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Addendum 1

Page 2, Section 2, the following shall be added:

ASTM D1141, *Standard Practice of the Preparation of Substitute Ocean Water*

Page 53, Section 6.2.4.6, change:

The tensile armors shall be subject to testing to confirm that the potential hydrogen evolution resulting from cathodic charging does not result in hydrogen embrittlement. The testing shall be conducted on degreased wire samples immersed in deaerated seawater (minimum 3 % NaCl) with the maximum negative cathodic potential applied. The wire shall be stressed to at least the maximum utilization level expected in service. The cathodic charging shall be applied for a minimum duration of 150 h. Post-test examination shall be conducted to confirm that no blistering or cracking of the wire sample has occurred.

to:

The tensile armor wires shall be tested to confirm that the potential hydrogen evolution resulting from cathodic charging does not result in hydrogen embrittlement. The testing shall be conducted on degreased wire samples immersed in aerated synthetic seawater that conforms to ASTM D1141, with a maximum negative cathodic potential applied per the manufacturer's specification.

NOTE The default value of the maximum negative potential is -1100 mV measured against the Ag/AgCl reference electrode.

The wire shall be stressed to its maximum utilization level expected in service. The cathodic charging shall be applied for a minimum duration of 150 h. Post-test examination shall be conducted, and the acceptance criterion shall be that no blistering or cracking of the wire sample has occurred.

Specification for Unbonded Flexible Pipe

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

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Specification for Unbonded Flexible Pipe

1 Scope

API 17J defines the technical requirements for safe, dimensionally and functionally interchangeable flexible pipes that are designed and manufactured to uniform standards and criteria. Minimum requirements are specified for the design, material selection, manufacture, testing, marking, and packaging of flexible pipes, with reference to existing codes and standards where applicable. See API 17B for guidelines on the use of flexible pipes.

API 17J applies to unbonded flexible pipe assemblies, consisting of segments of flexible pipe body with end fittings attached to both ends. API 17J does not cover flexible pipes of bonded structure. API 17J does not apply to flexible pipe ancillary components. Guidelines on flexible pipe ancillary components are given in API 17L1, API 17L2, and other API documents.

API 17J does not apply to flexible pipes that include nonmetallic tensile and pressure armor wires.

The applications addressed by API 17J are sweet and sour service production, including export and injection applications. Production products include oil, gas, water, and injection chemicals. API 17J applies to both static and dynamic flexible pipes used as flowlines, risers, and jumpers. API 17J does not apply to flexible pipes for use in choke and kill line applications. Annex H of API 17B provides recommendations for the application of fiber reinforced polymer materials for pressure armor and tensile armor in unbonded flexible pipe.

NOTE 1 See API 16C for choke and kill line applications.

NOTE 2 API 17K provides guidelines for bonded flexible pipe.

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

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

API Technical Report 17TR1, *Evaluation Standard for Internal Pressure Sheath Polymers for High Temperature Flexible Pipes*

API Technical Report 17TR2, *The Ageing of PA-11 in Flexible Pipes*

ASME Boiler and Pressure Vessel Code ¹, Section IX: *Welding and Brazing Qualifications*

ASTM A29 ², *Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for*

¹ ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

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

ASTM A480, *Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*

ASTM A668, *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 C518, *Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*

ASTM D256-10, *Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics*

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

ASTM D638-10, *Standard Test Method for Tensile Properties of Plastics*

ASTM D664-09a, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

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

ASTM D789, *Standard Test Methods for Determination of Relative Viscosity of Polyamide (PA)*

ASTM D792-08, *Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*

ASTM D974-08e1, *Standard Test Method for Acid and Base Number by Color-Indicator Titration*

ASTM D1044-08, *Standard Test Method for Resistance of Transparent Plastics to Surface Abrasion*

ASTM D1141, *Standard Practice of the Preparation of Substitute Ocean Water*

ASTM D1238, *Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer*

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

ASTM D1505, *Standard Test Method for Density of Plastics by the Density-Gradient Technique*

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

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

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

ASTM D6869, *Standard Test Method for Coulometric and Volumetric Determination of Moisture in Plastics Using the Karl Fischer Reaction (the Reaction of Iodine with Water)*

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

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

ASTM E831, *Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis*

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

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

ASTM G48-03, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*

DNV ³, *GL IMO Resolution A 753 (18)* (Recommended by DNV-GL3 in lieu of withdrawn DNV Classification Note 6.1.)

EN 287-1 ⁴, *Qualification test of welders—Fusion welding—Part 1: Steels*

EN 10204:2004, *Metallic products—Types of inspection documents*

ISO 62 ⁵, *Plastics—Determination of water absorption*

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

ISO 178, *Plastics—Determination of flexural properties*

ISO 179 (all parts), *Plastics—Determination of Charpy impact properties*

ISO 307, *Plastics—Polyamides—Determination of viscosity number*

ISO 527-1, *Plastics—Determination of tensile properties—Part 1: General principles*

ISO 527-2, *Plastics—Determination of tensile properties—Part 2: Test conditions for moulding and extrusion plastics*

ISO 604, *Plastics—Determination of compressive properties*

ISO 899-1, *Plastics—Determination of creep behaviour—Part 1: Tensile creep*

ISO 1133, *Plastics—Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics*

ISO 1183 (all parts), *Plastics—Methods for determining the density of non-cellular plastics*

ISO 3384, *Rubber, vulcanized or thermoplastic—Determination of stress relaxation in compression at ambient and at elevated temperatures*

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

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

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

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

ISO 8301, *Thermal insulation—Determination of steady-state thermal resistance and related properties—Heat flow meter apparatus*

³ Det Norske Veritas GL, Veritasveien 1, 1322 Høvik, Oslo, Norway, www.dnvgl.com.

⁴ European Committee for Standardization, CEN Management Centre, Rue de Stassart 36, B-1050 Brussels, Belgium, www.cenorm.be.

⁵ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

ISO 8302, *Thermal insulation—Determination of steady-state thermal resistance and related properties—Guarded hot plate apparatus*

ISO 9352, *Plastics—Determination of resistance to wear by abrasive wheels*

ISO 10474:2013, *Steel and steel products—Inspection documents*

ISO 11357-1, *Plastics—Differential scanning calorimetry (DSC)—Part 1: General principles*

ISO 11357-4, *Plastics—Differential scanning calorimetry (DSC)—Part 4: Determination of specific heat capacity*

ISO 11359-2, *Plastics—Thermomechanical analysis (TMA)—Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 13847, *Petroleum and natural gas industries—Pipeline transportation systems—Welding of pipelines*

Lloyds Fire Test ⁶, *Lloyds Register of Shipping, Fire Testing—Memorandum ICE/Fire OSG 1000/499*

NACE MR0175 ⁷, *Petroleum and Natural Gas Industries - Materials for use in H₂S-Containing Environments in Oil and Gas Production*

NACE TM 01-77, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H₂S Environments*

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

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

annulus

Space between two extruded polymer layers, for example, the internal pressure sheath and external sheath that is sealed in the end fitting.

NOTE Permeated gas and liquid are generally free to move and mix in the annulus.

⁶ Lloyd's Register EMEA, 71 Fenchurch Street, London EC3M 4BS, United Kingdom, www.lr.org.

⁷ NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77084-4906, www.nace.org.

3.1.3**antibuckling tape**

A polymer, fabric, wire, fiber, or other reinforcement wound around the tensile armors, compressing the wires/strips against the pipe body to resist radial buckling of these wires/strips.

3.1.4**antiwear layer**

Nonmetallic layer, either extruded thermoplastic sheath or tape wrapping, normally used to minimize wear between structural layers.

3.1.5**bellmouth**

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

3.1.6**bend limiter**

Any device used to restrict bending of the flexible pipe.

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

3.1.7**bend radius**

Radius of curvature of the flexible pipe measured from the pipe centerline.

NOTE Storage and operating minimum bend radius (MBR) are defined in 5.3.1.

3.1.8**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.

3.1.9**bend stiffener**

Ancillary conical shaped component that locally reduces bending stresses and curvature of the pipe to acceptable levels; usually attached to either an end fitting or a support structure where the flexible pipe passes through the bend stiffener.

3.1.10**bend stiffener latching mechanism**

A structure or mechanism that allows a riser bend stiffener to be connected to a structure allowing the bending to be transferred from the riser bend stiffener to that structure.

3.1.11**bending stiffness**

The resistance to bending from an applied bending moment—product of the effective elastic modulus and moment of inertia of the flexible pipe. The bending stiffness may vary with tension, pressure, and temperature.

3.1.12**bonded pipe**

Flexible pipe in which the steel 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.

3.1.13**buckling of tensile armors**

Buckling of the tensile armors in the radial (birdcaging) or lateral direction caused by axial compression (true wall compression), associated or not with pipe bending, twist, or torsion and affected by the annulus condition (flooded or dry).

3.1.14**burst disk**

Weak points in the outer sheath designed to burst when the gas pressure in the annulus exceeds a specified value.

NOTE The weak point is induced by reducing the thickness of the sheath over a localized area.

3.1.15**carcass**

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

NOTE The carcass may be used externally to protect the external surface of the pipe; this is referred to as "abrasion protection."

3.1.16**choke and kill line jumpers**

Flexible pipe jumper located between a marine drilling riser steel choke line and kill line and blowout preventer.

3.1.17**connector**

Device used to provide a leak-tight structural connection between the end fitting and adjacent piping. Connectors include bolted flanges, clamped hubs, and proprietary connectors.

NOTE They may be designed for diver-assisted makeup or for diverless operation using either mechanical or hydraulic apparatus.

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**crushing loads**

Compressive guidance-induced loads or localized compressive loads imposed on the pipe during its installation (laying or retrieval operations) by typical laying equipment such as tensioners, wheel, sheave, chute, gutter, and handling collars or during the operating conditions where the line is bent under tension onto a radius such as J-tube bend, bellmouth, and mid-water arch gutter.

3.1.20**design differential pressure**

The difference between design external pressure and design pressure.

NOTE Design pressure is defined in 4.4.2.

3.1.21**design external pressure**

Maximum external pressure applied to a pipe during installation, operation, or retrieval, after considering tidal and wave effects, which is the maximum pressure acting external to a sheath layer.

NOTE It can be either the full external pressure or the maximum annulus pressure acting on a sheath, whichever is larger.

3.1.22

design methodology

A consistent approach to the design of a component or system.

3.1.23

design methodology verification report

Evaluation report prepared by an independent verification agent (IVA) at the time of an initial review, 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.

3.1.24

design tension

Maximum tensile load applied to a pipe during installation, operation, or retrieval, after considering the associated internal fluid density and pressure.

3.1.25

differential pressure

The difference between the local internal pressure and the external hydrostatic pressure at each cross section.

3.1.26

dry conditions

Tested in air at conditions defined by the international standard atmosphere.

3.1.27

dynamic application

Service in which flexible pipe is exposed to a large number of cyclically varying loads and deflections during permanent operation.

3.1.28

end fitting

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

3.1.29

event, abnormal operation

An event due to infrequent loads (e.g. pressures in excess of the design, accidental conditions).

3.1.30

event, extreme operation

An event that produces responses having a low probability of being exceeded in the lifetime of the riser [e.g. an event with a return period (RP) of 100 years].

3.1.31

event, extreme temporary

An event of short duration due to infrequent loads (e.g. pressures and environments in excess of operating plan, accidental conditions).

3.1.32

event, normal operation

An event such as plan of operation; normal; in-place pressure testing; connected operation; and integrity, maintenance, and repair.

3.1.33**event, normal temporary**

An event of limited duration, such as transport, installation, retrieval, and field test.

3.1.34**event, survival**

An event involving conditions that exceed extreme design events where fluid containment is just maintained (i.e. material strength utilization is permitted to reach unity).

3.1.35**fishscaling**

Tendency of a wire or strip to not lay flat against the underlying layer, often caused by improper preforming during armor winding. Fishscaling can occur in the tensile armor, pressure armor, or carcass layers.

3.1.36**flexible flowline**

Flexible pipe, wholly or in part, resting on the seafloor or buried below the seafloor, and used in a static application. The term flowline is used in this document as a generic term for flexible flowlines.

3.1.37**flexible pipe****pipe**

Assembly of a pipe body and end fittings where the pipe body is composed of 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 composed of metallic and polymer layers.

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

3.1.38**flexible riser**

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

3.1.39**independent verification agent****IVA**

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.

3.1.40**insulation layer**

Additional layer added to the flexible pipe to increase the thermal insulation properties, usually located between the outer tensile armor layer and the outer sheath.

3.1.41**intermediate sheath**

Extruded polymer layer located between internal pressure and outer sheaths, which may be used:

- as a barrier to external fluids in smooth bore pipes;
- as an antiwear layer;

- as a barrier from external fluids for insulation layers, avoiding water absorption and creep and thus avoiding reduction in the pipe thermal exchange coefficient (TEC); or,
- in avoiding flooding of an inner annulus when an outer annulus is flooded due to an outer sheath breach.

3.1.42**internal pressure sheath**

Polymer layer excluding any sacrificial layers that ensures internal-fluid integrity. This layer may consist of a number of sublayers, excluding sacrificial layers.

3.1.43**jumper**

Short flexible pipe used in subsea and topside, static, or dynamic applications. Dynamic topside jumpers also includes the class of flexible pipe whose dynamic response derives from vessel motion only (e.g. turret applications).

3.1.44**lateral buckling**

Failure mode of a flexible pipe often associated with a combination of reverse end-cap loading and localized dynamic bending, whereby the tensile armor wires buckle in the lateral or in-plane direction.

3.1.45**lay angle**

Angle between the axis of a spiral wound element (e.g. armor wires) and a line parallel to the flexible pipe longitudinal axis.

3.1.46**laying tension**

Maximum tensile load to which the pipe shall be subjected during installation or retrieval operations.

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**new pipe design**

A 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.

3.1.51**operation plan**

Purchaser-specified plan of operation for the flexible pipe.

3.1.52**outer sheath**

Polymer layer used to protect the pipe against penetration of seawater and other external environments, corrosion, abrasion, and mechanical damage. This layer may consist of a number of sublayers.

3.1.53**ovalization**

Out-of-roundness of the pipe, 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.

3.1.54**overall heat transfer coefficient****OHTC**

A 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

3.1.55**permanent operation**

Operational condition in which pipe is only subjected to frequent loading and where pressures are less than or equal to the design pressure.

3.1.56**piggyback**

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

3.1.57**pipe concept**

A pipe concept 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.

3.1.58**pressure armor layer**

Structural layer with a lay angle close to 90° that increases the resistance of the flexible pipe to internal and external pressure and mechanical crushing loads; structurally supports the internal pressure sheath; and typically consists of an interlocked metallic construction, which may be reinforced by an overlying flat metallic spiral layer.

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**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.

3.1.61**quality**

Conformance to specified requirements.

3.1.62**quality assurance**

Planned, systematic, and preventive actions that are required to ensure that materials, products, or services meet specified requirements.

3.1.63**quality control**

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

3.1.64**rough bore**

Flexible pipe with a carcass as the innermost layer.

3.1.65**service life**

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

3.1.66**smooth bore**

Flexible pipe with an internal pressure sheath as the innermost layer.

3.1.67**sour service**

Service conditions with a H₂S content exceeding the minimum specified by NACE MR0175.

NOTE 1 Sour service condition in the bore does not always lead to sour service conditions in the pipe annulus.

NOTE 2 Design pressure is used to assess bore conditions; operating pressure is used to assess annulus condition.

3.1.68**static application**

Flexible pipes not exposed to significant cyclically varying loads or deflections during permanent operations.

3.1.69**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.

3.1.70**sweet service**

Service conditions that have a H₂S content less than that specified by NACE MR0175.

3.1.71**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).

3.1.72**tensile armor layer**

Structural layer with a lay angle typically between 20° and 55°, which consists of helically wound metallic wires and is used to sustain, totally or partially, tensile loads and internal pressure.

NOTE Tensile armor layers are typically counter-wound in pairs.

3.1.73**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.

3.1.74**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.

NOTE The TEC is typically determined for conditions corresponding to the design water depth and steady state annulus environment (intact and seawater flooded) and accounting for water absorption in the insulation layers.

3.1.75**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.

3.1.76**torsional limp stiffness**

The ability of a flexible pipe to resist twist, at constant tension, when subjected to torsion loads applied in the opposite direction to the lay angle of the outermost tensile armors.

3.1.77**true wall force**

The axial force acting in the pipe wall.

3.1.78**unbonded flexible pipe**

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

3.2 Acronyms, Abbreviations, and Symbols

CIV	corrected inherent viscosity
DSC	differential scanning calorimeter
FAT	factory acceptance test
HAZ	heat-affected zone
HIC	hydrogen-induced cracking
HV	hardness on Vickers scale
ID	internal diameter
IPU	integrated pipe umbilical
IVA	independent verification agent
LR	locking radius

MBR	minimum bending radius
MPI	magnetic particle inspection
NDE	nondestructive examination
OBR	operating bend radius
OD	outer diameter
OHTC	overall heat transfer coefficient
OLT	offshore leak test
PA	polyamide
PE	polyethylene
PSL	product specification level
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
RAO	response amplitude operator
RP	return period
SIT	structural integrity test
S-N	curves showing stress range vs number of cycles
SR	storage minimum bend radius
SSC	sulfide stress cracking
TAN	titrated acid number
TEC	thermal exchange coefficient
TFL	through flowline
TPE	thermo-plastic elastomer
UHB	upheaval buckling
UV	ultraviolet
WPS	welding procedure specification
XLPE	crosslinked polyethylene
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

4 Functional Requirements

4.1 General

The purchaser shall specify the functional requirements for the flexible pipe. The purchasing guidelines in Annex B give a sample format for the specification of the functional requirements.

Functional requirements not specifically required or not specified by the purchaser and that can affect the design, materials, manufacturing, and testing of the pipe shall be specified by the manufacturer and submitted to the purchaser.

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

4.2 Overall Requirements

4.2.1 Flexible Pipe

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

- a) the pipe shall provide a leak-tight conduit,
- b) the pipe shall be capable of withstanding all design loads and load combinations defined in Section 5,
- c) the pipe shall perform its function for the specified service life,
- d) the flexible pipe materials shall be compatible with the environment to which the materials are exposed.

4.2.2 End Fitting

The manufacturer shall demonstrate that the end fittings, which are an integral part of the flexible pipe, also meet the following:

- a) the end fitting shall provide a structural interface between the flexible pipe and the support structure;
- b) when applicable, 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.

4.3 General Design Parameters

The purchaser shall specify any project-specific design requirements, including the requirements of 4.4 to 4.6 and the following:

- a) nominal internal diameter (ID);
- b) length and length tolerances of flexible pipe, including end fittings—whether length tolerance is defined symmetrically around nominal or skewed to either side should depend on the criticality for the system;
- c) service life.

4.4 Internal Fluid Parameters

4.4.1 General

The purchaser shall specify the internal fluid parameters for the application. The parameters listed in Table 1 shall be specified. Expected variations in the internal fluid parameters over the service life shall be specified.

Table 1—Internal Fluid Parameters

Parameter	Comment
Internal pressure	See 4.4.2
Temperature	See 4.4.3
Fluid composition	See 4.4.4
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

4.4.2 Internal Pressure Definitions

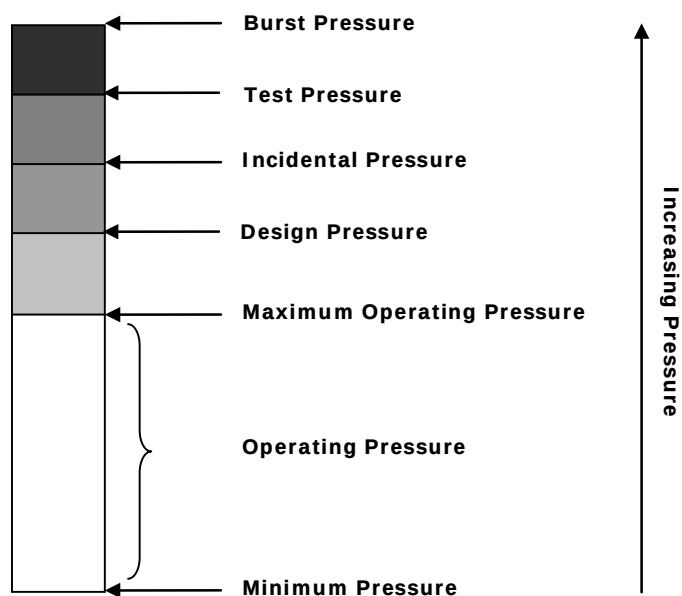
The internal pressures that are relevant to the design, testing, and operation of an unbonded flexible pipe are defined in Figure 1 and Table 2.

The following internal pressures shall be specified by the purchaser:

- a) design pressure,
- b) maximum operating pressure,
- c) incidental pressure.

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

- a) operating pressure profiles along the pipe and through the service life;
- b) system design pressure;
- c) FAT, OLT, and offshore SIT pressure requirements of the purchaser and/or governing certifying authorities;
- d) maximum pressurization rate;
- e) maximum depressurization rate or profile change with time;
- f) 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);
- g) minimum pressure (vacuum pressure if relevant).



4.4.3 Temperature Definitions

The internal temperatures that are relevant to the design, testing, and operation of an unbonded 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.

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

- a) upset temperatures (number and range of cycles);
- b) gas-cooling effects (time/temperature curve);
- c) fluid thermal characteristics;
- d) flow characteristics;
- e) storage, transport, and installation conditions;
- f) 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 or not to the pressure cycles).

Table 2—Internal Pressure Definitions

Pressure ⁽¹⁾	Definition
Minimum pressure	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 ⁽²⁾ , 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 1.1 times the design pressure.
Test 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 times the design pressure for flexible risers and topside jumpers and 1.3 times the design pressure for flexible flowlines and subsea jumpers. If applicable, the maximum differential pressure can be used instead of 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 times either (a) the design pressure of the pipe or (b) system design pressure, whichever is lower.
SIT (on-board integrity test) ⁽³⁾	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 integrity test) ⁽⁴⁾	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 times 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.
NOTE 1 The pressure can be a function of location along the pipe and/or time. NOTE 2 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. NOTE 3 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. NOTE 4 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.	

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 ⁽³⁾ normal operation
Design temperature	The maximum and minimum internal temperature to which the pipe is subjected during permanent ⁽³⁾ operation
Incidental ⁽²⁾ temperature	The maximum and minimum internal temperature that is unlikely to be exceeded during the life of the pipe
NOTE 1 At the inner surface of the pipe.	
NOTE 2 Incidental temperatures should be specified on the basis of abnormal operating considerations, including unplanned transient events.	
NOTE 3 "Permanent" operating conditions are defined in Table 6.	

4.4.4 Fluid Composition

The purchaser shall specify produced fluids (composition of individual phases), injected fluids, and continual and occasional chemical treatments (dosages, exposure times, concentrations, and frequency). In the specification of the internal fluid composition, the following shall be defined:

- a) all parameters that define service conditions (for a reference condition), including partial pressure (or concentration; include information about location, temperature and pressure for specified data) of H₂S and CO₂, organic acids (formic, acetic, propanoic), pH of aqueous phase in situ, titrated acid number (TAN) (in accordance with ASTM D664 or ASTM D974), and water content and ionic composition (produced water, seawater, and free water);
- b) gases, including oxygen, hydrogen, methane, and nitrogen;
- c) liquids, including oil composition, alcohols, and produced water ionic composition;
- d) aromatic components;
- e) corrosive agents, including bacteria, chlorides, organic acids, and sulphur-bearing compounds;
- f) injected chemical products, including alcohols and inhibitors for corrosion, hydrate, paraffin, scale, and wax (including concentrations of dissolved oxygen);
- g) solids, including sand, precipitates, scale, hydrates, wax, and biofilm.
- h) drilling, completion, or workover fluids (including concentrations of dissolved oxygen).

4.5 External Environment

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

4.6 System Requirements

4.6.1 Minimum System Requirements

4.6.1.1 General

The purchaser shall specify the system functional requirements of the project. Annex B may be referenced for guidelines. Unless otherwise stated in 4.6.1, the minimum system requirements in 4.6.1.2 to 4.6.1.12 shall be specified by the purchaser.

4.6.1.2 Application Definition

The flexible pipe system shall be specified including flowline, riser or jumper, and ancillaries. The flexible pipe application shall be specified as either static or dynamic, and the expected number of load cycles and magnitudes should be specified for dynamic cases. The flexible pipe global configuration shall be specified.

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, 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
Backfill or cover soil	Description of backfill and cover material type, density, and significant properties for use in UHB or related calculations and analysis
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

4.6.1.3 Corrosion Protection

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

- end fitting internal and external corrosion protection;
- cathodic protection system for the pipe;
- protection voltage, current source, and current density;
- 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.

4.6.1.4 Thermal Insulation

Performance requirements of the flexible pipe for heat loss or retention shall be specified. OHTC's 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.

4.6.1.5 Gas Venting

The purpose of a gas-venting system is to prevent excessive pressure buildup in the annulus of the pipe. If gas venting is required, the following shall be specified:

- a) gas-venting system components;
- b) vented gas flow rate
- c) restrictions on gas-venting locations;
- d) interface requirements;
- e) gas-monitoring system;
- f) underwater vent valves, as applicable;
- g) back pressure of the vent system to which the pipe is connected;
- h) integrity inspection of annulus.

4.6.1.6 Pigging and Through Flowline (TFL) Requirements

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

4.6.1.7 Fire Resistance

The purchaser shall specify whether fire resistance is required. If required, the following information should be specified:

- a) fire temperature, source, and surrounding material;
- b) need to extinguish or cool the pipe structure;
- c) fire-extinction method;
- d) duration required for pipe survivability;
- e) transported medium;
- f) heated steel in contact with polymeric material in the flexible pipe;
- g) pipe-abandonment facility and its fire protection capability;
- h) pipe function;
- i) flashpoint of transported medium in the event of a leak;
- j) depressurization time.

4.6.1.8 Piggyback Lines

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

4.6.1.9 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.

4.6.1.10 Interface Definitions

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

- a) regulations, codes, and standards, including definition of code breaks;
- b) geometric, dimensional, and imposed loading data;
- c) purchaser-supplied installation aids and equipment;
- d) purchaser-supplied pull-in and connection tools and terminations;
- e) vessel/platform interface structures such as I-tubes and bellmouths;
- f) interfacing subsea equipment such as christmas tree and manifolds;
- g) manufacturer scope of supply.

4.6.1.11 Inspection and Condition Monitoring

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

4.6.1.12 Shipping, Storage, and Handling

Any requirements for shipping, storage, and handling with respect to all conditions, facilities, equipment, and procedures involved shall be specified.

4.6.1.13 Installation and Retrieval Requirements

Performance requirements for installation and retrieval services to be provided shall be specified, considering the following as a minimum.

- a) For installation/retrieval by the purchaser, the purchaser shall specify any requirements on load restrictions, clamping/tensioner loads and dimensions, vessel motions, overboarding chute or wheel requirements, installation tolerances, and port facility limitations, as well as transpooling between different vessels.
- b) For installation/retrieval by the manufacturer, the purchaser shall specify any requirements for season, environment, vessel limitations, installation tolerances, restrictions due to conflicting activities and installation scope (including trenching, burial, testing, inspection, surveying, and documentation), installation and retrieval with empty or flooded pipe, and number of foreseen installation and retrieval operations.

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

4.6.1.14 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:

- a) flow rate,
- b) pressure variation,
- c) maximum heat output,
- d) chemical composition,
- e) maximum temperature reached by the chemical reaction,
- f) temperature profile along pipe,
- g) duration of the cleaning operation,
- h) number of cleaning operations to be performed during pipe service life.

4.6.2 Flowline and Riser Parameters

Requirements for design and analysis of the flowline and riser (or jumpers) 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.

5 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 in Annex B), with reference to the requirements of Section 4.

5.1.2 Definition of Load Classes

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.

The design load cases shall be defined to analyze, as applicable, the effect on the flexible pipe of functional, environment, and accidental loads. See API 17B for guidelines on the analysis techniques to be used for the loads given in Table 7.

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 5.1.3. All loads that act on the flexible pipe shall be evaluated for the load conditions specified in Table 6. Variation of the loads in time and space and 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. 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.