

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.

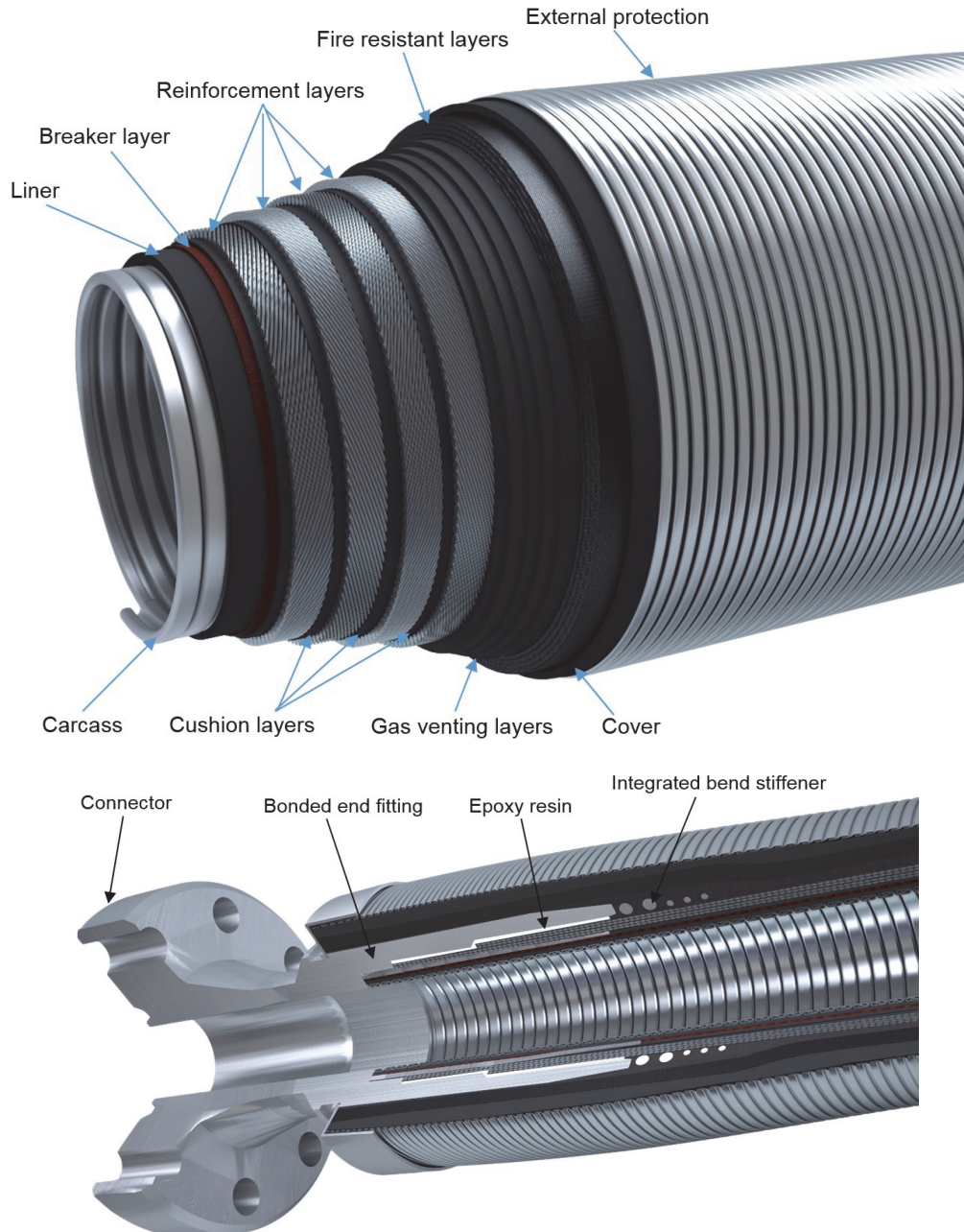


Figure 1a—Typical Bonded Flexible Pipe—Flowline and Riser

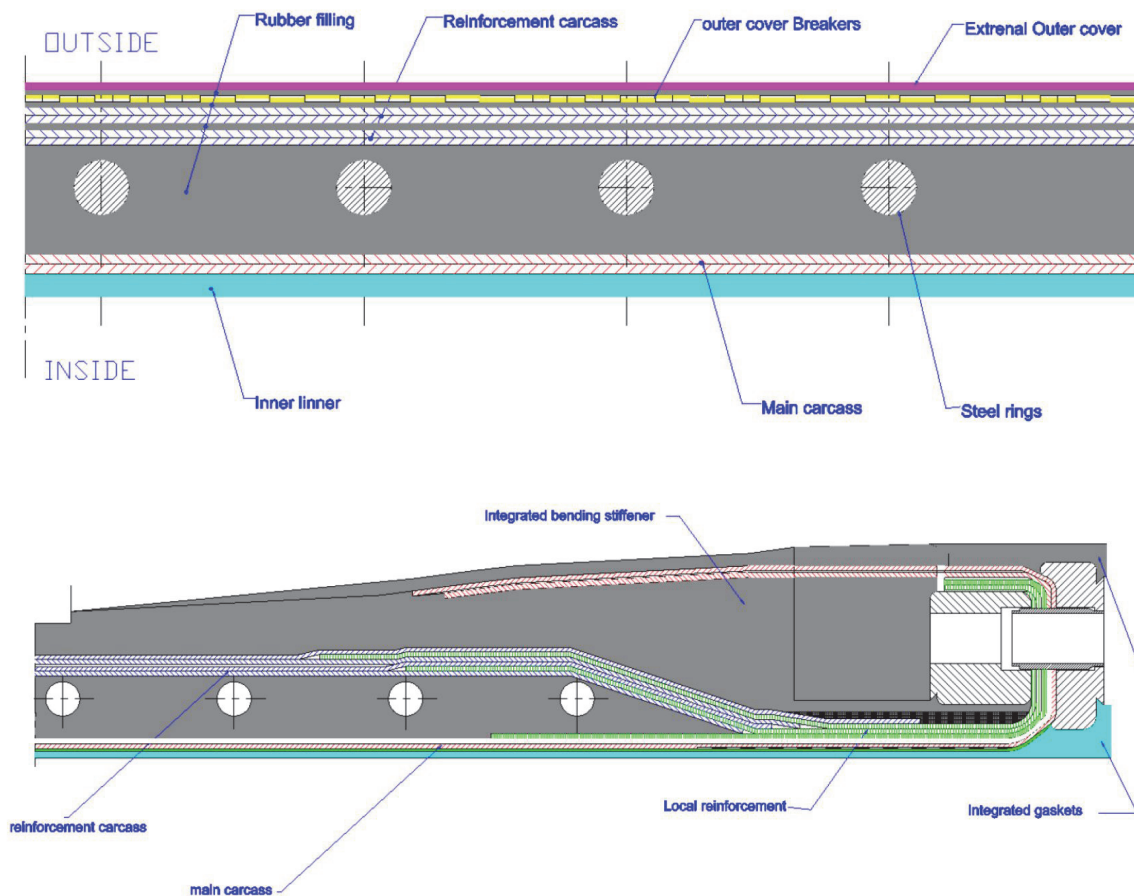


Figure 1b—Typical Bonded Flexible Pipe—Loading and Discharge Hose

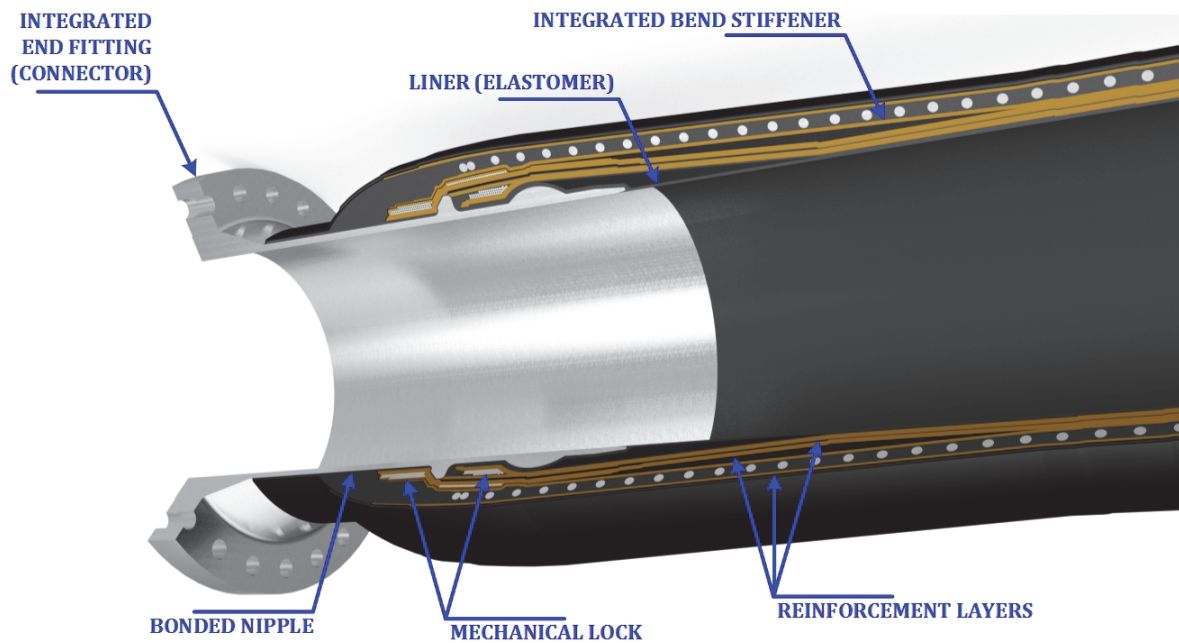
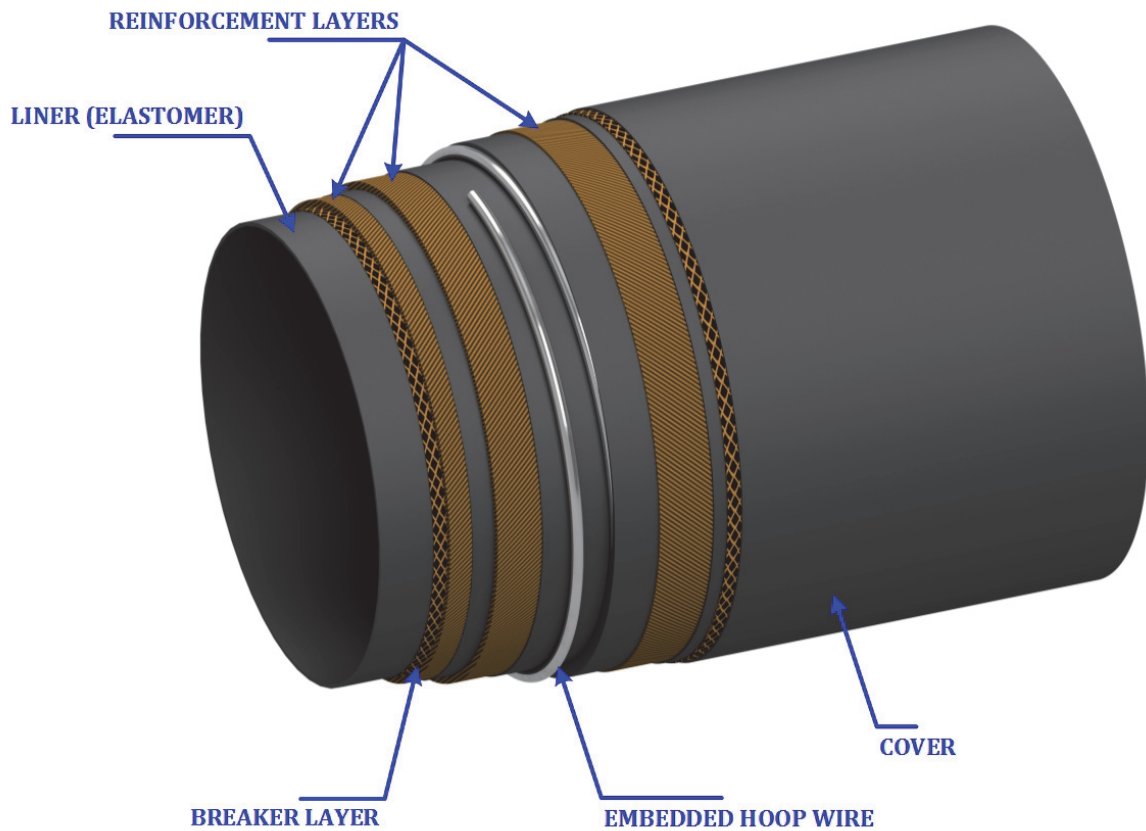


Figure 1c—Typical Bonded Hose—Body and End

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*

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 H₂S-containing environments in oil and gas production*

NACE TM0177, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H₂S Environments*

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, Genève, 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 $\times$ 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:

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

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 H₂S 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 H₂S 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 ₂ S	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, 1 st 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.

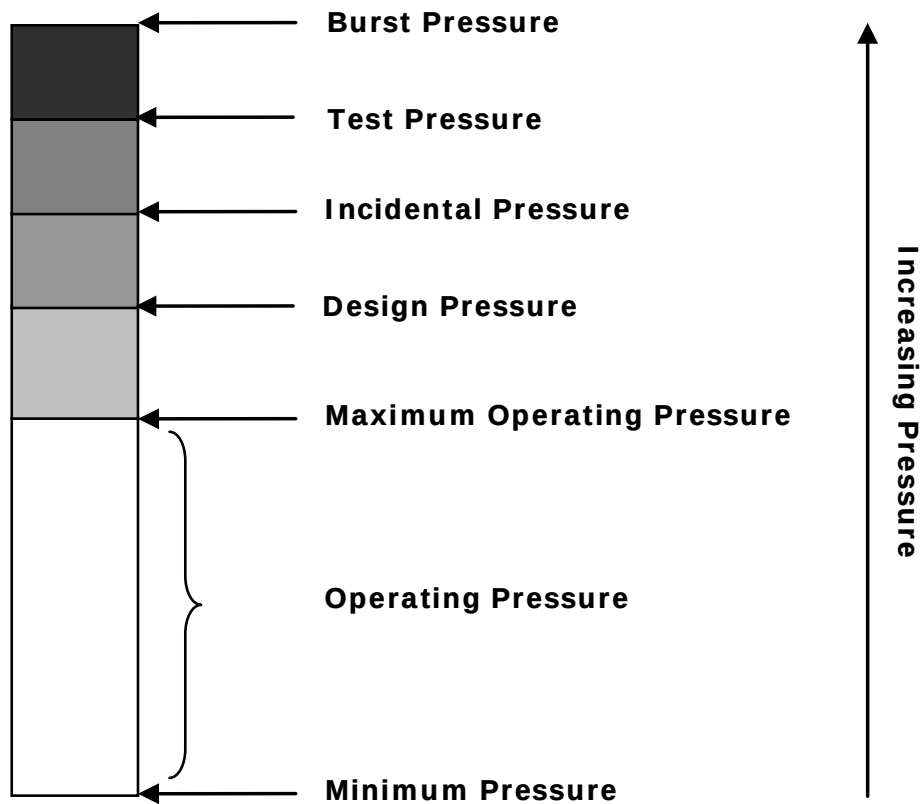


Figure 1—Internal Pressure Definitions

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 H₂S and CO₂, 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;