to this pressure until stabilization is achieved. The pressure can be considered stabilized when the pressure drop is less than 1 % in a one-hour period, or 0.15 bar for test pressures below 15 bars. Pressure level at the beginning of the hold period shall be at least the nominal test pressure.

The hold period shall not start until the equipment and pressure-monitoring gauge have been isolated from the pressure source.

The hydrostatic test pressure shall be held for a period not less than eight hours. During the test, pressure and temperature (ambient and internal) shall be recorded at least every 15 minutes. Depressurization shall be performed at a rate in accordance with the manufacturer's test procedure.

After depressurization, the end-fitting areas shall be visually examined for any sign of permanent deformation or damage in both the pipe and the end fittings.

If a pig has been used for filling or emptying the pipe, the cups shall be examined for damage and wear. Damage or excessive wear shall be recorded and reported to the purchaser.

9.3.3 Acceptance Criteria

Pressure loss due to all occurrences in the hold period, excluding external temperature fluctuations, shall not exceed:

— 1 % of the test pressure at the start of the eight-hour period or,

— 0.2 MPa (2 bar) for pressures between 20 MPa (200 bar) and 1.5 MPa (15 bar) or,

— 0.1 MPa (1 bar) for pressures below 1.5 MPa (15 bar).

The manufacturer shall have documented procedures to calculate the pressure loss due to external temperature fluctuations, and where 9.3.4 applies, creep effects and pipe elongation. These procedures and calculations shall be verified by an IVA. No leakage shall be observed from the pipe during the test. No permanent deformation or damage shall be observed in the area of the end fittings. Permanent elongation of the pipe shall not exceed 0.7 %. For pipes of 6 m (19.7 ft) and shorter, bolt holes of the flange of one end of the pipe shall remain in line with bolt holes of the flange of the other end of the pipe, within a tolerance of one bolt hole diameter.

9.3.4 Procedure and Acceptance for Hoses Where Creep Significantly Affects Stabilization Times

Where creep effects are a significant effect in the hose pressure response, for example where the hose utilizes polymer textile reinforcement, the manufacturer shall have documented procedures to calculate the pressure loss when isolated from the pressure source, the volume increase at constant pressure, and damage due to creep effects. These procedures and calculations shall be verified by an IVA.

In cases where, after two hours of stabilization, creep still causes significant loss of pressure (such that pressure will drop below 100 % of nominal test pressure), pressure may be topped up during the test. The manufacturer shall monitor the volume of water added during the test and perform calculations to show that this is due to creep effects only. The manufacturer shall demonstrate by validated calculations or prototype testing that the hose design can withstand the standard test procedure outlined in 9.3.1 and 9.3.2 through extended stabilization.

Creep damage ratio during FAT shall not exceed 2.5 %. In cases where creep damage during FAT would be greater than 2.5 % of the creep damage ratio, test duration shall be reduced in order to reduce creep damage ratio to 2.5 % during FAT, followed by a vacuum test. Minimum hold period shall be 30 minutes.

9.4 Electrical Continuity and Electrical Isolation Tests

9.4.1 Purpose

The purpose of the electrical continuity and isolation tests are to ensure that the pipe cathodic protection system will be efficient and that the carcass is electrically isolated from the end terminations.

The hose may connect to independent cathodic protection systems; electric isolation might be required. Electrically discontinuous hoses may be used to prevent electrical arcing at the manifold during connection and disconnection of hoses.

9.4.2 Procedure

For electrically continuous pipes, the electrical continuity test shall be performed between the two end fittings. Electrical isolation tests shall be performed between the end fittings and the carcass when applicable. Electrical continuity and isolation measurements shall be recorded.

9.4.3 Acceptance Criteria

For the electrical continuity test, the electrical resistance between the end fittings should be less than 1 Ω/100 m + 1 Ω for the pipe or as specified by the purchaser.

For the electrical isolation test of rough-bore pipes the electrical resistance between the internal carcass and the end fittings shall be greater than 1 kΩ unless the materials are galvanically identical.

9.5 Kerosene Test

9.5.1 Purpose

The objective of the kerosene test is to detect any permeation or leakage of a hydrocarbon liquid through the pipe liner.

9.5.2 Procedure

This test shall be carried out immediately prior to the vacuum test. The kerosene test is conducted by filling the pipe with kerosene and venting the air. The pipe is pressurized to design pressure that is then maintained for 24 hours. After this period, the pipe is depressurized, drained, dried, and observed for any blistering, leakage, or separation of the inner tube from the textile reinforcements or from the end fitting.

9.5.3 Acceptance Criteria

For pipes without a carcass, blistering or leakage shall cause the pipe to be rejected.

9.6 Vacuum Test

9.6.1 Purpose

9.6.1.1 General

The objective of the vacuum test is to indicate the adequacy of the bond strength of the liner to other pipe layers.

9.6.1.2 Alternatives

This test can be carried out within 24 hours of the kerosene or the hydrostatic test to determine the resistance of the pipe to permeation or migration of fluids or gases. The vacuum test “pulls” the kerosene or test fluid out of the pipe body if significant permeation or migration has occurred.

9.6.2 Procedure

The adequacy of the vulcanization of the bonded construction pipe is indicated by the bond strength of the liner to the other layers of the pipe. If applicable, a vacuum test is recommended to verify the adequacy of this bond. The pipe should be vacuum tested to -0.085 MPa (-0.850 bar) gauge for a period of 10 minutes. Plastic windows should be adapted to both ends of the pipe length so that visual inspection of the interior can be made by utilizing an adequate light source in one end and directing its beam to the other. The pipe should be examined inside as well as outside for any deformities.

9.6.3 Acceptance Criteria

Collapse of the pipe liner, failure of adhesion between layers within the body of the pipe, blisters, other deformities, and evidence of kerosene or test fluid migration in the hose body, shall cause the pipe to be rejected.

9.7 Tensile Test for SWI (Seawater Intake) Pipe

9.7.1 Purpose

The purpose of this test is to verify the tensile resistance of the hose. Manufacturers shall verify the hose for use up to a specified axial load on the first pipe, and one for every tenth pipe of the same design thereafter. This test is for SWI BFP only, which is generally designed for low pressure.

9.7.2 Procedure

The hose shall be installed in a straight line and empty. One end of the sample is fixed and an axial load is applied to the other end. The load shall be increased at a rate prescribed by the manufacturer to prevent shock load.

The target test load shall be equal to 1.1 times the maximum tension as determined by the dynamic analysis for operating/permanent/extreme conditions as per Table 6. However, the test tension shall not result in utilization of the critical tensile layer in excess of 0.91. The hold period of the test shall be 15 minutes. Applied tensile load shall be recorded continuously during the test; elongation shall be measured/recorded every 5 minutes.

The load shall be removed at a rate prescribed by the manufacturer to prevent shock load. Permanent elongation of the pipe shall be measured after at least one hour of the test.

The tensile test shall be followed by a hydrostatic pressure test as per 9.3. The hydrostatic pressure test shall be followed by a vacuum test as per 9.6.

9.7.3 Acceptance Criteria

The pipe shall be visually inspected after the test, no visible damage is acceptable. Permanent elongation shall be less than 0.7 %.

10 Marking and Packaging

10.1 Marking

The flexible pipe marking shall be applied to both end fittings, and shall make the pipe permanently identifiable for the specified service life. As a minimum, the following markings shall be applied:

- API 17K designation;
- serial number of pipe;
- manufacturer name or mark;
- manufacture date;
- design pressure (absolute or differential);
- storage MBR (for reeled products).

If requested by the purchaser, the following markings may be applied:

- circular markings at regular intervals with length for reference in installation and survey. The markings shall be large enough and colored so as to be clearly visible against the pipe background under typical ROV illumination;
- longitudinal strips to assess twist;
- design water depth, or minimum design water depth if based on differential design pressure.

Additional markings shown in API 17B shall also be considered.

10.2 Packaging

The flexible pipe shall be packaged in accordance with the manufacturer's specifications. If stored on reels or carousels, the pipe shall not be subjected to a bend radius less than the storage MBR. The end fittings and connectors should be wrapped in heavy-duty protections unless packed in crates and pallets that have adequate protection. Both ends of the pipe shall be covered and the sealing surface protected. The manufacturer's specifications shall include procedures for storage and packaging of integral components mounted on the pipe, including bend stiffeners. Storage blinds, ropes/wires, shackles, and other required handling equipment, shall be identified in the packaging procedures. The manufacturer's specifications shall include procedures for controlling back tension and closeness of wraps for reels to be used for pipe installation.

The packaging shall be such that the pipe is protected against all expected environmental occurrences when stored outdoors. A protective cover should be used. The flexible pipe, including end fittings, should not protrude beyond the edges of transport reels or pallets, such that abrasive damage could occur to the pipe.

If the pipe is to be installed off the reel and free flooded, the inboard end fitting shall be vented.

The manufacturer shall label the minimum temperature for storage and unspooling.

Annex A
(informative)

API Monogram Program
Use of the API Monogram by Licensees

A.1 Scope

The API Monogram® is a registered certification mark owned by the American Petroleum Institute (API) and authorized for licensing by the API Board of Directors. Through the API Monogram Program, API licenses product manufacturers to apply the API Monogram to new products which comply with product specifications and have been manufactured under a quality management system that meets the requirements of API Q1. API maintains a complete, searchable list of all Monogram licensees on the API Composite List website (http://compositelist.api.org).

The application of the API Monogram and license number on products constitutes a representation and warranty by the licensee to API and to purchasers of the products that, as of the date indicated, the products were manufactured under a quality management system conforming to the requirements of API Q1 and that the product conforms in every detail with the applicable standard(s) or product specification(s). API Monogram Program licenses are issued only after on-site audits have verified that an organization has implemented and continually maintained a quality management system that meets the requirements of API Q1 and that the resulting products satisfy the requirements of the applicable API product specification(s) and/or standard(s). Although any manufacturer may claim that its products meet API product requirements without monogramming them, only manufacturers with a license from API can apply the API Monogram to their products.

Together with the requirements of the API Monogram license agreement, this annex establishes the requirements for those organizations who wish to voluntarily obtain an API license to provide API monogrammed products that satisfy the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program requirements.

For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, N. W., Washington, DC 20005 at certification@api.org.

A.2 Normative References

For Licensees under the Monogram Program, the latest version of this document shall be used. The requirements identified therein are mandatory.

A.3 Terms and Definitions

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

A.3.1
API monogrammable product
Product that has been newly manufactured by an API Licensee utilizing a fully implemented API Q1 compliant quality management system and that meets all the API-specified requirements of the applicable API product specification(s) and/or standard(s).

A.3.2
API product specification
Prescribed set of rules, conditions, or requirements attributed to a specified product that address the definition of terms; classification of components; delineation of procedures; specified dimensions; manufacturing criteria; material requirements, performance testing, design of activities; and the measurement of quality and quantity with respect to materials; products, processes, services, and/or practices.

A.3.3
API-specified requirements
Requirements, including performance and Licensee-specified requirements, set forth in API Q1 and the applicable API product specification(s) and/or standard(s).

NOTE Licensee-specified requirements include those activities necessary to satisfy API-specified requirements.

A.3.4
Design package
Records and documents required to provide evidence that the applicable product has been designed in accordance with API Q1 and the requirements of the applicable product specification(s) and/or standard(s).

A.3.5
Licensee
Organization that has successfully completed the application and audit process, and has been issued a license by API to use the API Monogram Mark.

A.4 Quality Management System Requirements

An organization applying the API Monogram to products shall develop, maintain, and operate at all times a quality management system conforming to API Q1.

A.5 Control of the Application and Removal of the API Monogram

Each licensee shall control the application and removal of the API Monogram in accordance with the following:

a) Products that do not conform to API specified requirements shall not bear the API Monogram.

b) Each licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by this annex and any applicable API product specification(s) and/or standard(s). The marking procedure shall:
    1) define the authority responsible for application and removal of the API Monogram and license number;
    2) define the method(s) used to apply the Monogram and license number;
    3) identify the location on the product where the API Monogram and license number are to be applied;
    4) require the application of the date of manufacture of the product in conjunction with the use of the API Monogram and license number;
    5) require that the date of manufacture, at a minimum, be two digits representing the month and two digits representing the year (e.g. 05-12 for May 2012) unless otherwise stipulated in the applicable API product specification(s) or standard(s); and
    6) define the application of all other required API product specification(s) and/or standard(s) marking requirements.

c) Only an API licensee shall apply the API Monogram and its designated license number to API monogrammable products.

d) The API Monogram and license number, when issued, are site-specific and subsequently the API Monogram shall only be applied at that site specific licensed facility location.

e) The API Monogram may be applied at any time appropriate during the production process but shall be removed in accordance with the licensee’s API Monogram marking procedure if the product is subsequently found to be out of conformance with any of the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program.

For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. Requirements for alternative API Monogram marking are detailed in the, *API Alternative Marking Agreement (AMA)*, available on the API Monogram Program website at: http://www.api.org/products-and-services/api-monogram-and-apiqr/documents#tab certification-documents.

A.6 Design Package Requirements

Each licensee and/or applicant for licensing shall maintain a current design package for all of the applicable products that fall under the scope of each Monogram license. The design package information shall provide objective evidence that the product design meets the requirements of the applicable and most current API product specification(s) and/or standard(s). The design package(s) shall be made available during API audits of the facility.

In specific instances, the exclusion of design activities is allowed under the Monogram Program, as detailed in Advisory # 6, available on API Monogram Program website at http://www.api.org/products-and-services/api-monogram-and-apiqr#tab advisories.

A.7 Manufacturing Capability

The API Monogram Program is designed to identify facilities that have demonstrated the ability to manufacture equipment that conforms to API specifications and/or standards. API may refuse initial licensing or suspend current licensing based on a facility's level of manufacturing capability. If API determines that additional review is warranted, API may perform additional audits (at the organization's expense) of any primary subcontractors to ensure their compliance with applicable specifications.

Facilities with capabilities that are limited to the processes or activities defined below do not meet the manufacturing capability requirements to produce new products, and therefore, shall not be licensed or be the basis for licensing under the API Monogram Program:

— Capabilities that are limited to performing final inspection and testing of the product, except for testing agencies as specified in API Spec 14A and/or API Spec 6AV1;

— Buying, selling and/or distributing finished products and materials;

— Design and development activities;

— Tearing-down and/or re-assembling of products/components; and,

— Repairing or remanufacturing of existing, used, worn or damaged products.

In all instances where requirements for manufacturing or manufacturing facilities are explicitly identified within the API product specification, those requirements shall take precedence over this advisory.

A.8 API Monogram Program: Nonconformance Reporting

API solicits information on products that are found to be nonconforming with API specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification and/or standard deficiencies or nonconformities against API specified requirements. Customers are requested to report to API all problems with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at http://ncr.api.org/ncr.aspx.

Annex B
(informative)

Purchasing Guidelines

B.1 General

Table B.1 gives purchasing guidelines for flexible pipes.

A separate form should be completed for each length of flexible pipe.

The manufacturer should specify in the design premise the values assumed for all parameters in Table B.1 not specified by the purchaser.

Table B.1—Flexible Pipe Purchasing Guidelines

<table>
<tr><th colspan="2">General Information</th></tr>
<tr><td rowspan="2">Client:</td><td>Client reference:</td></tr>
<tr><td rowspan="2">Project:</td></tr>
<tr><td>Phone:</td></tr>
<tr><td>Fax:</td><td rowspan="2">Location:</td></tr>
<tr><td>Purchaser’s technical contact:</td></tr>
<tr><td>Conformance to API 17K required? ☐ Yes ☐ No</td><td>Enquiry date:</td></tr>
<tr><td>API Monogram required? ☐ Yes ☐ No</td><td>Required response date:</td></tr>
<tr><th colspan="2">General Design Parameters</th></tr>
<tr><td>Internal pipe and end fitting diameters (m):</td><td>Maximum axial load (kN):</td></tr>
<tr><td>Length required (m):</td><td>Maximum effective tension (kN):</td></tr>
<tr><td>Tolerance required on length (m ± m, or %):</td><td>Torsional balance requirement (deg/m):</td></tr>
<tr><td>Pipe structural requirements (MBR, bend stiffness):</td><td>Compression strength requirement (kN):</td></tr>
<tr><td>Number of vent ports inside end fitting; and Gas monitoring system</td><td>Design load case probabilities
(1 year, 100 years)</td></tr>
<tr><td>Mass requirements (kg/m) in air empty:</td><td>Installation:</td></tr>
<tr><td>External protection requirements (external carcass):</td><td>Normal operation:</td></tr>
<tr><td>Service life (years):</td><td>Abnormal operation:</td></tr>
<tr><td colspan="2">Specification of normal and abnormal load cases, including accidental loads, and definition of load combinations to be used in the design:</td></tr>
<tr><td colspan="2">°C = degree Celsius; °F = degree Fahrenheit; g = gram; K = kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million (deprecated unit); TAN = titrated acid number; TFL = through flowline; W = watt.</td></tr>
</table>

Table B.1—Flexible Pipe Purchasing Guidelines (continued)

Internal Fluid Parameters	
General	**Flow Rate and Thermal Calculations**
Fluid description (oil, gas, water):	Flow rate (m^3/day):
Flow regime description (single, phase, slug):	Fluid density (kg/m^3):
Flow direction:	Viscosity (Pa·s):
Pressures	Minimum inlet pressure (MPa):
Design pressure (MPa):	Required outlet pressure (MPa):
Operating pressure (MPa):	Fluid heat capacity (kJ/kg·°C):
Vacuum conditions (MPa):	**Fluid Compositional Data**
Differential internal pressure (MPa):	NaCl content (mass percent of water):
Temperatures	Chloride content (mg/l) [1]:
Design minimum temperature (°C):	Gas-oil ratio (m^3/m^3):
Design maximum temperature (°C):	Water cut (volume percent):
Operating temperature profile (°C):	Alcohols? ❑ Yes ❑ No
Number of extreme temperature cycles (°C):	Aromatic components? ❑ Yes ❑ No
Incidental temperature (°C):	
Service Definition	Corrosive agents? ❑ Yes ❑ No
Description (sweet/sour):	Inhibitors (scale, paraffin)? ❑ Yes ❑ No
NACE MR0175 to apply? ❑ Yes ❑ No	Injected chemicals? ❑ Yes ❑ No
H_2S partial pressure [MPa; (bar)]:	Solids, precipitates, etc.? ❑ Yes ❑ No
CO_2 partial pressure [MPa; (bar)]:	*If available, attach details of full fluid compositional data and expected variation over the service life. Also, attach details of any aromatic components, corrosive agents, inhibitors, alcohols, solids, or injected chemicals in the fluid composition.*
pH of aqueous phase:	
TAN (mg KOH/g):	
[1] Equivalent to parts per million (ppm), a deprecated unit.	

Table B.1 (*continued*)

External Environment (Static Loads)	
Water depths	**Soil data**
Design water depth (m):	Soil description (clay, sand):
Minimum tidal variation (m):	Soil shear strength (kPa):
Maximum tidal variation (m):	Angle of internal friction (degrees):
Attach details of water depth variation over flexible pipe route.	Lateral friction coefficient:
Air temperatures	Longitudinal friction coefficient:
Minimum temperature (°C):	Seabed scour/sand waves occur? ❑ Yes ❑ No *If available, attach seabed profile.*
Maximum temperature (°C):	
Minimum storage/transport/installation temperature (°C):	Other
Maximum storage/transport/installation temperature (°C):	Marine growth to be considered? ❑ Yes ❑ No *If yes, attach details.*
Seawater data	
Density:	Ice effects to be considered? ❑ Yes ❑ No *If yes, attach details.*
pH value:	
Minimum surface temperature (°C):	Sunlight exposure? ❑ Yes ❑ No
Maximum surface temperature (°C):	Current data attached? ❑ Yes ❑ No *Attached current data should be given as a function of water depth, direction and return period.*
Minimum seabed temperature (°C):	
Maximum seabed temperature (°C):	
External Environment (Dynamic Loads)	
Wave data attached? ❑ Yes ❑ No *Attached wave data should be given in terms of significant wave, maximum wave, equivalent periods, spreading functions, scatter diagrams, as a function of direction, and return period. For irregular seas, the wave spectrum data should be specified.*	Wind data attached? ❑ Yes ❑ No *Attached wind data should be given in terms of maximum 3-sec, 1-min, 10-min, and 1-h wind speeds, as a function of direction, height above water level, and return period.*

Table B.1 (*continued*)

General System Requirements	
General	
System description (flowline, riser, jumper, subsea, topsides):	
Application definition (static, dynamic):	
Pipe bore description (rough, smooth):	
Corrosion Protection Requirements	
Corrosion protection required? ❑ Yes ❑ No	
Cathodic protection system required? ❑ Yes ❑ No	**Other**
Electrical continuity required? ❑ Yes ❑ No	Fire resistance required? ❑ Yes ❑ No Specify (Lloyds/DNV/API 16C):
End-fitting coatings required? ❑ Yes ❑ No	Pigging, TFL, workover, etc. required? ❑ Yes ❑ No
External coating description:	Piggyback required? ❑ Yes ❑ No
Internal coating description:	*If yes, attach details.*
If available, allowable electrical resistance, protection voltage, current source, and current density should be specified.	Pressure and tensile armor weld location restrictions? ❑ Yes ❑ No
Thermal Insulation	Interface definitions/specifications (refer to 4.6.1.10):
Thermal insulation required? ❑ Yes ❑ No	
Required outlet temperature (°C):	
Required insulation U-value (W/m^2K):	Exothermal chemical reaction cleaning required? ❑ Yes ❑ No
Insulation U-value should be based on pipe ID and be for the pipe alone. Specify any allowances that can be made for external effects such as soil.	Inspection condition monitoring required? ❑ Yes ❑ No
Connector	*If yes, give details of requirements.*
Lower connector type (flange, pipe):	
Upper connector type (flange, pipe):	
Attach welding specification seal type and sizes, and responsibility for supply and mounting of components.	

Table B.1 (*continued*)

Flowline Parameters	
Flowline routing description attached? ❑ Yes ❑ No	**Upheaval Buckling**
Guides and supports (I-tubes, J-tubes):	Upheaval buckling to be checked? ❑ Yes ❑ No
Protection requirements	Required minimum soil coverage (m):
Impact resistance to accidental loads? ❑ Yes ❑ No	Allowable bend radius (m):
Trenching? ❑ Yes ❑ No	Load cases attached? ❑ Yes ❑ No
Rock dumping? ❑ Yes ❑ No	**Other**
Mattresses? ❑ Yes ❑ No	On-bottom stability to be checked? ❑ Yes ❑ No
Other? ❑ Yes ❑ No	Crossover requirements? ❑ Yes ❑ No
Attach details of specified protection system(s), including GA drawings, possible accidental occurrences (trawl boards, dropped objects, anchors, etc.), design impact loads.	Required pipe attachments (bend restrictors, clamps): *Attach drawings of all items.*
Riser Parameters (Dynamic Line)	
General	**Interference**
Riser configuration (lazy-S, steep wave), **azimuth angle, and declination angle where applicable:** *Attach description of riser configuration and GA drawing(s) of all relevant details.*	Interference/clashing check required? ❑ Yes ❑ No *Attach details of all possible interface areas, including other risers, mooring lines, platform columns, vessel pontoons, tanker heel, and so forth, and specify allowable interferences/clashing.*
Riser upper connection description (platform, tanker) **and coordinates**:	**Vessel Motion Data**
Riser lower connection description (seabed, vessel) **and coordinates:**	Vessel motion data attached? ❑ Yes ❑ No
Required pipe attachments (bend stiffeners, bend restrictors, buoys): *Attach drawings of all items.*	*Attached vessel motion data should be specified in terms of the following for the relevant loading conditions. Attached data should include a general layout drawing, showing vessel heading, North point, riser(s) in plan, and mooring lines.* — Vessel static and dynamic offsets for all conditions. — Vessel data, dimensions, drafts, etc. — Vessel first- and second-order motions, in terms of heave, surge, sway, yaw, roll and pitch **and/or motion time traces**. — Vessel motion phase data and specification. — Reference point for motions. — Mooring system design, including line properties and anchor locations. — Position tolerances.

Table B.1 (*continued*)

Additional Requirements
Materials required in addition to API 17K? ❑ Yes ❑ No *If yes, specify details.*
Manufacturing required in addition to API 17K? ❑ Yes ❑ No *If yes, specify details.*
Selection of PSL Level for 7.11.6 (default is PSL 2-3)? ❑ Yes ❑ No *If yes, specify details.*
EFAT required in addition to API 17K? ❑ Yes ❑ No *If yes, specify details.* *Refer to API 17B for EFAT procedure.*
Markings required in addition to API 17K? ❑ Yes ❑ No *If yes, specify details.*
Prototype tests required? ❑ Yes ❑ No *If yes, specify details.*
Additional national authority/government regulations? ❑ Yes ❑ No *If yes, specify details.*
Purchaser inspection required? ❑ Yes ❑ No *If yes, specify details.*
General requirements in addition to API 17K? ❑ Yes ❑ No *If yes, specify details.*

Table B.1 (*continued*)

<table>
<tr><th colspan="2">Delivery, Installation, and Maintenance Requirements</th></tr>
<tr><td colspan="2">Delivery requirements:</td></tr>
<tr><td colspan="2">Shipping, packing, and storage requirements:</td></tr>
<tr><td colspan="2">Documentation requirements:

Purchaser should specify if a separate installation manual is required.</td></tr>
<tr><td>Installation Requirements</td><td>Maintenance</td></tr>
<tr><td>Method:</td><td rowspan="15">Maintenance required? ❑ Yes ❑ No

If yes, specify details.</td></tr>
<tr><td>Vessel:</td></tr>
<tr><td>General:

Where relevant, the purchaser should specify any requirements for season, environment, vessel limitations, restrictions due to conflicting activities, and installation scope (including trenching, burial, testing, inspection, surveying, and documentation).</td></tr>
<tr><td>Installation Design Criteria</td></tr>
<tr><td>Equipment bend radius (m):</td></tr>
<tr><td>Tensioner crush loads (kN):</td></tr>
<tr><td>Installation/lifting device requirements:</td></tr>
<tr><td>Transport reel used for installation?
❑ Yes ❑ No</td></tr>
<tr><td>Pipe internal fluid at delivery (empty, water-filled):</td></tr>
<tr><td>Seawater flooding requirements (exposure time?
❑ Yes ❑ No</td></tr>
<tr><td>Where relevant, the purchaser should specify details such as length of tensioners, shape of tensioner shoes, number of belts, diameter of wheels, reels, ramp angles, and surface shape.</td></tr>
<tr><td>Installation test requirements:</td></tr>
<tr><td>Installation vessel motions and offsets attached?
❑ Yes ❑ No

Attached details should, in general, reflect data requirements in the vessel motion data requirements listed under riser parameters (above).</td></tr>
</table>

Annex C
(informative)

Flexible Pipe Datasheet

Table C.1 in this annex gives guidelines for the minimum data to be provided on a flexible pipe datasheet.

In addition, the manufacturer should also provide separately an isometric schematic of the pipe cross section clearly showing the layer-by-layer construction.

Table C.1—Flexible Pipe Datasheet Minimum Requirements

<table>
<tr><th colspan="7">General Information</th></tr>
<tr><td colspan="4">Client</td><td colspan="3">Project</td></tr>
<tr><td colspan="4">Bore fluid</td><td colspan="3">Water depth (m, ft)</td></tr>
<tr><td colspan="4">Inner diameter (mm, in.)</td><td colspan="3">Outer diameter (mm, in.)</td></tr>
<tr><td colspan="4">Design pressure (MPa, psi)</td><td colspan="3">Design temperature (°C, °F)</td></tr>
<tr><td colspan="4">Operating pressure (MPa, psi)</td><td colspan="3">Operating temperature (°C, °F)</td></tr>
<tr><th colspan="7">Theoretical Pipe Properties</th></tr>
<tr><td colspan="4">Internal volume (l/m, cf/ft)</td><td colspan="3">External volume (l/m, cf/ft)</td></tr>
<tr><td colspan="4">Weight in air empty (kg/m, lbf/ft)</td><td colspan="3">Weight in air full of seawater (kg/m, lbf/ft)</td></tr>
<tr><td colspan="4">Weight in seawater empty (kg/m, lbf/ft)</td><td colspan="3">Weight in seawater full of seawater (kg/m, lbf/ft)</td></tr>
<tr><td colspan="4">Specific gravity in seawater empty (–)</td><td colspan="3">Specific gravity in seawater full of seawater (–)</td></tr>
<tr><td colspan="4">MBR storage (m, ft)</td><td colspan="3">MBR static (m, ft)</td></tr>
<tr><td colspan="4">MBR dynamic (m, ft)</td><td colspan="3"></td></tr>
<tr><td colspan="4">Burst pressure (MPa, psi)</td><td colspan="3">Collapse pressure (MPa, psi) (for subsea applications only)</td></tr>
<tr><td colspan="4">Maximum allowable tension (kN,, lbf)</td><td colspan="3">Maximum allowable axial compression (kN, lbf)</td></tr>
<tr><td></td><td colspan="2">Bending stiffness</td><td colspan="4">Axial stiffness at 20 °C (kN, kip)</td></tr>
<tr><td>Section</td><td>Bending stiffness at BFP empty (kN-m^2, lbf-ft^2)</td><td>at MOP (kN-m^2, lbf-ft^2)</td><td>In tension at BFP empty</td><td>In compression at BFP empty</td><td>In tension at MOP</td><td>In compression at MOP</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Torsional stiffness at 20 °C (KNm^2/deg, kip.ft^2/deg)</td></tr>
<tr><td colspan="4">End connection type - End A</td><td colspan="3">End connection type - End B</td></tr>
<tr><td colspan="4">Overall heat transfer coefficient (w/m^2K, Btu/hrft^2 °F) (for subsea applications only)</td><td colspan="3">Thermal exchange coefficient (w/mK, Btu/hrft °F) (for subsea applications only)</td></tr>
<tr><td colspan="7">NOTE Manufacturer to specify the temperature at which the properties are stated. MOP: maximum operating pressure.</td></tr>
</table>

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