INTERNATIONAL STANDARD

ISO 13628-2

Second edition
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Petroleum and natural gas industries — Design and operation of subsea production systems —

Part 2: Unbonded flexible pipe systems for subsea and marine applications

Industries du pétrole et du gaz naturel — Conception et exploitation des systèmes de production immergés —

Partie 2: Systèmes de canalisations flexibles non collées pour applications sous-marines et en milieu marin

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13628-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

This second edition cancels and replaces the first edition (ISO 13628-2:2000), which has been technically revised.

ISO 13628 consists of the following parts, under the general title *Petroleum and natural gas industries — Design and operation of subsea production systems*:

— *Part 1: General requirements and recommendations*

— *Part 2: Unbonded flexible pipe systems for subsea and marine applications*

— *Part 3: Through flowline (TFL) systems*

— *Part 4: Subsea wellhead and tree equipment*

— *Part 5: Subsea umbilicals*

— *Part 6: Subsea production control systems*

— *Part 7: Completion/workover riser systems*

— *Part 8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems*

— *Part 9: Remotely Operated Tool (ROT) intervention systems*

— *Part 10: Specification for bonded flexible pipe*

— *Part 11: Flexible pipe systems for subsea and marine applications*

The following parts are under development:

— *Part 12 dealing with dynamic production risers*

— *Part 13 dealing with remotely operated tools and interfaces on subsea production systems*

Introduction

This part of ISO 13628 is based on API Specification 17J, *Specification for unbonded flexible pipe*, Second edition, November 1999, and the Amendment issued June 2002. This part of ISO 13628 has been technically revised and updated to cater to the needs of the international oil and natural gas industries.

Users of this part of ISO 13628 should be aware that further or differing requirements might be needed for individual applications. This part of ISO 13628 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 part of ISO 13628 and provide details.

Petroleum and natural gas industries — Design and operation of subsea production systems —

Part 2: Unbonded flexible pipe systems for subsea and marine applications

1 Scope

This part of ISO 13628 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 ISO 13628-11 for guidelines on the use of flexible pipes and ancillary components.

This part of ISO 13628 applies to unbonded flexible pipe assemblies, consisting of segments of flexible pipe body with end fittings attached to both ends. This part of ISO 13628 does not cover flexible pipes of bonded structure. This part of ISO 13628 does not apply to flexible pipe ancillary components. Guidelines for bend stiffeners and bend restrictors are given in Annex B.

NOTE 1 Guidelines for other components are given in ISO 13628-11.

This part of ISO 13628 does not apply to flexible pipes that include non-metallic tensile armour wires. Pipes of such construction are considered as prototype products subject to qualification testing.

The applications addressed by this part of ISO 13628 are sweet and sour service production, including export and injection applications. Production products include oil, gas, water and injection chemicals. This part of ISO 13628 applies to both static and dynamic flexible pipes used as flowlines, risers and jumpers. This part of ISO 13628 does not apply to flexible pipes for use in choke-and-kill line applications.

NOTE 2 See API Specification 16C for choke-and-kill line applications.

NOTE 3 ISO 13628-10 provides guidelines for bonded flexible pipe.

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.

ISO 62, *Plastics — Determination of water absorption*

ISO 75-1, *Plastics — Determination of temperature of deflection under load — Part 1: General test method*

ISO 75-2, *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite*

ISO 178, *Plastics — Determination of flexural properties*

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

ISO 180, *Plastics — Determination of Izod impact strength*

ISO 306, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*

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 868, *Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness)*

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

ISO 974, *Plastics — Determination of the brittleness temperature by impact*

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 8457-2, *Steel wire rod — Part 2: Quality requirements for unalloyed steel wire rods for conversion to wire*

ISO 8692, *Water quality — Freshwater algal growth inhibition test with unicellular green algae*

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

ISO 10423:2003, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and christmas tree equipment*

ISO 10474:1991, *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 13628-4, *Petroleum and natural gas industries — Design and operation of subsea production systems — Part 4: Subsea wellhead and tree equipment*

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

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*

API [1)] Spec 16C, *Specification for Choke and Kill Systems*

ASME [2)] Boiler and Pressure Vessel Code, Section IX, "*Welding and Brazing Qualifications*"

ASTM [3)] A29, *Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for*

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1) American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005, USA

2) American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA

3) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428, USA

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

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

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

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

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 D1693, *Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics*

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 E94, *Standard Guide for Radiographic Examination*

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

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

ASTM E428, *Standard Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Examination*

ASTM E709, *Standard Guide for Magnetic Particle Examination*

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 [4] Fire Test, *DNV Classification Note 6.1 Test (Fire Test)*

EN [5] 287-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

EN 288-1, *Specification and approval of welding procedures for metallic materials Part 1: General rules for fusion welding*

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4) Det Norske Veritas, Veritasveien 1, 1322 Høvik, Norway

5) European Committee for Standardization, CEN Management Centre, 36, rue de Stassart, B-1050, Brussels

EN 288-2, *Specification and approval of welding procedures for metallic materials Part 2: Welding procedure specification for arc welding*

EN 288-3, *Specification and approval of welding procedures for metallic materials Part 3: Welding procedure tests for the arc welding of steels*

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

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

NACE [7] TM 01-77, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments*

3 Terms and definitions

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

3.1
ancillary components
components used to control the flexible pipe behaviour, such as bend stiffeners and buoyancy modules

3.2
annulus
space between the internal pressure sheath and outer sheath

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

3.3
anti-wear layer
non-metallic layer, either extruded thermoplastic sheath or tape wrapping, used to minimize wear between structural layers

3.4
bellmouth
part of a guide tube, formed in the shape of a bellmouth, and designed to prevent overbending of the flexible pipe

3.5
bend limiter
any device used to restrict bending of the flexible pipe

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

3.6
bend radius
radius of curvature of the flexible pipe measured from the pipe centreline

NOTE Storage and operating minimum bend radius (MBR) are defined in 6.3.1.

3.7
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

6) Lloyd's Register EMEA, 71 Fenchurch Street, London, EC3M 4BS, United Kingdom

7) NACE International, 1440 South Creek Drive, Houston, Texas 77084-4906 USA

3.8
bend stiffener
ancillary conical shaped component, which locally supports the pipe to limit bending stresses and curvature of the pipe to acceptance levels

NOTE Bend stiffeners can be either attached to an end fitting or a support structure where the flexible pipe passes through the bend stiffener.

3.9
bending stiffness
ability of a flexible pipe to resist deflection when subjected to bending loads at constant tension, pressure and temperature

3.10
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

3.11
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.

3.12
carcass
interlocked metallic construction that can be used as the innermost layer to prevent, totally or partially, collapse of the internal pressure sheath or pipe due to pipe decompression, external pressure, tensile armour pressure, and mechanical crushing loads

NOTE The carcass may be used externally to protect the external surface of the pipe.

3.13
choke-and-kill line
flexible pipe jumper located between choke manifold and blow-out preventer

3.14
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 may be designed for diver-assisted makeup or for diverless operation using either mechanical or hydraulic apparatus.

3.15
crossover
flexible flowline crossing another pipe already laid on the seabed

NOTE The underlying pipe may be a steel pipe or another flexible pipe. It may be required to support the overlying pipe to prevent overbending or crushing of the new or existing pipes.

3.16
design methodology verification report
evaluation report prepared by an independent verification agent at the time of an initial review, for a specific manufacturer, confirming the suitability and appropriate limits on the manufacturer’s design methodologies

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

3.17
design pressure
minimum or maximum pressure, inclusive of operating pressure, surge pressure including shut-in pressure where applicable, vacuum conditions and static pressure head

3.18
dynamic application
flexible pipe configuration that is subjected to loads that vary in time, or whose deflections or boundary conditions vary in time

3.19
end fitting
mechanical device which forms the transition between the flexible pipe body and the connector whose different pipe layers are terminated in the end fitting in such a way as to transfer the load between the flexible pipe and the connector

3.20
fishscaling
tendency of one tensile armour wire edge to lift off of the underlying layer because of deflection or incorrect twist deformation during armour winding

3.21
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 flowlines.

3.22
flexible 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 without a significant increase in bending stresses

NOTE Normally the pipe body is built up as a composite structure composed of metallic and polymer layers. The term “pipe” is used in this document as a generic term for flexible pipe.

3.23
flexible riser
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)

3.24
independent verification agent
independent party or group, selected by the manufacturer, who can verify the indicated methodologies or performance based on the technical literature, analyses, and test results and other information provided by the manufacturer

NOTE The agent is also called upon to witness some measurements and tests related to material qualification.

3.25
insulation layer
additional layer added to the flexible pipe to increase the thermal insulation properties, usually located between the outer tensile armour layer and the outer sheath

3.26
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 or as an anti-wear layer

3.27
internal pressure sheath
polymer layer that ensures internal-fluid integrity

NOTE This layer may consist of a number of sub-layers.

3.28
jumper
short flexible pipe used in subsea and topside, static, or dynamic applications

3.29
lay angle
angle between the axis of a spiral wound element (for example, armour wires) and a line parallel to the flexible pipe longitudinal axis

3.30
outer sheath
polymer layer used to protect the pipe against penetration of seawater and other external environments, corrosion, abrasion and mechanical damage, and to keep the tensile armours in position after forming

3.31
piggyback
two pipes attached at regular intervals with clamps, where either or both of the pipes can be flexible

3.32
pressure armour 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 backed up by a flat metallic spiral layer

3.33
quality
conformance to specified requirements

3.34
quality assurance
planned, systematic, and preventive actions that are required to ensure that materials, products, or services meet specified requirements

3.35
quality control
inspection, test or examination to ensure that materials, products or services conform to specified requirements

3.36
quality programme
established documented system to ensure quality

3.37
rough bore
flexible pipe with a carcass as the innermost layer

3.38
service life
period of time during which the flexible pipe fulfils all performance requirements

3.39
smooth bore
flexible pipe with an internal pressure sheath as the innermost layer

3.40
sour service
service conditions at the design pressure with a H_2S content exceeding the minimum specified by ISO 15156 (all parts)

3.41
static application
flexible pipes not exposed to significant cyclically varying loads or deflections during normal operations

3.42
sweet service
service conditions at the design pressure which have a H_2S content less than that specified by ISO 15156 (all parts)

3.43
tensile armour 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 armour layers are typically counter-wound in pairs.

3.44
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

3.45
ultimate strength
maximum tensile stress that a material can withstand before rupture

3.46
unbonded flexible pipe
pipe construction consists of separate unbonded polymeric and metallic layers, which allows relative movement between layers

3.47
visual examination
examination of parts and equipment for visible defects in material and workmanship

3.48
yield strength
stress level at which a metal or other material ceases to behave elastically

4 Symbols and abbreviated terms

DSC	differential scanning calorimetry
FAT	factory acceptance test
GA	general arrangement
HAZ	heat-affected zone
HIC	hydrogen-induced cracking
HV	hardness on Vickers Scale
ID	internal diameter
MBR	minimum bend radius
NDE	non-destructive examination
PA	polyamide
PE	polyethylene
PSL	production specification level
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
RAO	response amplitude operator
SSC	sulfide stress cracking
S-N	curves showing stress range vs. number of cycles
TAN	titrated acid number
TFL	through-flowline
UNS	Unified National Standard or Unified Numbering System
UV	ultraviolet
σ_{y}	material yield stress
σ_{u}	material ultimate stress

5 Functional requirements

5.1 General

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

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

5.1.3 If the purchaser does not specify a requirement, and 5.1.2 does not apply, the manufacturer may assume that there is no requirement.

5.2 Overall requirements

5.2.1 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 herein.

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 material is exposed.

e) The flexible pipe materials shall conform to the corrosion control requirements specified herein.

5.2.2 End fitting

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

a) The end fitting shall provide a structural interface between the flexible pipe and the support structure.

b) 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.

5.3 General design parameters

The purchaser shall specify any project-specific design requirements, including the requirements of 5.4 to 5.6 and the following:

a) nominal internal diameter;

b) length and tolerances of flexible pipe, including end fittings;

c) service life.

Purchasing guidelines are given in Annex A.

5.4 Internal fluid parameters

5.4.1 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 shall be specified for the internal fluid parameters of Table 1. Expected variations in the internal fluid parameters over the service life shall be specified.

Table 1 — Internal fluid parameters

Parameter	Comment
Internal pressure	See 5.4.2
Temperature	See 5.4.3
Fluid composition	See 5.4.4
Service definition	Sweet or sour in accordance with 5.4.4 a)
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

5.4.2 Internal pressure

5.4.2.1 The following internal pressures shall be specified:

a) maximum design pressure;

b) minimum design pressure.

5.4.2.2 The following internal pressures should be specified:

a) operating pressure or pressure profile through service life;

b) factory and field-test pressure requirements of governing and/or certifying authorities.

5.4.3 Temperature

5.4.3.1 The following temperatures shall be specified:

a) design minimum temperatures;

b) design maximum temperatures.

The operating temperature or temperature profiles through the service life should be specified.

5.4.3.2 The design minimum and maximum temperatures are the minimum and maximum temperatures that can be experienced by the flexible pipe throughout the service life. These design temperatures may be specified on the basis of the following minimum set of considerations:

a) operating temperatures;

b) upset temperatures (number and range of cycles);

c) gas-cooling effects (time/temperature curve);

d) fluid thermal characteristics;

e) flow characteristics;

f) storage, transport and installation conditions.

5.4.4 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). In the specification of the internal fluid composition, the following should be defined:

a) all parameters that define service conditions, including partial pressure of H_2S and CO_2, pH of aqueous phase, TAN (in accordance with ASTM D664 or ASTM D974), and water content (produced water, seawater, and free water);

b) gases, including oxygen, hydrogen, methane, and nitrogen;

c) liquids, including oil composition and alcohols;

d) aromatic components;

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

f) injected chemical products including alcohols and inhibitors for corrosion, hydrate, paraffin, scale, and wax;

g) solids, including sand, precipitates, scale, hydrates, wax, and biofilm.

5.5 External environment

The purchaser should specify the project external environmental parameters. The parameters listed in Table 2 should be considered. The design water depth shall be the maximum water depth to which the pipe section may be exposed.

Table 2 — 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, 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, sand waves and variations along pipe route
Marine growth	Maximum values and variations along length
Ice	Maximum ice accumulation or drifting icebergs and ice floes
Sunlight exposure	Length of pipe exposed during operation and storage conditions
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

5.6 System requirements

5.6.1 Minimum system requirements

5.6.1.1 General

5.6.1.1.1 The purchaser shall specify the system functional requirements of the project. The requirements of 5.6.1.2, 5.6.1.9, and 5.6.1.10 shall be specified by the purchaser. Specification of the other system requirements defined in Clause 5 should be considered. Annex A may be referenced for guidelines.

5.6.1.1.2 The purchaser should specify the documentation, as listed in Clause 9, to be delivered by the manufacturer.

5.6.1.2 Application definition

The flexible pipe system shall be specified as either flowline, riser or jumper. 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.

5.6.1.3 Corrosion protection

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

a) end fitting internal and external corrosion protection;

b) cathodic protection system for the pipe;

c) protection voltage, current source and current density.

5.6.1.4 Thermal insulation

The purchaser should specify any performance requirements of the flexible pipe for heat loss or retention. Overall heat transfer coefficients 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.

5.6.1.5 Gas venting

A gas-venting system shall be required to prevent excessive pressure build-up in the annulus of the pipe. Requirements the purchaser has for the gas-venting system should be specified, considering the following:

a) gas-venting system components;

b) allowable gas permeation rates;

c) restrictions on gas-venting locations;

d) interface requirements;

e) gas-monitoring system.

5.6.1.6 Pigging and 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 should be specified.

5.6.1.7 Fire resistance

Fire resistance requirements for the pipe design should be specified, with reference to Lloyds or DNV fire test requirements (see 6.4.6.1).

5.6.1.8 Piggyback lines

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

5.6.1.9 Connectors

The connector requirements for both end fittings in the flexible pipe shall be specified. This shall include, as a minimum, connector type, welding specification, seal type, and sizes.

5.6.1.10 Interface definitions

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

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) manufacturer scope of supply.

5.6.1.11 Inspection and condition monitoring

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

5.6.1.12 Installation requirements

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

a) For installation by the purchaser, he or she should specify any requirements on load restrictions, clamping/tensioner loads, overboarding chute requirements, installation tolerances and port facility limitations.

b) For installation by the manufacturer, the purchaser should specify for 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).

5.6.1.12.2 The purchaser should specify any requirements for recoverability and reusability of the flexible pipe within its service life.

5.6.1.13 Exothermal chemical reaction cleaning

The purchaser should specify the relevant parameters for the pipe-cleaning operations by means of exothermal chemical reaction, considering the following as a minimum:

a) flow rate;

b) pressure variation;

c) maximum heat output;

d) chemical composition.

5.6.2 Flowline parameters

The purchaser should specify to the manufacturer his requirements for design and analysis of the flowline (or static jumper) system additional to the requirements of Clause 6. The parameters listed in Table 3 should be considered.

5.6.3 Riser parameters

The purchaser shall specify to the manufacturer his requirements for design and analysis of the riser (or dynamic jumper) system additional to the requirements of Clause 6. The parameters listed in Table 4 should be considered.

Table 3 — Flowline parameters

Parameter	Details
Flowline routing	Route drawings, topography, seabed/soil conditions, obstacles, and installed equipment and pipelines
Guides and supports	Proposed geometry of guides, I-tubes, J-tubes, and bellmouths through which flowline is to be installed
Protection requirements	Trenching, rock dumping, mattresses, and extent of protection requirements over length of pipe. Design impact loads, including those from trawl boards, dropped objects, and anchors
On-bottom stability	Allowable displacements
Upheaval buckling	Specification of design cases to be considered by manufacturer
Crossover requirements	Crossing of pipes (flexible and rigid), including already installed pipes and gas lines
Pipe attachments	Bend restrictors, clamps, and attachment methods
Load cases	Definition of yearly probability for installation and normal and abnormal operation. Specification of accidental load cases and yearly probabilities

Table 4 — Riser parameters

Parameter	Details
Riser configuration	Specification of any requirements for the configuration, including description (lazy-S, steep wave, etc.), layout and components. Selection of configuration or confirmation of suitability of specified configuration
Connection systems	Descriptions of upper and lower connection systems, including quick disconnection systems and buoy disconnection systems, connection angles and location tolerances
Pipe attachments	Bend stiffeners, buoys, etc., and attachment methods
Attached vessel data	Data for attached floating vessels, including the following: a Vessel data, dimensions, drafts, and the like; b Static offsets; c First (RAOs) and second order motions; d Vessel motion phase data; e Vessel motion reference point; f Mooring system interface data; g Position tolerances.
Interference requirements	Specification of possible interference areas, including other risers, mooring lines, platform columns, vessel pontoons, tanker keel, and so on, and definition of allowable interference/clashing
Load cases	Definition of yearly probability for installation, and normal and abnormal operation specification of accidental load cases and yearly probabilities

6 Design requirements

6.1 Loads and load effects

6.1.1 General

The pipe design is based on the information supplied by the purchaser (see guidelines of Annex A), with reference to the requirements of Clause 5. All relevant information shall be defined in the design premise (see 9.2) including design load cases. Results of the design load case analyses shall be included in the design load report (see 9.3).

6.1.2 Definition of load classes

6.1.2.1 Loads are classified as functional, environmental (external), or accidental, defined as follows.

a) Functional loads are all loads on the pipe in operation, including all loads that act on the pipe in still water except wind, wave or current loads.

b) Environmental loads are loads induced by external environmental parameters.

c) Accidental loads are loads caused by accidental occurrences.

Load classes and many subclasses are listed in the left column of Table 5.

6.1.2.2 The design load cases shall be defined to analyse, as applicable, the effect on the flexible pipe of functional, environment, and accidental loads. See ISO 13628-11 for guidelines on the analysis techniques to be used for the loads given in Table 5.

6.1.3 Load combinations and conditions

6.1.3.1 The flexible pipe design shall be shown to meet the design requirements under the load combinations specified in 6.1.3. All loads, including loads specified in 6.1.2.2, that act on the flexible pipe, shall be evaluated. Variation of the loads in time and space, load effects from the flexible pipe system and its supports as well as environmental and soil conditions shall be analysed.

6.1.3.2 The design load conditions that shall be analysed are installation, normal operation (recurrent and extreme), abnormal operation and factory acceptance testing. Load combinations shall be as defined in the notes for Table 5 and the column headings in Table 6. Load combinations with a yearly probability of occurrence less than 10^{-4} can be ignored. Factory acceptance test (FAT) load combinations shall be defined by the manufacturer based on the FAT procedures.

6.1.3.3 Design checks shall be carried out for any temporary conditions specified by the purchaser or the manufacturer. These shall be subject to the same design criteria as the design load conditions, as specified in Table 6.

6.1.3.4 The simultaneous occurrence of different load combinations shall be defined in the manufacturer’s design premise (see 9.2). The probability of specific load classes or subclasses may be specified by the purchaser based on project-specific conditions. The probabilities of accidental and installation-related events should be specified by the purchaser (Tables 3 and 4). If the purchaser does not specify probabilities, the manufacturer shall propose the probabilities that are used for the individual events in the design premise.

6.1.3.5 The design-load cases analysed shall be derived from the loading conditions specified in 6.1.2.2 and the column headings in Table 6.

6.1.4 Design-load effects

6.1.4.1 In the pipe design, the manufacturer shall account for the effects of internal and external pressures. When the external hydrostatic pressure is included in the calculation of the design internal pressure for the pipe, then the manufacturer shall specify the water depth at which the design internal pressure is given. This shall also be specified in the pipe markings (see 11.1).

6.1.4.2 Hydrodynamic load effects shall be determined by validated and documented methods that account for the kinematics of the seawater and the interaction effects of the different environmental phenomena. See ISO 13628-11 for guidelines on analysis methods.

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

6.1.4.4 Any accidental loads or combinations thereof can damage or render unfit for service a flexible pipe. Load cases that include accidental loads (e.g., increased offsets due to anchor line or thruster failures) and do not violate the requirements of Table 6, define a limit on the safe occurrence of the accidental loads. Some accidental loads (e.g., fire and explosion) might not be easily analysed in terms of the requirements in Table 6. In such cases, testing shall be used to define safe working times of other limits associated with the accidental load.

6.2 Pipe design methodology

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

a) description of theoretical basis, including calculation procedures for the pipe design parameters required for the design report, as specified in 9.4;

b) calculation method for all pipe layers and components;

c) verification of the theoretical basis with prototype tests. The verification shall include the capacity of all pipe structural layers. Simplified conservative analysis methods for checking of non-critical layers, such as anti-wear layers, are acceptable if the method does not influence the reliability of the calculation of stresses in the other layers.

d) documented basis for stress concentration factors used for the steel materials, including stress concentrations at and within the end-fitting interface, at clamped accessories and due to contact with rigid surfaces, manufacturing tolerances and load-induced gaps;

e) manufacturing and design tolerances, manufacturing-induced stresses, welds and other effects that influence structural capacity;

f) documentation of the service life methodology, subject to the requirements of 6.3.4.

Table 5 — Load combinations of load classes, load conditions

Load classes and subclasses	Load conditions		
	Normal operation		Abnormal operation
	Recurrent operation	Extreme operation	
Functional loads			
a Loads due to weight and buoyancy of pipe, contents, and attachments, both temporary and permanent.	X	X	X
b Internal pressure as specified in 5.4.2.	Max./Min. operating pressure	Design pressure	Design pressure
c Loads from pressure and temperature variations.	X	X	X
d External pressure.	X	X	X
e External soil or rock reaction forces for trenched, buried, or rock dumped pipes.	X	X	X
f Static reaction and deformation loads from supports and protection structures.	X	X	X
g Temporary installation or recovery loads, including applied tension and crushing loads, impact loads, and guidance-induced loads.	X	X	X
h Residual installation loads, which remain as permanent loads in the pipe structure during service.	X	X	X
i Loads and displacement due to pressure and tension-induced rotation.	X	X	X
j Testing pressures, including installation, commissioning, and maintenance pressures.	As specified by Tables 6 and 7	As specified by Tables 6 and 7	As specified by Tables 6 and 7
k Interaction effects of bundled or clamped pipes.	X	X	X
l Loads due to rigid or flexible pipe crossings, or spans.	X	X	X
m Loads due to positioning tolerances during installation.	X	X	X
n Loads from inspection and maintenance tools.	X	X	X
Environmental loads			
Loads caused directly or indirectly by all environmental parameters specified in Table 2.	Conditions to meet $P_c = 10^{-2}$	Conditions to meet $P_c = 10^{-2}$	Survival conditions
Accidental loads			
Loads and motions caused directly or indirectly by accidental occurrences, including the following:	Not applicable	See [a]	See [b]
1 Dropped objects	"	"	"
2 Trawl board impact	"	"	"
3 Internal over-pressure	"	"	"
4 Compartment damage or unintended flooding	"	"	"
5 Failure of thrusters	"	"	"
6 DP failure	"	"	"
7 Anchor line failure	"	"	"
8 Failure of turret drive system	"	"	"
Environmental loads shall be combined with the operation conditions to the specified probability of occurrence.			

[a] Load combinations of the Functional, Environmental and Accidental Loads tabulated in Table 5, as shown in Table 6, shall be analysed if the yearly combined probability, P_c, of occurrence is equal to or greater than 10^{-2}.

[b] Load combinations, as shown in Table 6, of the functional, environmental and accidental loads tabulated in Table 5, shall be analysed if the yearly combined probability, P_c, of occurrence is between 10^{-2} and 10^{-4}.

Table 6 — Flexible pipe layer design criteria

Flexible pipe layer	Design criteria	Service conditions			Installation		Hydrostatic pressure test — FAT and field acceptance
		Normal operation		Abnormal operation	Functional and environmental	Functional, environmental and accidental	
		Recurrent operation	Extreme operation				
		Functional and environmental	Functional, environmental and accidental	Functional, environmental and accidental			
Internal pressure sheath	Creep	The maximum allowable reduction in wall thickness below the minimum design value due to creep in the supporting structural layer shall be 30 % under all load combinations.					
Internal pressure sheath	Bending Strain	The maximum allowable strain shall be 7,7 % for PE and PA, 7,0 % for PVDF in static applications and for storage in dynamic applications, and 3,5 % for PVDF for operation in dynamic applications. For other polymer materials, the allowable strain shall be as specified by the manufacturer, who shall document that the material meets the design requirements at that strain.					
Internal carcass [a]	Stress bucking load [b]	[0,67] for $D_{max} \leqslant 300$ m $\left[\left(\frac{D_{max}-300}{600}\right)\times 0,18+0,67\right]$ for $300\text{ m} < D_{max} < 900$ m [0,85] for $D_{max} \geqslant 900$ m					
Tensile armours	Stress [c]	0,67	0,85	0,85	0,67	0,85	0,91
Pressure armours	Stress	0,55	0,85	0,85	0,67	0,85	0,91
Outer sheath	Strain	The maximum allowable strain shall be 7,7% for PE and PA. For other polymer materials the allowable strain shall be as specified by the manufacturer, who shall document that the material meets the design requirements at that strain.					

[a] For mechanical loads the permissible utilization of the internal carcass shall be as specified for the pressure armours.

[b] D_{max} is the maximum water depth including tidal and wave effects.

[c] The design criterion for the pressure and tensile armours is permissible utilization as defined in 6.3.1.4.

6.2.2 The independent verification agent shall review and evaluate the design methodology to establish the range of applications for which it is suitable. The independent verification agent shall issue a certificate and a report describing the limits and constraints of the design methodology. The certificate shall be included by the manufacturer in the design report (see 9.4), and the design methodology verification report shall be available for review by the purchaser.

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

6.2.4 It shall be shown that variations in dimensions within manufacturing tolerances do not change utilization values by more than 3 % above the values specified in Table 6.

6.2.5 The calculation of the thickness for all metallic layers shall include allowances for wear and uniform corrosion rates calculated for the service life.

6.2.6 If the pipe design is outside the envelope of previously verified designs, then the manufacturer shall perform sufficient prototype tests to verify the design methodology for this new design and obtain a revision or amendment of the design methodology verification report by an independent verification agent. The prototype tests shall verify fitness-for-purpose for those design parameters which are outside the previously validated envelope. See ISO 13628-11 for guidelines on the tests which should be performed and recommendations on the test procedures.

6.3 Pipe structure design

6.3.1 Design criteria

6.3.1.1 The pipe layers shall be designed to the criteria specified in Table 6, subject to the requirements of Clause 6.

6.3.1.2 The utilization for the internal pressure sheath shall be calculated based on both the maximum allowable creep and maximum allowable strain of the polymer material, subject to the requirements of 6.3.2.1.

6.3.1.3 The utilization for the internal carcass shall be calculated as specified in 6.3.1.4, taking account of the three water-depth ranges defined in Table 6. The manufacturer shall evaluate buckling failure modes in the carcass and pressure armours, and shall confirm by analysis that the layers meet the design requirements. Hydrostatic collapse calculations for the carcass can account for the support provided by the pressure armour layer. The methodology for this calculation shall be documented. When applicable, the manufacturer shall evaluate collapse-failure mode due to pressure build-up between the pressure sheath and the adjacent sacrificial layers and should confirm by analysis that all design requirements are met.

6.3.1.4 The utilization for the pressure and tensile armour layers shall be calculated as

utilization equals stress divided by structural capacity

where stress is the calculated stress in the actual layer. The stress shall be calculated using the design methodology specified in 6.2.1, subject to the design requirements of 6.3.2. The calculated value shall include dynamic loads and be based on average stress in the layer. The average stress shall be calculated based on distributing the total layer load uniformly over all wires in the layer. The structural capacity shall be either the yield strength, or 0,9 times the ultimate tensile strength of the material where tensile testing can accurately identify only this latter property. The yield or ultimate strength value used for design shall be either the mean value minus two standard deviations from the documented test data or the minimum value as certified by the supplier.

6.3.1.5 The utilization for the outer sheath shall be calculated based on the maximum allowable strain, subject to the requirements of 6.3.2.2.

6.3.1.6 The storage minimum bend radius (MBR) shall be calculated as the minimum bend radius that satisfies all the requirements of Table 6. The bend radius required to cause locking in the interlocked layers shall be calculated. The storage MBR shall be at least 1,1 times the MBR to cause locking.

6.3.1.7 The operating MBR for static applications (all loading conditions) shall be a minimum of 1,0 times the storage MBR, and for dynamic applications, (all loading conditions) shall be a minimum of 1,5 times the storage MBR. For dynamic applications the safety factor on operating MBR may be reduced from 1,5 to 1,25 for abnormal operation and normal operation with accidental loads.

6.3.1.8 Fatigue life calculations shall be performed in accordance with the requirements of 6.3.4. The predicted fatigue life shall be at least 10 times the service life. Corrosion analysis (as specified in 6.3.4) shall show that the material loss from corrosion does not cause utilization factors to exceed the criteria of Clause 6 under all load combinations.

6.3.1.9 Reliability-based design may be applied as an alternative design method. All relevant design criteria for the reliability-based design cases should then be considered. It shall be proven that the level of safety obtained is not less than that given by this part of ISO 13628 for comparable design cases.

6.3.2 Design requirements for pipe layers

6.3.2.1 Internal pressure sheath

6.3.2.1.1 As a minimum, the internal pressure sheath shall be analysed for the following load cases:

a) most critical combination of internal pressure, temperature, operating MBR, and polymer condition;

b) hydrotest pressure at ambient temperature and storage MBR.

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

a) creep due to bridging of gaps in the reinforcement layer;

b) stress variations from pressure and temperature cycling caused by the fluids inside the pipe bore and the pipe annulus, including unpressurized-pipe scenarios;

c) contact pressure from the carcass and armour layers;

d) strain due to pipe bending, axial elongation and compression, torsion, and radial expansion;

e) weight of all layers adjacent to the pressure sheath that are not independently supported in the end fitting.

6.3.2.1.3 The methodology used for calculating the wall thickness of the internal pressure sheath shall be validated by documented tests or field experience and shall comply with the following minimum requirements.

a) The gap between pressure armour wires used in the wall thickness calculations shall be the maximum gap while bending to the operating MBR (storage MBR for hydrotest) and accounting for manufacturing tolerances.

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

6.3.2.1.4 The manufacturer shall show through analysis that, with the minimum mechanical properties of the material, maximum gap in the supporting layer and at design maximum temperature and pressure, no failure due to creep of the polymer into gaps in the adjacent metallic layers shall occur.

6.3.2.1.5 For dynamic applications, the manufacturer shall have documented test records to verify that crack initiation, due to notch sensitivity and stress raisers, does not occur in the material used for the internal pressure sheath. This does not apply to sacrificial layers used in multiple internal pressure sheath constructions.

6.3.2.2 Outer sheath

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

6.3.2.3 Intermediate sheath

If an intermediate sheath is designed to prevent leakage of annulus fluid outside the layer or to prevent seawater ingress beyond this layer, then the design of this sheath shall meet the requirements of 6.3.2.1. For dynamic applications, intermediate sheaths shall withstand wear due to relative motion between layers. Wrinkles and cracking due to bending should be avoided.

6.3.2.4 Internal carcass

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

a) collapse with minimum specified internal pressure, maximum external pressure, maximum pipe ovality, and pipe bent to an agreed bend radius. The external pressure shall be either the full external pressure acting on the outside of the internal pressure sheath or the maximum annulus pressure if this exceeds the external pressure.

b) fatigue in the carcass strips;

c) crack growth along the carcass strip due to bending-induced stresses in interlocked spirals. The carcass design shall be in such a way that crack growth shall not occur;

d) loads induced by thermal expansion and contraction, and/or swelling of the internal pressure sheath;

e) erosion and corrosion.

6.3.2.5 Pressure armours

The pressure armours shall be designed for the required hoop strength and shall account for control of gaps between wires and prevention of loss of interlock.

6.3.2.6 Tensile armours

6.3.2.6.1 The tensile armours shall be designed for the required axial strength. The design shall account for any requirements for torsional properties, control of gaps between wires and hoop strength, in particular for pipe designs that do not include pressure armours.

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

6.3.2.7 Additional layers

6.3.2.7.1 Thermal-insulation layers shall be designed in accordance with the requirements of 6.4.3.

6.3.2.7.2 Anti-wear layers shall be designed to meet the requirements of 7.1.2.6 and shall not act as a sealing layer. The consequences of additional stresses occurring in the tensile armour layers due to local failure of the anti-wear layer should be evaluated and documented as an accidental load case.

6.3.2.7.3 Additional external-protection layers, whether polymer or metallic, shall be designed to prevent external damage or wear occurring in the outer sheath, based on the design conditions specified by the purchaser.

6.3.3 End fitting

6.3.3.1 The end fittings shall be designed for reliable termination of all pipe layers, such that leakage, structural deformation or pull-out of wires or extruded layers does not occur for the service life of the pipe, taking account of all relevant factors, including shrinkage, creep, ageing and pressure effects. The end fittings shall be designed for the thermal and pressure cycles defined for the service conditions of the particular dynamic or static application, taking into account all effects listed in 6.3.2.1. The design methodology for end fittings shall be documented and shall be verified by documented tests and analyses. The methodology shall account for manufacturing tolerances. The design shall account for supporting loads from any ancillary components attached to the end fitting, including bend stiffeners.

6.3.3.2 The design of the end fitting shall ensure sealing of both the internal pressure sheath and the outer sheath at the end fitting. The design of the end-fitting crimping/sealing mechanism shall ensure that the combined strain induced by the in-service pull-out forces and installation of the end-fitting seal ring does not result in failure of the sheath over the service life.

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

6.3.3.4 Accounting for all physically possible load combinations, the design requirements in Equations (1) and (2) shall apply for the pressure-containing parts of the end fittings:

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

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

where

σ_t is the tensile hoop stress;

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

n is the permissible utilization factor as specified in Table 7.

Table 7 — End-fitting permissible utilization factors

Item	Service conditions			Installation		Hydrostatic pressure test — FAT and field acceptance
	Normal operation		Abnormal operation	Functional and environmental	Functional, environmental and accidental	
	Recurrent operation	Extreme operation				
	Functional and environmental	Functional, environmental and accidental	Functional, environmental and accidental			
Permissible utilization	0,55	0,85	0,85	0,67	0,85	0,91

6.3.3.5 For dynamic applications, fatigue life calculations shall be performed in accordance with the requirements of 6.3.4. The predicted fatigue life shall be at least ten times the service life.

6.3.3.6 Selection of end-fitting materials shall be in accordance with the requirements of Clause 7.

6.3.3.7 The thickness of weld overlay material may be included in the wall thickness in end fitting analyses, provided: that the material strength of the weld overlay material is equal or greater than the strength of the parent material, and that a qualified weld procedure is documented.

6.3.4 Service life analysis

6.3.4.1 Service life — Static applications

6.3.4.1.1 The service life analysis of flexible pipes for static applications shall document the properties of the pipe materials for the specified service life, in accordance with the requirements of Clause 7. The minimum strength for metallic materials and minimum elongation at break for polymer materials, during the service life of the pipe, shall be used in the design calculations. The analysis shall include as a minimum the following:

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

b) corrosion and erosion of steel components.

6.3.4.1.2 If static pipes are submerged, the effect of corrosion of steel components in the annulus shall account for permanent contact with water of appropriate salinity and oxygen ingress rate. Determination of salinity and oxygen ingress rate may consider the presence of multiple exterior sheath layers and insulation.

6.3.4.1.3 Service life for sweet service applications shall be determined as follows, subject to the requirements of 6.3.1:

a) degradation of polymer layers to the limiting criteria for use with criteria to be specified by the manufacturer;

b) localized and general corrosion of pressure and tensile armours to where the reduction in cross-section results in an increase in the utilization factor to 0,85. The basis for this assessment shall be as stated in 7.2.4.3.1.

6.3.4.1.4 Service life for sour service applications shall be determined as follows, subject to the requirements of 6.3.1:

a) assessment of service life as in 6.3.4.1.3;

b) design shall also document compliance with the requirements of 7.2.4.2.

6.3.4.2 Service life — Dynamic applications

6.3.4.2.1 For dynamic applications, the requirements of 6.3.4.3 shall apply. In addition, a fatigue analysis shall be performed for both the pressure and tensile armour layers that shall take account of all mechanical and dynamic effects that can introduce failure modes into the pipe in the dynamic application. As a minimum, the effects of wear, fatigue, fretting, material degradation including corrosion and degradation and draining of lubricant shall be accounted for. If welds on the pressure armour wire cannot be avoided in the fatigue-critical areas (for example, hang-off and touch-down areas), then these welds shall be qualified for the fatigue loads expected at the locations of the welds. Such qualification can be achieved by testing of welded wire samples to confirm the fatigue performance (the SN curves of the parent wire material) assumed in the design or by developing S-N curves for welded pressure armour wires for the same annulus conditions.

6.3.4.2.2 Dynamic applications shall be evaluated in accordance with the requirements of 6.3.4.2.5 if the H_2S content exceeds NACE requirements for sour service. Otherwise the application shall be evaluated in accordance with the requirements of 6.3.4.2.4.

6.3.4.2.3 Steel wires for use in flexible pipes can be sensitive in fatigue to low levels of H_2S, and thus, for dynamic service, the combined effects of H_2S and alternating stresses in the presence of water shall be evaluated in accordance with 7.2.4.5 c).

6.3.4.2.4 Service life for sweet service applications shall be determined as follows, subject to the requirements of 6.3.1.

a) according to assessment for static applications under 6.3.4.1.3;

b) assessment of service life for pressure and tensile armours based on data from 7.2.4.5;

c) The basis for this assessment shall be the riser annulus vented to atmosphere and watertight to seawater. The predicted environment should account for permeation and consumption due to corrosion of the armour wires due to the presence of CO_2 and water. Oxygen leaking in through the venting system should be included when relevant. Service life with the annulus flooded shall also be calculated.

6.3.4.2.5 Service life for sour-service applications shall be determined as follows, subject to the requirements of 6.3.1:

a) assessment shall be as 6.3.4.2.4 for sweet service based on data from 7.2.4.2.4, including fatigue life assessments for both dry-vented annulus and seawater-flooded annulus;

b) a verified model shall be required to assess the H_2S and CO_2 partial pressures with the associated pH level in the annulus and the time to reach saturation of the annulus environment.

6.3.4.3 Fatigue analysis

For dynamic applications, fatigue calculations using Miner's methods and S-N data in accordance with 7.2.4.5 shall be performed for the pressure and tensile armours. If it has been demonstrated from testing in accordance with 6.3.4.2 and 7.2.4.5(c) that all stresses are below an endurance limit established by testing, Miner's calculations are not required. If any fatigue stress is above the endurance limit, fatigue damage shall be calculated based on Miner's method using design S-N curves that have been validated for the wire materials used, under the applicable service environments. The fatigue life analysis shall also confirm that the internal pressure sheath and outer sheath maintain integrity under the calculated alternating strains.

6.3.4.4 Ageing

Ageing of Polyamide PA-11 should be based on the guidelines provided in API Technical Report 17TR2.

6.4 System design requirements

6.4.1 General

6.4.1.1 The design of the flexible pipe should account for all system requirements specified in 5.6, as listed in Table 8, and account for additional requirements specified in 6.4.2 to 6.4.6. The design shall be documented to meet all interface requirements specified by the purchaser or by the manufacturer.

Table 8 — System-related pipe design requirements

General requirements	Flowline requirements	Riser requirements
Corrosion protection	Flowline routing	Riser configuration
Thermal insulation	Guides and supports	Connection systems
Gas venting	Protection requirements	Pipe attachments
Pigging and TFL requirements	On-bottom stability	Vessel data
Fire resistance	Upheaval buckling	Interference requirements
Piggyback lines	Crossover requirements	Load cases
Connectors	Pipe attachments	
Interface definitions	Load cases	
Inspection and condition monitoring		
Installation requirements		
Exothermal chemical reaction cleaning		

6.4.1.2 The effect of trenching, burying or rock-dumping pipes shall be checked for upheaval buckling, upheaval creep and termination load capacity resulting from pressure and temperature-induced axial elongation. The effect of pipe-bending-stiffness variations, resulting from time, temperature and pressure on the pipe loads should be analysed.

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

6.4.1.4 The polymer/steel friction coefficient for the outer sheath material shall be documented for design of the pipe for installation tensioner compression forces and for design of devices to be clamped to the pipe.

6.4.1.5 The lateral and longitudinal polymer/soil friction coefficients shall be documented for the outer sheath for on-bottom stability design.

6.4.2 Corrosion protection

6.4.2.1 Galvanic corrosion

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

6.4.2.2 Surface treatment

All external steel surfaces shall be prepared and coated in accordance with internationally recognized standards for corrosion protection in all environmental conditions specified in Clause 5, unless the material is documented to be corrosion-resistant in the specified environment.

6.4.2.3 Corrosion allowance

6.4.2.3.1 Requirements for internal and external corrosion allowances shall be evaluated in accordance with the location, conditions of installation and the requirements specified in Clause 5. The manufacturer shall document this evaluation and its effect on the pipe components.

6.4.2.3.2 Corrosion in the carcass or armour layers at the end-fitting interface shall not cause damage to any sealing barrier or locking mechanism.

6.4.2.3.3 Corrosion-resistant overlay or corrosion-resistant alloys may be used in preference to a corrosion allowance. The manufacturer shall have documented records on the suitability of the corrosion-resistant overlay or alloys for the specified application and environment.

6.4.2.4 Cathodic protection

6.4.2.4.1 Design of a cathodic protection system shall be in accordance with the requirements of 5.6.1.3. The design of cathodic protection systems by means of anodes electrically connected to a pipe end fitting, requires electrical continuity between tensile armours and end fitting. The cathodic protection system design methodology shall be documented. See ISO 15589-2 for guidelines on the design of cathodic protection systems.

6.4.2.4.2 The manufacturer shall identify the area of outer sheath damaged and the surface area of armour wires to be protected in the event of damage to the outer sheath and document the philosophy upon which these values have been based.

6.4.3 Thermal insulation

6.4.3.1 The materials used for thermal insulation layers shall be selected such that overall heat-transfer coefficient does not degrade to a level below the value specified in 5.6.1.4 for the service life.

6.4.3.2 When selecting thermal-insulating material, the deterioration of its physical and mechanical properties caused by fluids in the pipe annulus shall be documented by the manufacturer, with tests to be within the specified requirements.

6.4.3.3 The design of the thermal insulation system shall be based on the assumption that the outer protective barrier can be damaged or deteriorated, thereby exposing the insulating material to air and/or seawater. Bulkheads or additional polymer sheaths may be used to limit the volume of the pipe structure flooded. The design methodology, including outer sheath-damage assumptions, shall be documented.

6.4.3.4 Conditions experienced during storage, transportation, handling, installation and operation shall be analysed. The analysis shall document that permanent deformation of the insulation layers, resulting from crushing caused by items including tensioners, reels, sheaves, rollers, self-weight and impact loads, does not change the heat-transfer coefficient beyond the specified requirements.

6.4.4 Gas venting

6.4.4.1 The gas-venting system shall be designed to the requirements of 5.6.1.5 and the following:

a) safe removal of diffused components;

b) no uncontrolled pressure build-up outside the pipe if the pipe is located within an enclosed space;

c) chemical resistance of all parts exposed to the permeated fluid and seawater.

6.4.4.2 The following design requirements shall apply to the gas-venting system.

a) The design of gas-relief valves shall ensure that the valve opens before the annulus pressure reaches 50 % of the documented burst-disk design failure pressure. It shall be documented that the valve will open (or burst-disk-fail) before the outer sheath bursts, when the sheath wall thickness is at the minimum tolerance and the pipe is bent to the operating MBR.

b) The maximum vent system pressure in the annulus shall not collapse or blister the internal pressure sheath during decompression of the system.

c) Burst disks shall not be used as part of the gas-venting system for riser applications.

d) Gas-relief valves used as part of a venting system for a subsea pipe shall not allow ingress of seawater.

e) If gas relief valves are used, two valves per end fitting shall be required as a minimum.

f) The valve design shall account for the specified marine growth conditions.

6.4.4.3 The gas drainage shall be through the end fitting of the pipe unless otherwise specified in 5.6.1.5.

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

6.4.5 Pigging and TFL operations

6.4.5.1 The flexible pipe shall be designed for the pigging, TFL, workover and other tool requirements specified in 5.6.1.6. The selection of dimensional tolerances, including ovality, shall account for the specified requirements. See ISO 13628-3 for guidelines on TFL systems.

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

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

6.4.6 Fire resistance

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

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

a) fire temperature, source, and surrounding material;

b) need to extinguish or cool the pipe structure;

c) fire-extinction method;

d) time required to extinguish;

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.

6.4.6.2 If fire resistance is required in accordance with 5.6.1.7, the pipe shall be tested in accordance with Lloyds Fire Test, DNV Fire Test, or API Spec 16C unless previous testing of the design has been performed and documented.

7 Materials

7.1 Material requirements

7.1.1 General

7.1.1.1 The requirements of Clause 7 shall apply to polymer materials including additives; flat, round or shaped metal wire forms; and finished or semi-finished end-fitting components, as delivered to the pipe manufacturer by suppliers. Clause 7 does not cover the use of composite materials for structural layers.

7.1.1.2 The manufacturer shall have on file records of tests demonstrating that the materials selected for a specific application meet the functional requirements specified in Clause 5 for the service life, for both operation and installation conditions. The documented test records shall conform to the requirements of 7.2. Where suitable qualification records do not exist, the manufacturer shall conduct testing relevant to the application according to 7.2.

7.1.1.3 All materials, including anti-wear layers, tapes, lubricants and other manufacturing aids used in the flexible pipe construction shall be documented to be compatible with seawater and permeated gases and liquids at design temperatures. Compatibility can be limited to determination that decomposition of these materials does not create by-products harmful to functional layers (such as the internal pressure sheath) of the pipe. The manufacturer shall document that all lubricants and corrosion protection coating used in the manufacture of the pipe are compatible with all other structural or pressure-sealing materials in the pipe.

7.1.2 Polymer materials

7.1.2.1 General

The manufacturer shall utilize documented design standards based on tests as specified in Table 9 that define the pre-qualified range and combination of exposure conditions for each of the polymers used in the internal pressure sheath, anti-wear layer/tape, intermediate sheath, outer sheath and insulation layer.

Table 9 — Property requirements for extruded polymer materials

Characteristic	Tests	Internal pressure sheath	Intermediate sheath/Anti-wear layer	Outer sheath	Insulation layer
Mechanical/physical properties	Resistance to creep	X	X	X	X
	Yield strength/elongation	X	X	X	—
	Ultimate strength/elongation	X	X	X	X
	Stress relaxation properties	X	—	—	—
	Modulus of elasticity	X	X	X	—
	Hardness	—	—	X	—
	Compression strength	—	—	X	X
	Hydrostatic pressure resistance	—	—	—	X
	Impact strength	—	—	X	—
	Abrasion resistance	—	—	X	—
	Density	X	X	X	X
	Fatigue	X	X	X	
	Notch sensitivity	X	—	—	—
Thermal properties	Coefficient of thermal conductivity	X	X	X	X
	Coefficient of thermal expansion	X	X	X	X
	Softening point	X	X	X	X
	Heat capacity	X	X	X	X
	Brittleness (or glass transition) temperature	X	—	X	—
Permeation characteristics	Fluid permeability	X	X	X	X
	Blistering resistance	X	—	—	—
Compatibility and ageing	Fluid compatibility	X	X	X	X
	Ageing tests	X	X	X	—
	Environmental stress cracking	X	X	X	—
	Weathering resistance	—	—	X	—
	Water absorption	X	—	X	X
The property requirements specified for the insulation layer apply to the use of both polymers and non-polymers. Test procedures are specified in Table 11. There are no property requirements for manufacturing aid materials.					

7.1.2.2 Internal pressure sheath

7.1.2.2.1 The manufacturer shall document the mechanical, thermal, fluid compatibility and permeability properties of the material for the internal pressure sheath, as specified in Table 9, for a range of temperatures and pressures that shall include the design values.

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

7.1.2.2.3 If the conveyed fluid contains gas, the polymer shall be shown, by testing, not to blister or degrade during rapid depressurization from the maximum pressure and temperature conditions. The effect of ageing and swelling on permeability shall be analysed. The manufacturer shall specify the criteria to be applied to the polymer for assessment of serviceability (embrittlement, creep, shrinkage, swelling, plastic deformation, and so forth) and quantify its application, using results of testing as in 7.1.2.2.2.

7.1.2.2.4 If the internal pressure sheath is composed of multiple layers, then dissimilar materials shall not be used in the multiple layer construction, unless there is documented test evidence that the materials fulfil the design requirements for the specified life and service conditions.

7.1.2.3 Intermediate sheath

The manufacturer shall document the properties specified in Table 9 for the intermediate sheath material.

7.1.2.4 Outer sheath

7.1.2.4.1 The manufacturer shall document the properties specified in Table 9 for the outer sheath material.

7.1.2.4.2 A documented evaluation shall be performed by the manufacturer to confirm compatibility of the outer sheath with all permeated fluids, ancillary components and all external environmental conditions specified in 5.5.

7.1.2.5 Insulation layer

7.1.2.5.1 For the insulation layer material, the manufacturer shall document the properties specified in Table 9. The thermal conductivity of the layer shall be documented for both dry and flooded (seawater) conditions where applicable and for the design and operating temperatures and pressures. Degradation of thermal performance over the specified service life, resulting from pressure, temperature, annulus environment and seawater, where applicable, shall be analysed. Creep in the insulation material shall not result in loss of thermal insulation, such that the overall thermal insulation of the pipe is less than the design requirements. The term “dry conditions” means tested in air at conditions defined by the international standard atmosphere.

7.1.2.5.2 The manufacturer shall document and verify with tests that the compressive strength of the insulation material is sufficient to withstand all expected compressive loads within the design requirements of 6.4.3. Flooding of the annulus shall not affect this requirement.

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

7.1.2.6 Anti-wear layers

For the anti-wear layer material, the manufacturer shall document the properties specified in Table 9. For dynamic applications, the manufacturer shall have documented tests that the anti-wear layer performs its function, preventing wear between adjacent steel and/or extruded polymer layers, for the specified service life.

7.1.3 Metallic materials

7.1.3.1 General

Metallic material selection shall consider corrosive attack appropriate to the environment to which the layer is exposed over the specified service life of the pipe. Materials for sour-service applications shall be tested in accordance with 7.2.4.2. All metallic components designed for, or that can be exposed to, cathodic protection shall be made of materials that have documented resistance against hydrogen embrittlement in the applicable environment.

7.1.3.2 Carcass

7.1.3.2.1 The manufacturer shall document the properties and characteristics specified for the carcass in Table 10. For the specified application, the manufacturer shall evaluate, for each of the listed characteristics, the suitability of the selected carcass material and shall have available for review by the purchaser documented tests to confirm the suitability of the material for the application, together with the criteria for acceptance.

Table 10 — Property requirements for metallic wire and strip materials and weldments

Properties/Characteristics	Parameter	Carcass	Pressure armour	Tensile armour
Alloy properties	Chemical composition	X	X	X
	Microstructure	X	X	X
Mechanical properties	Yield strength	X	X	X
	Ultimate strength	X	X	X
	Elongation	X	X	X
	Hardness	X	X	X
	Fatigue resistance	X	X	X
	Erosion resistance	X	—	—
Material characteristics	SSC and HIC resistance		X	X
	Corrosion resistance	X	X	X
	Cracking resistance under cathodic protection	—	—	X
	Chemical resistance	X	X	X
Test procedures are specified in Table 12.				

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

7.1.3.2.3 If the conveyed fluid contains entrained solids, the manufacturer should calculate the erosion and erosion/corrosion rates for the specified fluid velocities and content over the service life of the pipe, and should document that the calculated wear rates do not cause failure of the carcass.

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

7.1.3.3 Pressure and tensile armours

7.1.3.3.1 The manufacturer shall document the properties and characteristics specified for the pressure and tensile armours in Table 10, subject to the requirements of 7.1.3.2.1.

7.1.3.3.2 For the specified application, the manufacturer shall document the sensitivity to corrosion (uniform and pitting) or cracking (SSC, HIC, hydrogen embrittlement and fretting) occurring in the carbon steel materials selected for the pressure and tensile armours and the manufacturer shall have documented test records that confirm the suitability of the material and weldments for the particular application.

7.1.4 End fitting

7.1.4.1 Metallic materials

7.1.4.1.1 End-fitting metallic components for primary pressure-containing parts shall be wrought or forged in accordance with the requirements of ASTM A668, ASTM A29 or ASTM A182 Grade F51 (duplex steel). For sour service applications, metallic materials shall be in accordance with ISO 15156 (all parts).

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

7.1.4.1.3 The end fitting shall be resistant to corrosion, either by way of material selection or by means of the combination of a suitable coating and cathodic protection. The material for the end-fitting internal surfaces shall have documented resistance to erosion due to solids entrained in the conveyed fluid. All metallic components designed for, or that can be exposed to, cathodic protection shall be made of materials that have documented resistance against hydrogen embrittlement in the applicable environment.

7.1.4.1.4 For applications requiring weld overlay, all surfaces exposed to the conveyed fluid shall be documented by tests to be corrosion resistant. The internal pressure sheath and outer sheath seal rings and pipe layer sealing surfaces shall be corrosion resistant.

7.1.4.2 Epoxy material

7.1.4.2.1 The epoxy filler material used to embed the tensile armours shall be documented to withstand the temperatures experienced by the end fitting during manufacture and service for the specified service life. Consideration shall be given to the maximum temperatures that can be experienced by the end fitting in enclosed spaces, such as underneath fire insulation and bend stiffeners.

7.1.4.2.2 The manufacturer shall document the compressive strength of the epoxy at a temperature between 20 °C and 25 °C, and at design minimum and maximum temperatures. Glass-transition temperature, fluid compatibility and ageing characteristics of the epoxy shall be documented. The epoxy used in testing shall be mixed and cured according to the suppliers' specifications.

7.2 Qualification requirements

7.2.1 General

7.2.1.1 Test requirements

The physical, mechanical, chemical and performance characteristics of all materials in the flexible pipe shall be verified by the manufacturer through a documented qualification programme. The programme shall confirm the adequacy of each material based on test results and analysis that shall demonstrate the documented fitness for purpose of the materials for the specified service life of the flexible pipe. As a minimum, the qualification programme shall include the tests specified in Clause 7. The qualification of materials by testing should consider all processes (and their variation) adopted to produce the pipe that can impair the properties and characteristics required by the design.

7.2.1.2 Test data

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

7.2.1.3 Applicability

7.2.1.3.1 Only materials with identical specified chemistry and processing history (heat treatment and cold deformation), as used in the qualification testing, shall be regarded as qualified.

7.2.1.3.2 Documented operational experience may be accepted as verification of long-term properties in environments that are equal to or less severe than the documented experience. The severity of the environment for metallic components shall be determined by temperatures, stresses, contact pressures, corrosive environments, pH, chloride content, injected chemicals, concentrations of H_2S and CO_2 and other conditions deemed by the manufacturer or purchaser to be detrimental. The environmental factors considered for polymers shall include temperatures, stresses, strains, pressures, concentrations of water, aromatics, alcohols, H_2S and CO_2, UV exposure, acidic conditions (lower pH or higher TAN) and other conditions deemed by the manufacturer or purchaser to be detrimental.

7.2.1.4 Test methods

The test methods shall be as specified in 7.2. Where test methods are not specified, the manufacturer may use his or her own methods and/or criteria or other ones developed by the raw materials supplier. In such cases, the methods and/or criteria shall be documented and the results correlated with the specific material application. The documented qualification performance shall be verified by an independent verification agent.

7.2.2 Polymer materials

7.2.2.1 Samples used for qualification testing

Samples used for qualification testing shall be taken from extruded material. For thermoplastic materials, moulded specimens are not acceptable. If the polymer contains a plasticizer, tests shall be performed to determine the properties of both the plasticized and deplasticized material.

7.2.2.2 Polymer sheaths, insulation layer and anti-wear layer materials

In the qualification programme, the manufacturer shall test and document, for the polymer sheaths, insulation layer and anti-wear layer materials, the properties specified in Table 9. The test procedures specified in Table 11 shall be used. Where no International Standard test procedure is available, the manufacturer shall document the test procedure.

7.2.2.3 PVC as insulation material

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

7.2.3 Polymer test procedures

7.2.3.1 Fluid permeability

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

a) sample: sample shall be taken from an extruded polymer sheath;

b) thickness: minimum is 1 mm (0.04 in);

c) diameter: minimum is 70 mm (2.76 in);

d) temperature: sufficient tests to allow for linear interpolation should be performed;

e) pressure: criterion for temperature applies [same as for 7.2.3.1.1 d)].

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

7.2.3.2 Blistering resistance

7.2.3.2.1 Blistering resistance tests shall reflect the design requirements, relating in particular to fluid conditions, pressure, temperature, number of decompressions and decompression rate. The following conditions shall apply as a minimum.

a) fluid mixtures: Use gas components of specified environment as documented in the test procedure.

b) soak time: Use sufficient to ensure saturation.

c) test cycles: If available, use expected number of decompressions, or else use 20 cycles as a minimum.

d) decompression rate: If available, use expected decompression rate, or else use as a minimum 7 MPa/min (1 015 psi/min).

e) thickness: Internal pressure sheath wall thickness as a minimum.

f) temperature: Use the expected decompression temperature.

g) pressure: Use design pressure as a minimum.

h) procedure: After each depressurization the sample shall be examined at a magnification of 20x for signs of blistering, swelling and slitting.

7.2.3.2.2 The acceptance criterion shall be that no blister formulation or slitting is observed.

7.2.3.3 Fluid compatibility

7.2.3.3.1 The manufacturer shall document the evaluation of all components of the environment to which the polymer is exposed and perform tests on those components that are considered to possibly have adverse effects on the polymer. The criteria for acceptance shall be verified by an independent verification agent.

7.2.3.3.2 Fluid compatibility tests shall be performed to the manufacturers’ or material suppliers’ documented procedures. These laboratory tests with extruded samples may be used to determine gross incompatibility. These tests shall be based on the design conditions of temperature, pressure and strain. As a minimum, tensile strength, elongation at break, visual appearance and fluid absorption (mass gain) and desorption (mass loss), shall be measured/evaluated in the test carried out in accordance with the procedure specified in Table 11.

Table 11 — Test procedures for extruded polymer materials

Characteristic	Tests	Test procedure [a]		Comments [b]
		ISO or clause number [b]	ASTM [b]	
Mechanical/ physical properties	Resistance to creep	ISO 899-1	ASTM D2990	Due to temperature and pressure
	Yield strength/elongation	ISO 527-1 ISO 527-2	ASTM D638	—
	Ultimate strength/elongation	ISO 527-1 ISO 527-2	ASTM D638	—
	Stress relaxation properties	ISO 3384	ASTM E328	—
	Modulus of elasticity	ISO 527-1 ISO 527-2	ASTM D638	—
	Hardness	ISO 868	ASTM D2240 or ASTM D2583	—
	Compression strength	ISO 604	ASTM D695	—
	Hydrostatic pressure resistance	—	—	—
	Impact strength	ISO 179 (all parts) or ISO 180	ASTM D256	At design minimum temperature
	Abrasion resistance	ISO 9352	ASTM D4060	Or ASTM D1044
	Density	ISO 1183 (all parts)	ASTM D792	Or ASTM D1505
	Fatigue	—	ISO 178	[c]
	Notch sensitivity	ISO 179 (all parts)	ASTM D256	—
Thermal Properties	Coefficient of thermal conductivity	—	ASTM C177, ASTM C518	—
	Coefficient of thermal expansion	ISO 11359-2	ASTM E831	—
	Heat distortion temperatures	ISO 75-1 ISO 75-2	ASTM D648	—
	Softening point	ISO 306	ASTM D1525	—
	Heat capacity	ISO 11357-1 ISO 11357-4	ASTM E1269	—
	Brittleness temperature	ISO 974	ASTM D746	Or glass transition temperature (ASTM E1356)
Permeation characteristics	Fluid permeability	7.2.3.1	—	As a minimum to CH_4, CO_2, H_2S and methanol, where present, at design temperature and pressure
	Blistering resistance	7.2.3.2	—	At design conditions
Compatibility and ageing	Fluid compatibility	7.2.3.3	—	—
	Ageing tests	7.2.3.4	—	—
	Environmental stress cracking	—	ASTM D1693-05	Method C. PE only
	Weathering resistance	—	—	Effectiveness of the UV stabilizer
	Water absorption	ISO 62	ASTM D570	Insulation material only

[a] The test procedures apply to polymer sheath materials and insulation layer materials, both polymer and non-polymer. The property requirements are specified in Table 9.

[b] For the purposes of the requirements for the listed test, the ASTM reference(s) listed is/are equivalent to the associated ISO International Standard, where one is given. Example: For the purposes of the procedure for the resistance-to-creep test, ASTM D2990 is the equivalent of ISO 899-1.

[c] The ISO 178 methodology for determination of flexural properties can be used as a basis for establishing a fatigue test methodology or can be modified in accordance with fatigue test methodologies established by manufacturers. The results of all tests made by the manufacturer and/or suppliers shall be available for review by the purchaser.

7.2.3.4 Ageing test

7.2.3.4.1 The manufacturer shall have documented ageing-prediction models for each polymer in the flexible pipe. The models shall be based on testing and experience and shall predict the ageing or deterioration of the polymer under the influence of environmental and load conditions that have been identified to be relevant through testing. As a minimum, polymer ageing models for PE shall consider temperature and ageing models for PA-11 shall consider temperature, water cut, and pH. For PVDF materials, the assessment of ageing shall include the effect of temperature, chemical environment and mechanical load. Special attention should be given to de-plasticization, fluid absorption and changes of dimensions. Creep, cyclic strain and relaxation shall be investigated on aged and unaged samples. The ageing models may include accumulated damage concepts based on blocks of time or operational cycles of temperature/pressure under different exposure conditions. Ageing may be determined by change in either specified mechanical properties or in specified physico-chemical characteristics, which includes reduction in the plasticizer content of the material.

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

7.2.4 Metallic materials

7.2.4.1 General

The qualification test requirements for carcass, pressure armour, and tensile armour layer materials shall be as specified in Table 12.

Table 12 — Qualification test requirements for metallic materials (carcass strip, pressure armour, and tensile armour wires) and weldments

Tests	Test procedure	Comments
Chemical composition	ISO 8457-2 [a]	
Yield strength/elongation	ISO 8692	
Ultimate strength/elongation	ISO 8692	
Hardness	ISO 6507-1	Sour service applications only (Armour wires only)
SSC and HIC	7.2.4.2	To specified environments (Armour wires only)
Corrosion resistance	7.2.4.3	To specified environments (Armour wires only)
Erosion resistance	7.2.4.4	Carcass only
Fatigue resistance	7.2.4.5	Pressure and tensile armours in dynamic applications only
Hydrogen embrittlement	7.2.4.6	Only armour wires with $\sigma_y \geqslant 700$ MPa [b] (101 526 psi) and/or $\sigma_u \geqslant 900$ MPa (130 534 psi) and exposed to cathodic protection
Chemical resistance	—	To specified environments

[a] For the purposes of this provision, ASTM A751 is equivalent to ISO 8457-2.

[b] MPa = megapascals.

7.2.4.2 SSC and HIC testing

7.2.4.2.1 For sour service static applications, the threshold limits of the steel wire material to HIC and SSC shall be determined following 7.2.4.2.2 and 7.2.4.2.3, according to manufacturers' documented criteria.

7.2.4.2.2 To determine the resistance of the steel wire material to HIC and SSC the wires shall be subjected to the NACE TM 01-77 test (SSC) at a constant pH between 3,5 and 3,8. The threshold level for the occurrence of SSC shall be determined by loading multiple tensile specimens to increasing stress levels which will give a fail/no fail test result. For tensile armour wire, tensile load tests shall be performed, and for pressure armour wire, ring tests should be used where practical for pipes with diameters less than 152,4 mm (6 in), otherwise four-point bend tests should be used.

7.2.4.2.3 The manufacturer shall additionally demonstrate through analysis or testing (duration 720 h) the SSC performance at the actual service conditions of the steel wire material. The actual service conditions comprise the equivalent partial pressure of H_2S, CO_2 and CH_4 in the annulus, in aqueous solution (3 % NaCl minimum) at ambient pressure and temperature. If the manufacturer does not have a verified model for calculating annulus conditions, then pipe-bore partial pressures shall be used. Samples loaded to at least 90 % of their actual yield stress shall be tested at operating conditions. Analysis of the performance from this test may be used to project minimum expected service life for a static application when combined with results of 7.2.4.3 and 7.2.4.4. The CH_4 may be replaced with another inert gas.

7.2.4.2.4 For dynamic applications, the pressure armour and tensile armour materials shall be subjected to the qualification testing specified in 7.2.4.5, for the specific application. S-N data shall clearly define the endurance limit, if this exists, for the material under the design conditions and shall be documented, or generated for the conditions in 7.2.4.5.

7.2.4.2.5 Production welds shall be included in steel wires to be qualified for sour service applications.

7.2.4.3 Corrosion resistance

7.2.4.3.1 For static applications, steel wires should be subjected to the following testing and evaluation, or equivalent documentation provided:

a) exposure to aerated and de-aerated seawater (minimum 3 % NaCl), without protective cathodic potential;

b) exposure to the predicted annulus environment based on equivalent partial pressures of the transported fluids, without presence of seawater.

7.2.4.3.2 Corrosion rate should be measured through testing. The general corrosion rate and occurrence of pitting should be documented and used to identify a minimum and most likely service life based upon expected mean service conditions, assuming the pipe annulus is flooded with seawater during installation.

7.2.4.3.3 For dynamic applications, steel wires shall be subjected to tests defined under 7.2.4.3.1 b). Assessment of corrosion through the service life should be on the basis that the pipe annulus is not flooded with water.

7.2.4.4 Erosion resistance

The manufacturer shall demonstrate, either with tests or analytical data based on tests, that the innermost layer has sufficient erosion resistance to meet the design requirements for the specified service life, subject to the requirements of 7.1.3.2.3. See ISO 13628-11 for recommendations on erosion tests.

7.2.4.5 Fatigue resistance

For dynamic applications, steel wires shall be subjected to the following testing and evaluation or equivalent documentation provided. See ISO 13628-11 for recommendations on fatigue testing and interpretation. S-N data shall be documented or generated for the listed conditions:

a) exposed to air, at atmospheric pressure, at a temperature of 12 °C to 23 °C (53.6 °F to 73.4 °F), with wires as rolled and degreased and tested to manufacturer's specifications;

b) exposed to seawater (minimum 3 % NaCl), at atmospheric pressure, at a temperature of 12 °C to 23 °C (53.6 °F to 73.4 °F), with wires as rolled and degreased and tested to manufacturers' specifications.

c) exposed to the predicted annulus environment for relevant transported fluids, with wires as rolled and degreased and tested to manufacturers' specifications.

7.2.4.6 Hydrogen embrittlement

The tensile armours 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 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.

7.2.5 End fitting

7.2.5.1 Metallic materials

7.2.5.1.1 Test samples used in the qualification of metallic materials for end-fitting components shall be in accordance with 7.2.5.1.2 and 7.2.5.1.3. The qualification programme shall test in accordance with the specified procedure and document the following properties and characteristics of the metallic materials for the primary end-fitting components:

a) chemical composition: ASTM A751;

b) tensile properties: ISO 8692;

c) Charpy impact: 7.2.5.1.4 and 7.2.5.1.5;

d) hardness: 7.2.5.1.6;

e) SSC & HIC resistance: 7.2.4.2.1.

If duplex stainless steel end fittings are specified, they should be tested for pitting resistance in accordance with ASTM G48-03, Method A.

7.2.5.1.2 The mechanical properties of forgings shall be determined from test samples that represent the actual component, including being from the same heat and heat treatment batch, and having the same forging ratio. The location of test samples shall represent the heaviest thickness, and shall be taken in 1/4 t position from OD, where t is the thickness of the component.

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

7.2.5.1.4 Charpy V-notch impact testing shall be carried out in accordance with ISO 8692 for carbon or low-alloy steel forgings. Full-sized Charpy V-notch specimens in accordance with ISO 8692 shall be used whenever possible. The notch shall be perpendicular to the surface. The test temperature shall be – 20 °C (– 4 °F) or the design minimum temperature if lower than – 20 °C(– 4 °F). Energy values shall be in accordance with the manufacturer’s specifications, which shall specify minimum single energy values and minimum average of three values, acceptable specimen sizes to be 10 mm by 10 mm (0.39 in by 0.39 in), 10 mm by 7,5 mm (0.39 in by 0.30 in) and 10 mm by 5 mm (0.39 in by 0.20 in).

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

7.2.5.1.6 The hardness tests of carbon steel forgings and corrosion resistant weld overlays shall be performed in accordance with ISO 6506-1, ISO 6508-1, or ISO 6507-1. The results shall be to manufacturers’ specifications, which shall distinguish between sour and sweet service applications. For sour service, hardness values shall be in accordance with ISO 15156 (all parts).

7.2.5.2 Epoxy material

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

a) compression [8] strength: ASTM D695 or
shear strength: 7.2.5.3;

b) glass transition temperature: ASTM E1356;

c) fluid compatibility: 7.2.3.3;

d) ageing test: 7.2.3.4;

e) degree of cure: DSC to ASTM D5028.

7.2.5.3 Shear strength test

7.2.5.3.1 The manufacturer shall have documented procedures for evaluating the shear strength of the epoxy material. The epoxy samples used to determine the shear strength shall be moulded and cured under the same temperature and humidity conditions as when filling end fittings.

7.2.5.3.2 The relationship between shear strength and temperature of the cured epoxy material shall be determined. Reference ISO 13628-11 for guidance.

7.3 Quality assurance requirements

7.3.1 General

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

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

7.3.1.3 As a minimum, materials shall be certified to ISO 10474:1991, 3.1, certificate 3.1B (EN 10204:2004, 4.1). Materials shall be tested at suppliers' or manufacturers' work site in accordance with the requirements and procedures specified in Table 13. Test results shall be recorded on material test certificates.

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8) The manufacturer may choose based on the applicability of the compression or shear data to his design methodology.

Table 13 — Minimum raw material quality control test requirements

Material	Test	Frequency	Comments
Polymers	Composition	One per batch	Measure weight percent of all additives, including plasticizers and UV stabilizers
	Viscosity	One per batch [a]	Sheath material (PA-11 only); ISO 307[b] procedure
	Extractables	One per batch	Applies to plasticized materials only
	Impurities	One per batch	Sheath material [c] (with exception of pigmented plastics)
	Density	One per batch	Sheath material (PE only) ASTM D1505 procedure
	Melt flow index	One per batch [a]	Sheath material. ASTM D1238 procedures
Metallic Wires and strips	Chemical composition	One per batch	All wires and strips
	Tensile test	Two per coil [d]	All wires
	Bend test	Two per coil	All wires
	Hardness test	Two per coil	All wires
	Dimensions	Two per coil	All wires; start and end of coil; ASTM A480 procedures
End fittings	Chemical composition	One per heat [e]	Body material
	Tensile test	Two per heat	Body material
	Charpy V-notch	One set per heat	Body material; subject to 7.2.5.1.4 and 7.2.5.1.5
	Hardness test	One per heat	Body material; subject to 7.2.5.1.6
	Radiography	One	Welded neck only
Epoxy	Compression test	—	Refer to 8.6.4.2

[a] Only a measurement of viscosity or melt flow index, but not both, is required.

[b] For the purposes of this provision, ASTM D2857 is equivalent to ISO 307.

[c] Pigmented plastics cannot be evaluated for impurities.

[d] A coil is a continuous length of wire from the same forming process and heat treatment batch. If intermediate welds used to join coil sections for transport have been qualified by the subcontractor in accordance with the manufacturer's procedures, these welds may be kept during winding onto the pipe. If these welds have not been qualified, they shall be cut out of the coil during the winding of the pipe.

[e] Per heat refers to heat treatment batch.

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

7.3.1.5 For the internal pressure sheath, polymers shall be 100 % virgin material containing no regrind or other previously processed materials.

7.3.1.6 Requirements and criteria for surface condition of wires and shaped strips shall be established and documented by the manufacturer. As a minimum, the metallic materials shall have a surface finish free from cracks and hard spots.

7.3.2 Documentation requirements

7.3.2.1 The manufacturer's written specifications for polymer and metallic materials shall include, as a minimum, the requirements of Table 14.

Table 14 — Requirements of material specifications

Requirements	Metallic material	Polymer material
Material composition requirements, with tolerances	X	—
Generic base polymer (in accordance with ASTM D1418)	—	X
Physical and mechanical property requirements	X	X
Allowable melting and forming practices	X	—
Heat treatment procedures	X	—
Storage and age control requirements	X	X
NDE requirements	X	X
Acceptance and/or rejection criteria	X	X
Certification and records requirements	X	X
Marking, packaging, handling, and traceability requirements	X	X

7.3.2.2 The specification for end-fitting epoxy material shall include, as a minimum, trade mark, grade and colour of resin and hardener, mixing ratio, pot life, moulding temperature, and curing temperature and time.

7.3.3 Storage

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

7.3.3.2 All raw polymer material shall be bulk packaged in sealed containers having a moisture-resistant liner (hydroscopic materials only), with vacuum draw-off directly into machine hoppers/dryers to prevent ingress of contaminants. Damaged packages shall be evaluated to determine if the damage has resulted in contamination of the material. Contaminated material shall be rejected.

7.3.4 Traceability

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

8 Manufacturing requirements

8.1 Quality assurance requirements

8.1.1 General

8.1.1.1 Manufacturing operations shall be performed in accordance with the manufacturer's written specifications, which shall conform to the requirements of Clause 8. Special processes including welding, heat treatment and coating, shall be performed in accordance with the requirements of 8.7. The manufacturer shall maintain documentation on the qualification of special processes for review by the purchaser.

8.1.1.2 NDE shall be performed in accordance with the requirements of ASTM E709 (magnetic particle test), ASTM E165 (liquid penetrant test), ASTM A388 and ASTM E428 (ultrasonic test), and ASTM E94 (radiographic test), as applicable.

8.1.1.3 Quality control requirements for materials to be used in the pipe manufacturer shall be as specified in 7.3.

8.1.2 Documentation

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

8.1.2.2 The manufacturer's specification documentation shall be available for review by the purchaser and the following shall be documented as a minimum.

a) Layer-by-layer and step-by-step description of the manufacturing procedures, including quality control and NDE, for the complete flexible pipe, in other words all layers, sublayers, lubricants, tapes, end fittings and any other items forming an integral part of the final product. Procedures for special processes shall be documented.

b) The documentation shall include references to specifications and sources of all materials used in the manufacture of the flexible pipe, including the materials used for the manufacture of the layers and materials such as lubricants, corrosion-coating materials, anti-wear and non-metallic tapes.

c) The manufacturer shall document all parameters related to the quality of the final product that can be monitored during the manufacturing process. Both nominal values and ranges of these parameters shall be specified.

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

8.1.3 Process control

All the main steps in the manufacturing process shall be subject to inspection. The manufacturer's quality plan shall specify inspection points, inspection methods and acceptance criteria. Results of all inspections shall be recorded. The manufacturer shall record every non-conformance verified during manufacture of the pipe. Process control shall be performed as a minimum for the following manufacturing process as applicable:

a) carcass: preparation and winding of flat steel strip, welding of flat steel strip sections, performing, cold forming of carcass, reeling of interlocked carcass, preheating and drying prior to extrusions;

b) polymer layers: drying of pellets, extrusion and cooling of polymer and reeling of sheathed pipe;

c) pressure armours: preparation of flat or interlocked wire, feeding of pipe, winding of pressure reinforcement, welding of shaped and flat wire sections and coil reeling;

d) tensile armours: preparation of flat or interlocked wire, feeding pipe, winding of armour wires, welding of armour wires, application of tape, and coil reeling.

8.1.4 Handling during manufacture

8.1.4.1 The manufacturer shall have documented procedures for handling of intermediate and finished products during manufacture, packing and storage. The procedures shall include requirements for limits on pipe abrasion, mechanical damage, torsion, bending, and crushing when winding/unwinding pipe on reels and carousels or during end-fitting assembly.

8.1.4.2 The condition of all reels and carousels shall be such that any damage induced in the pipe is within the limits specified in the documented handling procedures.

8.1.4.3 Caterpillar tensioner guides and other handling and storage equipment shall not damage polymer extrusions such that thickness reductions below the tolerances specified in 8.8 are induced in the layer. The requirements of 8.3.2.1.1 with regard to flaws, including notches, indentations and other stress raisers being introduced in the polymer layers by handling equipment, shall apply.

8.1.4.4 The manufacturer shall use documented procedures for the rewinding of flat or shaped wires from the supplier's shipping reel to the manufacturer's reel or bobbin.

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

8.2 Carcass

8.2.1 General

8.2.1.1 The carcass profile shall be determined at the start and end of each production run to be in accordance with the documented acceptance criteria. The occurrence of sharp edges in the formed carcass layer shall be prevented.

8.2.1.2 For carcass layers made up in sections, the join-up procedures for the sections shall be qualified for all loads expected at the locations of these connections and documented. The manufacturer should ensure that only the minimum number of carcass join-up welds are incorporated into the flexible pipe.

8.2.2 Inspection and acceptance criteria

8.2.2.1 The external surface of the as-formed carcass and armour layers shall be visually examined for flaws, including dents, cracks, scratches, shavings, gouges, corrosion, scaling, discoloured areas (blurring, scorching, staining and the like, except at welds), distorted or buckled strip or wire profile and significant scoring. Carcass profiles shall be additionally inspected for lack of interlock.

8.2.2.2 The outside diameter and ovality shall be measured and interlock checked at the start of the production run. Subsequent to this, these parameters shall be controlled (measured or checked) at intervals verified by the manufacturer to be acceptable. All results shall be recorded and shall be to manufacturer's specifications, which shall conform to the requirements of 8.8.

8.2.2.3 For carcass sections that are not manufactured on a mandrel, the internal diameter shall be measured and recorded at least every 10 m (32.81 ft) and shall be within the tolerances specified in 8.8. For carcass formed over the internal pressure sheath or over the outer sheath, the outer diameter shall be measured if it is not possible to measure the inner diameter.

8.3 Polymer extrusions

8.3.1 General

8.3.1.1 Extrusion of thermoplastic material shall be performed in accordance with the manufacturer's documented procedures. Each extrusion shall be controlled in accordance with an approved set-up sheet that provides settings for all essential variables based on the material and sizing of the product. The manufacturer shall have documented records to show that detrimental folding does not occur in the layer for the polymer material and wall thickness to be extruded.

8.3.1.2 The manufacturer should ensure that all extrusions are onto an underlying layer whose external surface conforms to the manufacturer's extrusion procedures.

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

a) temperature and pressure (or dew point) of raw material humidity control equipment;

b) extruder-screw feeding rate (or screw revolutions per minute);

c) extruder-barrel temperatures;

d) extruder-barrel pressures;

e) extruder-crosshead temperatures;

f) extruder-crosshead pressures;

g) rate of travel;

h) quenching water temperature.

8.3.1.4 The manufacturer shall test and ensure that the moisture content of hygroscopic materials is within supplier-specified tolerances prior to commencing the extrusion process. If PA-11 is used, the moisture content shall be tested in accordance with ASTM D789 (or ASTM D6869) procedures and shall be to the manufacturer's specifications.

8.3.1.5 Procedures and tools used for perforation of intermediate layers for gas-venting purposes shall not induce defects in underlying layers, subject to the requirements of 8.2.2.1. Perforation by melting with heated tooling is preferred.

8.3.2 Inspection and acceptance criteria

8.3.2.1 Visual examination

8.3.2.1.1 The manufacturer's specifications shall document acceptance criteria for flaws as a function of category (individual or cluster), size, position in material thickness, distance between flaws and number. A visual examination of the polymer layer external surface shall be performed to identify flaws, including holidays, bubbles, inclusions (black spots), discolouring, surface irregularities, extrusion weld lines, die scratches, die drools, notches and indentations. All flaws shall be in accordance with the manufacturer-specified acceptance criteria.

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

8.3.2.2 Dimensional measurements

Thickness and diameter measurements of the extruded layers shall be recorded at least every 10 m (32.81 ft) for the first 50 m (164.04 ft). Subsequent to this, the thickness and diameter shall be measured and recorded at intervals verified by the manufacturer to be acceptable. Measurements shall be taken after the cooling process.

8.3.2.3 Test requirements

8.3.2.3.1 For extrusion onto a metallic layer, the extruded internal pressure sheath shall be subject to a continuous high-voltage spark test or equivalent test, calibrated to detect a 1 mm (0.04 in) or smaller hole. The holiday detector shall be calibrated prior to the extrusion of the polymer layer material and thickness that is extruded. The detector shall be provided with an audible alarm.

8.3.2.3.2 For each extrusion of the internal pressure and outer sheath layers, a minimum of three samples shall be taken from both initial and final extruded sections and subjected to ultimate strength and elongation at break in accordance with the procedures specified in Table 11. The samples shall be stored at ambient temperature for a minimum of 6 h prior to testing. All test results shall be recorded and shall conform to the manufacturer's specifications.

8.4 Pressure and tensile armour layers

8.4.1 General

8.4.1.1 The manufacturer shall have documented procedures for the winding of the pressure armour and tensile armour layers onto the pipe, which shall ensure that the flat, round or shaped wires are laid to the design requirements. The procedures shall include requirements for the condition of the wires prior to winding and for the condition of the finished layer, such that the layer and underlying or overlying layers meet the manufacturer's specifications.

8.4.1.2 The procedures shall specify all parameters and allowable tolerances that are to be monitored and recorded at intervals verified by the manufacturer to be acceptable. The recorded values shall conform to manufacturer's specifications. As a minimum, diameter and pitch (for lay angle) shall be measured.

8.4.1.3 All welds shall be staggered along the length of the pipe in conformance with the manufacturer's specifications, which shall specify a minimum separation between welds.

8.4.1.4 Welds on the pressure armour wire should be avoided in the fatigue critical areas (for example, hang-off and touch-down areas).

8.4.2 Inspection and acceptance criteria

8.4.2.1 The pressure and tensile armour layers shall be visually examined in accordance with the requirements of 8.2.2.1.

8.4.2.2 The outside diameter shall be measured and recorded at least every 10 m (32.81 ft) for the first 50 m (164.04 ft) and subsequently at intervals verified by the manufacturer to be acceptable. The results shall be within the tolerances specified in 8.8. Armour layers shall be additionally inspected for wires on edge, fish scaling, and wire twists.

8.5 Anti-wear and insulation layers

8.5.1 General

The manufacturer shall ensure that anti-wear layers, taped layers used as manufacturing aids and insulation layers are applied in accordance with documented procedures. The procedures shall include requirements for control and monitoring of tape application and overlap of extruded profiled strip, and shall document acceptance criteria for flaws.

8.5.2 Inspection and acceptance criteria

8.5.2.1 The external surface of the anti-wear and insulation layers shall be visually examined over the entire length for flaws, including damage, distortion, folds and lack of interlock (for profiled insulation strip). Identified flaws shall conform to the manufacturer's specifications. Lack of interlock in profiled insulation strip layers shall not be acceptable.

8.5.2.2 The outside diameter shall be measured and recorded at least every 10 m (32.81 ft) for the first 50 m (164.04 ft) and subsequently verified at intervals by the manufacturer to be acceptable. The results shall be within the tolerances specified in 8.8.

8.6 End fitting

8.6.1 General

All operations in the manufacture, machining, assembly and inspection of end fittings shall be performed in accordance with the manufacturer's specifications, which shall meet the requirements of 8.6. All fitting operations shall be performed by qualified personnel (end fitters) in accordance with the manufacturer's approved procedures. The qualifications of end fitters shall be documented and shall be available for review by the purchaser.

8.6.2 Assembly

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

8.6.2.2 In the preparation of the internal pressure sheath under the end-fitting seal ring, any machining of this area shall not introduce notches or reduce the thickness of the sheath to less than the minimum design thickness. Acceptance criteria for out-of-roundness, wall thickness variations and surface roughness in this area shall be specified.

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

8.6.2.4 Prior to mixing the epoxy resin, all equipment required for the filling operation shall be checked for proper functioning. The mixing and curing of epoxy resin shall be according to the supplier's specifications. Filling shall be carried out in such a way that voids do not occur. Gas-relief drains in the end fitting shall not be obstructed by the epoxy.

8.6.3 Inspection and acceptance criteria

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

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

8.6.3.3 The manufacturer shall use a qualified and documented procedure to verify that sufficient epoxy resin has been injected into the end fitting, such that no voids are left in the end fitting that would affect its functional performance. It is recommended that the volume injected be checked by measuring the mass of injected epoxy.

8.6.4 Test requirements

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

a) all surfaces: 100 % visual examination;

b) carbon and low-alloy steel surfaces: 100 % magnetic particle or liquid penetrant inspection when geometry prevents MPI;

c) weld overlay surfaces: 100 % liquid penetrant;

d) end-fitting bodies: 100 % ultrasonic test;

e) circumferential butt-welds: 100 % radiographic test.

8.6.4.2 On completion of epoxy resin injection, a minimum of three samples shall be taken from the same mix as used for the end fitting. Results from compression strength tests carried out in accordance with ASTM D695 procedures shall be within the range specified by the manufacturer for the cured epoxy.

8.6.5 Connectors

All end-fitting connectors and components shall be in accordance with ISO 10423, ISO 13628-4, other recognized industry standard or as specified by the purchaser, and shall meet the requirements specified in 5.6.1.9.

NOTE For the purposes of this provision, API Spec 17D is equivalent to ISO 13628-4.

8.7 Special processes

8.7.1 Welding

8.7.1.1 Qualification

8.7.1.1.1 All welding operations shall be performed by qualified welders in accordance with the manufacturer’s approved procedures. Welding procedure specifications (WPS), welding procedure qualification records (WPQR) and welder qualifications shall be documented and shall be available for review by the purchaser. The purchaser shall have the option of witnessing the qualification of all welding procedures and welders and shall be given appropriate notice of the timing by the manufacturer. Welders and welding procedures shall be qualified in accordance with one of the following standards: ASME Boiler and Pressure Vessel Code, Section IX, EN 287-1, EN 288-1, EN 288-2, EN 288-3, ISO 13847 or equivalent. Procedures shall include acceptance/rejection criteria.

NOTE For the purposes of this provision, API Std 1104 is equivalent to ISO 13847.

8.7.1.1.2 As a minimum, qualification testing for flat, round, and shaped wires to be used for sweet-service applications shall include visual inspection, magnetic particle inspection, two tensile tests and either two-face or side guided-bend tests. The weld tensile test results shall have an ultimate tensile value equal to or greater than the minimum acceptable weld tensile value established by the manufacturer for the design application. Minimum tensile values shall be included in the WPS. The diameter of the guided-bend test mandrel shall be such that sufficient mechanical stress is introduced in the weld zone to show weld quality. For sour service, in addition to the above testing, a macro and hardness survey shall be performed. The macro shall be polished, etched and examined at a minimum of 10x magnification. Hardness tests shall be performed on the same sample. One test each, as a minimum, shall be made in the fusion or bond line, heat-affected zone (HAZ), edge of HAZ and unaffected base metal. Hardness test shall be to HV5 or HV10 (ISO 6507-1) or HV500 (ASTM E384). Results of all tests shall be in accordance with the manufacturer’s specifications.

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

8.7.1.2 Metallic layers

8.7.1.2.1 Every time there is a change in welding machine set-up, a minimum of two test welds shall be made to verify the set-up. The samples shall include all production heat treatments. The sample welds shall be subjected to the following tests as a minimum:

a) ultimate strength;

b) hardness (sour service);

c) bend;

d) dye-penetrant or magnetic particle;

e) visual examination as specified in 8.7.1.2.3.

8.7.1.2.2 The dye-penetrant test is required for non-magnetic alloys and the magnetic particle test is required for magnetic steel grades, and the test shall be performed after the bend test. Visual examination at 5x magnification of the weld HAZ at the outer surface of the bend may be used as an alternative to the magnetic particle test. The hardness test shall be performed in the area with maximum cold deformation. For carcass strip welds, only visual examination is required. Results from all tests shall be documented and shall be within the manufacturer's specifications.

8.7.1.2.3 Production welds shall exhibit a smooth surface across the full strip width and show full penetration. There shall be no cratering, edge washing or burn-through of the strip. The weld thickness shall be, as a minimum, that of the sheet thickness and shall be maximum 1 mm (0.04 in) above the surface. The weld shall be consistent across the strip with no undercut at the toes. For carcass join-up welds, the manufacturer shall ensure that all weld metal is ground smooth to prevent damage to extruded overlying layers.

8.7.1.2.4 Butt welds for joining carcass and armour layer wires and strips and for carcass join-up welds shall be subjected to the following inspection requirements:

a) carcass strip: 100 % visual examination;

b) carcass join-up: 100 % visual examination;

c) steel wire: 100 % visual examination and magnetic particle test.

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

8.7.1.2.6 Butt-welding of shaped wires shall utilize automatic or semi-automatic heat pressure welding devices.

8.7.1.3 Polymer layers

8.7.1.3.1 Repair welding of polymer layers, as permitted under the requirements of 8.9, shall be performed in accordance with the manufacturer's qualified procedures, which shall be available for review by the purchaser. The welding procedures shall contain acceptance/rejection criteria.

8.7.1.3.2 Inspection of polymer weld repairs shall check that the layer wall thickness and surface conditions conform to the manufacturer's specifications.

8.7.1.4 End fitting

All circumferential butt and overlay welds shall be performed in accordance with qualified and documented procedures. Inspection and test requirements shall be as specified in 8.6.4.1.

8.7.2 Heat treatment

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

8.7.3 Coating

8.7.3.1 Coatings applied to end-fitting components to limit corrosion due to internal, external or annulus environments shall be applied in accordance with the manufacturer's documented procedures, which shall include acceptance and rejection criteria.

8.7.3.2 The procedure for qualification of the metallic coating processes to be applied to the end fitting shall specify the following as a minimum:

a) bath composition;

b) control of temperature and time for heat treatments;

c) hardness test of coating;

d) adhesion test of coating;

e) optical microscopy or a similar method recommended to analyse the cross-section of the coated surface;

f) coating thickness measurement;

g) testing to confirm the resistance of coating to corrosion agents (for example, seawater and CO_2);

h) procedures for checking surface coating for flaws.

8.8 Manufacturing tolerances

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

a) carcass: external diameter;

b) polymer sheaths: thickness and external diameter;

c) pressure and tensile armours: external diameter and pitch (or lay angle).

8.8.2 The tolerance for the length of the flexible pipe shall be specified.

8.8.3 For pipes without pressure armour, the manufacturer shall demonstrate that tensile armour wire gaps are controlled such that the design requirements are met.

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

8.9 Repairs

8.9.1 The manufacturer shall have documented, qualified procedures for performing repairs and these procedures shall be available for review by the purchaser. The manufacturer shall document by additional tests and/or calculations that the repairs to the flexible pipe do not compromise the structural or long-term requirements of the pipe.

8.9.2 Repair of the internal pressure sheath is not permitted. Unacceptable defects found in this layer shall result in complete removal of the layer. Removal procedures are subject to review by the purchaser. Machining of the internal pressure sheath may be carried out to remove superficial discontinuities or localized excessive thickness, provided that the final thickness complies with the specified layer tolerances and that a proper surface finish is assured.

8.9.3 Repair of minor flaws in intermediate or external polymer layers is permitted. Polymer welding shall be performed as specified in 8.7.1.3. All repairs, including offshore repairs of outer sheaths, shall be performed in accordance with qualified procedures. The purchaser shall be permitted to inspect all repairs carried out. Offshore outer-sheath weld repair procedures shall be qualified on material exposed to an environment similar to the environment of the damaged outer sheath, with the same equipment, drying processes and sheltering as those at the repair site.

8.9.4 Any defects in armour metal welds shall be repaired by cutting out the weld and heat-affected zone and rewelding according to the specified procedures. Carcass strip-weld repairs are permitted prior to forming, provided a qualified repair procedure is used and visual inspection confirms the weld repair is acceptable. Inspection requirements for repair welds shall be as specified in 8.7.1.

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

8.9.6 Butt welds shall meet the requirements of 8.7.1.4. Repair welding shall comply with all the applicable required guidelines of ISO 10423:2003, PSL 2-3 unless PSL 4 is specified by purchaser. (See Table A.1, Additional requirements).

8.9.7 Tooling used for removal of defective layers shall be such that defects are not introduced into underlying layers. Special care is required when removing an extruded sheath to avoid contact between the knife and underlying armours.

9 Documentation

9.1 General

9.1.1 The minimum documentation that the manufacturer is to have available for the purchaser shall be as specified in Clause 9. The documentation requirements for materials and manufacturing shall be as specified in the relevant subclauses of this part of ISO 13628.

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

a) design premise: prior to pipe design;

b) design load report: prior to manufacture;

c) design report: prior to manufacture;

d) manufacturing quality plan: prior to manufacture;

e) fabrication specification: prior to manufacture;

f) as-built documentation: with supplied pipe;

g) operation manual: prior to delivery.

9.1.3 Issue of the documents in 9.1.2 by manufacturer to purchaser shall be in accordance with the requirements of 5.6.1.1.2.

9.2 Design premise

The design premise shall contain the parameters specified in Table 15. If the manufacturer has made assumptions on any of the parameters in Table 15, then it shall be specified in the design premise that the values are assumed.

Table 15 — Documentation requirements for the design premise

Parameter	Comments
Internal fluid parameters	All relevant internal fluid parameters, including, as a minimum, the parameters specified in Table 1
External environment	All relevant external environment parameters, including, as a minimum, the parameters specified in Table 2
System description	All relevant system parameters, including as a minimum, the parameters specified in 5.6
Service life	Including, where relevant, maintenance and replacement programmes
Design load case definition	All potential load cases for the flexible pipe system during manufacture, storage, transport, testing, installation, operation, and retrieval shall be addressed. A matrix showing the load cases to be checked for each component of the flexible pipe system shall be established and shall conform with the requirements of Clause 6.
Design accidental events	All accidental events and combinations of accidental other loads (functional and environmental) shall be specified. The load cases shall be included in the load case matrix.
Design criteria	Required safety margins and definitions of structural capacity shall be specified for each layer of the pipe and components, and shall conform with the requirements of Clause 6
Analysis parameters	These shall include hydrodynamic coefficients, structural parameters such as damping models, hydrodynamic wave models, and seabed parameters such as friction coefficients

9.3 Design load report

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

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

9.4 Design report

9.4.1 The design report shall contain a detailed description, including drawings, of each pipe component. The description shall include a layer-by-layer description of the pipe, including materials, wire cross section, lay angle, diameter, thickness, number of wires, and so forth.

9.4.2 Unless separate material specification documentation is issued, material specification and data shall be included in the design report. Material data shall include yield or tensile strengths and fatigue parameters for dynamic service (S-N curve slope, intercept and endurance limit) and shall identify fluid components that can adversely affect the material.

9.4.3 Each component shall be documented to have sufficient structural capacity to sustain the design loads and stresses listed in the design load report, with the safety margin specified in the design premise.

9.4.4 The design report shall specify the following properties for the flexible pipe:

a) diameters (internal and external);

b) weight per metre (in-air empty and seawater-filled, and in-seawater empty and seawater filled);

c) design pressures;

d) design temperatures;

e) design water depth;

f) MBR (storage and operating);

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

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

i) torsional stiffness (as a function of twist direction, tension, pressure and temperature).

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

a) permissible tension (as a function of bend radius);

b) permissible axial compression;

c) permissible crushing (radial);

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

e) pressure- and temperature-induced axial and radial expansion;

f) pressure- and tension-induced twist.

9.4.6 The independent verification agent's certificate for the design methodology (see 6.2.2) shall be included in the design report.

9.5 Manufacturing quality plan

The manufacturing quality plan shall specify all quality control procedures, including inspection points and test procedures. The manufacturing quality plan may be included in the fabrication specification.

9.6 Fabrication specification

The fabrication specification shall describe each step in the manufacturing process, including welding, heat treatment, type and extent of NDE and acceptance criteria, factory acceptance test procedures, fabrication method and allowable repair procedures. The specification shall ensure that the pipe is in accordance with the design.

9.7 As-built documentation

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

a) purchase order reference number;

b) equipment descriptions;

c) references to design specifications and drawings;

d) material certificates;

e) dimension control measurements;

f) factory acceptance test results;

g) all non-conformances identified during manufacture, and repairs performed;

h) welding procedure specifications and qualifications;

i) welder qualification records;

j) weld map;

k) NDE operator qualifications and NDE test records;

l) heat treatment records.

9.8 Operation manual

9.8.1 The operation manual shall be prepared for the system and shall address all maintenance tasks and restrictions, and emergency procedures, including repair procedures to be used on board the installation vessel, as specified by the manufacturer or purchaser. The manual shall include the following as a minimum:

a) layer-by-layer description (material specifications, thickness, lay angle, number of wires, and so forth);

b) diameters (internal and external);

c) weight per metre (in-air empty and seawater filled, and in-seawater empty and seawater filled);

d) design minimum and maximum pressure, and test pressures (specify if design pressure is absolute value or differential);

e) design minimum and maximum temperatures;

f) design water depth;

g) installation requirements;

h) interface requirements;

i) repair procedures;

j) handling, storage, winding/unwinding procedures;

k) gas venting system description and permeation rate;

l) decompression rate (gas service);

m) restrictions on internal fluid components (including H_2S and CO_2) and inhibitors;

n) pigging and TFL capabilities;

o) allowable loads;

p) maximum time with seawater or inhibited seawater in pipe and inhibitor requirements;

q) reference for as-built documentation.

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

10 Factory acceptance tests

10.1 General

10.1.1 The flexible pipe shall be subjected to factory acceptance tests, including gauge, hydrostatic pressure, electrical continuity, electrical resistance and gas-venting system tests, as applicable, to verify the manufacture of the pipe to the requirements of this part of ISO 13628. The purchaser shall have the option of witnessing all tests and shall be given appropriate notice of the timing by the manufacturer.

10.1.2 The hydrostatic test shall be required for all pipes. The electrical continuity and resistance tests shall be required for pipes that are cathodically protected. The gauge and electrical resistance tests are applicable only to rough bore structures. The gas-venting system test shall be required for pipes that have gas relief valves or ports installed in the end fittings.

10.1.3 The manufacturer's specifications shall specify the minimum time that shall elapse between the completion of the end-fitting mounting (including epoxy curing) and the start of the acceptance tests. The acceptance test programme shall comply with this minimum time.

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

10.1.5 If the acceptance criteria for a test are not met, the cause of the failure shall be investigated and a report submitted to the purchaser. Proposed corrective action shall be included in the report. The purchaser shall have the option of either rejecting the pipe or requiring a retest.

10.2 Gauge test

10.2.1 Procedure

10.2.1.1 The gauging test shall be performed prior to the hydrostatic test. The gauging pig shall be equipped with disk(s) capable of detecting any unacceptable obstruction.

10.2.1.2 The minimum diameter of the gauging pig shall be at least 95 % of the nominal ID or 10 mm (0.39 in) smaller than the ID for pipes with an ID less than 200 mm (7.87 in). The thickness of the gauging disk shall be between 5 mm and 10 mm (0.20 in to 0.39 in).

10.2.2 Acceptance criteria

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

10.3 Hydrostatic pressure test

10.3.1 Procedure

10.3.1.1 The minimum hydrostatic test pressure for flexible flowlines and subsea jumpers shall be 1,3 times the design pressure. For all other applications, including flexible risers and topside jumpers, the minimum hydrostatic test pressure shall be 1,5 times the design pressure. A higher test pressure can be required by local codes or regulators (e.g. NPD, MMS, HSE). Unless otherwise specified, potable water, filtered to 100 µm and with a chloride content less than 50 mg/l shall be used for the test fluid. If required to protect the internal carcass material, the water shall be chemically inhibited. A suitable dye may be added to assist in leakage detection.

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

10.3.1.3 The pressure shall be gradually increased, at a rate not greater than the manufacturer’s test procedure, to a level between 100 % and 110 % (see ISO 13628-11:—, 11.5.3.3) of the hydrostatic test pressure, and held for a period of at least 2 h to allow for stabilization. This maximum hydrostatic test pressure shall not cause the allowable utilization factors of Tables 6 and 7 to be exceeded. If necessary, the pressure shall be cycled to this pressure until stabilization is achieved. The pressure shall be considered stabilized when the pressure drop is less than 1 % in a 1 h period. Pressure shall then be increased between the nominal test pressure and the maximum hydrostatic test pressure.

10.3.1.4 The timing of the test shall not start until the equipment and pressure-monitoring gauge have been isolated from the pressure source.

10.3.1.5 The hydrostatic test pressure shall be held for a period of not less than 24 h. During the test, pressure and temperature (ambient and internal) shall be recorded at least every 30 min. Depressurization shall be performed at a rate in accordance with the manufacturer’s test procedure.

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

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

10.3.2 Acceptance criteria

Pressure loss due to all causes, including external temperature fluctuations, shall not exceed 4 % of the pressure at the start of the 24 h period. No leakage shall be observed from the pipe during the test. No permanent deformation or damage shall be observed in the area of the end fittings.

10.4 Electrical continuity and resistance tests

10.4.1 Procedure

10.4.1.1 The electrical continuity and resistance tests shall be performed after the hydrostatic test. If specified by the purchaser, the tests shall also be done prior to the hydrostatic tests.

10.4.1.2 The electrical continuity test shall be performed between the two end fittings. Electrical resistance tests shall be performed between the end fittings and the carcass. Electrical continuity and resistance measurements shall be recorded.

10.4.2 Acceptance criteria

The electrical resistance between the internal carcass and the end fittings shall be greater than 1 kΩ. The electrical resistance between the end fittings shall be less than 10 Ω/km of pipe.

10.5 Gas-venting system test

10.5.1 Procedure

10.5.1.1 This test shall demonstrate that the gas-relief system, including valves used to relieve pressure build-up in the pipe annulus, functions properly. This test shall be performed after the hydrostatic test.

10.5.1.2 Air or nitrogen gas shall be pumped into one end fitting at the design pressure for the gas-relief system. Gas release shall be checked at the other end fitting. All ports in the end fitting shall be tested individually. The procedure shall be repeated from the opposite end of the pipe. All valves shall be tested for relief pressure. All valves shall relieve within the manufacturer's specified range of relief pressure.

10.5.1.3 This procedure might not be feasible for long lengths of pipe. An alternate procedure is acceptable if it can be demonstrated to satisfy the same general requirements. The procedure used shall be documented in the manufacturer's written specification.

10.5.2 Acceptance criteria

Gas relief shall be confirmed at all ports individually. All valves shall relieve at the manufacturer's specified relief pressure. The inlet pressure required to obtain gas relief shall be less than 50 % of the documented burst disk failure pressure.

11 Marking and packaging

11.1 Marking

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

a) designation of this part of ISO 13628, i.e., ISO 13628-2;

b) serial number of pipe;

c) manufacturer name or mark;

d) manufacture date;

e) design pressure (absolute or differential);

f) storage MBR.

The following markings may be applied:

— circular markings at regular intervals with length for reference in installation and survey;

— longitudinal stripes on risers to assess twist.

11.2 Packaging

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

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

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

Annex A
(informative)

Purchasing guidelines

A.1 Table A.1 in this annex gives purchasing guidelines for flexible pipes.

A.2 A separate form should be completed for each length of flexible pipe.

A.3 The manufacturer should specify in the design premise the values assumed for all parameters in Table A.1 not specified by the purchaser.

Table A.1 — Flexible pipe purchasing guidelines

General information	
Client:	Client reference:
	Project:
Phone:	Location:
Fax:	
Purchaser's technical contact:	Enquiry date:
Conformance to ISO 13628-2 required? ☐ Yes ☐ No	Required response date:
General design parameters	
Internal diameter (m):	Maximum axial load (kN):
Length required (m):	Maximum effective tension (kN):
Tolerance required on length (m ± m):	Torsional balance requirement (ºC/m or ºF/m):
Pipe structural requirements (MBR, bend stiffness):	Compression strength requirement (kN):
	Design Load Case Probabilities (1 year, 100 Years)
Linear mass requirements (kg/m) in air empty:	Installation:
External protection requirements (external carcass):	Normal operation:
	Abnormal operation:
Service life (years):	Specification of normal and abnormal load cases, including accidental loads, and definition of load combinations to be used in the design:
°C = degree Centigrade; °F = degree Fahrenheit; g = gram; K = Kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million; TAN = titrated acid number; TF = through flowline; W = Watt NOTE "ppm" is a deprecated unit.	

Table A.1 (*continued*)

Internal fluid parameters	
General	TAN (mg KOH/g):
Fluid description (oil, gas, water):	Flow rate and thermal calculations
Flow regime description (single, phase, slug):	Flow rate (m^3/day):
Flow direction:	Fluid density (kg/m^3):
Pressures	Viscosity (Pa • s):
Design pressure [MPa (psi)]:	Minimum inlet pressure (MPa):
Max./Min. operating pressure and/or profile during the service life (MPa (psi)]:	Required outlet pressure (MPa):
Vacuum conditions [MPa (psi)]:	Fluid heat capacity (kJ/kg/°C):
Differential internal pressure [MPa (psi)]:	Fluid compositional data
Number and range of pressure cycles expected during the specified service life:	NaCl content (weight percent of water):
Temperatures	Maximum operational depressurisation and pressurization rates:
Design minimum temperature (ºC):	Chlorides content [mg/l (ppm)[a]]:
Design maximum temperature (ºC):	Gas-oil ratio (m^3/m^3):
Operating inlet temperature (ºC):	Water cut (volume percent):
Number and range of temperature cycles expected during the specified service life:	Alcohols? ☐ Yes ☐ No
Upset temperature and cycles (ºC):	Aromatic components? ☐ Yes ☐ No
Service Definition	Corrosive agents? ☐ Yes ☐ No
Description (sweet/sour):	Inhibitors (scale, paraffin)? ☐ Yes ☐ No
ISO 15156 (all parts) to apply? ☐ Yes ☐ No	Injected chemicals? ☐ Yes ☐ No
H_2S partial pressure (bar):	Solids, Precipitates, etc.? ☐ Yes ☐ No
CO_2 partial pressure (bar):	If available, attach details of full fluid compositional data and expected variation over the service life. Also, attach details of any aromatic components, corrosive agents, inhibitors, alcohols, solids, or injected chemicals in the fluid composition.
pH of aqueous phase:	
°C = degree Centigrade; °F = degree Fahrenheit; g = gram; K = Kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million; TAN = titrated acid number; TF = through flowline; W = Watt [a] "ppm" is a deprecated unit.	

Table A.1 (*continued*)

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

°C = degree Centigrade; °F = degree Fahrenheit; g = gram; K = Kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million; TAN = titrated acid number; TF = through flowline; W = Watt

NOTE “ppm” is a deprecated unit.

Table A.1 (*continued*)

General system requirements	
General	**Gas venting**
System description (flowline, riser, jumper, subsea, topsides):	Gas-venting required? ☐ Yes ☐ No
Application definition (static, dynamic):	System components (valves, burst disks):
Pipe bore description (rough, smooth):	Allowable gas permeation rate (l/m/day):
Corrosion protection pequirements	Venting-location restrictions?
Corrosion protection required? ☐ Yes ☐ No	Gas-monitoring system?
Cathodic protection system required? ☐ Yes ☐ No	**Other**
Electrical continuity required? ☐ Yes ☐ No	Fire resistance required? ☐ Yes ☐ No Specify (Lloyds/DNV/API Spec 16C):
End-fitting coatings required? ☐ Yes ☐ No	Pigging, TFL, workover, etc. required? ☐ Yes ☐ No
External coating description:	Piggyback required? ☐ Yes ☐ No
Internal coating description:	If yes, attach details.
If available, allowable electrical resistance, protection voltage, current source, and current density should be specified.	Pressure and tensile armour weld location restrictions? ☐ Yes ☐ No
Thermal insulation	Interface definitions/specifications (refer to 5.6.1.10):
Thermal insulation required? ☐ Yes ☐ No	
Required outlet temperature (°C):	
Required insulation U-valve (W/m^{2}K):	Exothermal chemical reaction cleaning required? ☐ Yes ☐ No
Insulation U-valve should be based on pipe ID and be for the pipe alone. Specify any allowances that can be made for external effects such as soil.	Inspection condition monitoring required? ☐ Yes ☐ No
Connector	If yes, give details of requirements.
Lower connector type (flange, pipe):	
Upper connector type (flange, pipe):	
Attach welding specification seal type and sizes, and responsibility for supply and mounting of components.	
°C = degree Centigrade; °F = degree Fahrenheit; g = gram; K = Kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million; TAN = titrated acid number; TF = through flowline; W = Watt NOTE “ppm” is a deprecated unit.	

Table A.1 (*continued*)

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

Table A.1 (*continued*)

Additional requirements	
Materials required in addition to ISO 13628-2? If yes, specify details.	☐ Yes ☐ No
Manufacturing required in addition to ISO 13628-2? If yes, specify details.	☐ Yes ☐ No
Selection of PSL category for 8.9.6 (default is PSL 2-3)? If yes, specify details.	☐ Yes ☐ No
FAT required in addition to ISO 13628-2? If yes, specify details.	☐ Yes ☐ No
Markings required in addition to ISO 13628-2? If yes, specify details.	☐ Yes ☐ No
Prototype tests required? If yes, specify details.	☐ Yes ☐ No
Additional national authority/government regulations? If yes, specify details.	☐ Yes ☐ No
Purchaser inspection required? If yes, specify details.	☐ Yes ☐ No
General requirements in addition to ISO 13628-2? If yes, specify details.	☐ Yes ☐ No
°C = degree Centigrade; °F = degree Fahrenheit; g = gram; K = Kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million; TAN = titrated acid number; TF = through flowline; W = Watt NOTE "ppm" is a deprecated unit.	

Table A.1 (*continued*)

Delivery, installation and maintenance requirements	
Delivery Requirements:	
Shipping, packing, and storage requirements:	
Documentation requirements:	
Purchaser should specify if a separate installation manual is required.	
Installation requirements	**Maintenance**
Method:	Maintenance required? ☐ Yes ☐ No If yes, specify details.
Vessel:	
General: Where relevant, the purchaser should specify any requirements for season, environment, vessel limitations, restrictions due to conflicting activities, and installation scope (including trenching, burial, testing, inspection, surveying, and documentation).	
Installation design criteria	
Equipment bend radius (m):	
Tensioner crush loads (kN):	
Installation/lifting device requirements:	
Transport reel used for installation? ☐ Yes ☐ No	
Pipe internal fluid at delivery (empty, water filled):	
Seawater flooding requirements (exposure time)? ☐ Yes ☐ No	
Where relevant, the purchaser should specify details such as length of tensioners, shape of tensioner shoes, number of belts, diameter of wheels, reels, ramp angles and surface shape.	
Installation test requirements:	
Installation vessel motions and offsets attached? ☐ Yes ☐ No	
Attached details should, in general, reflect data requirements in vessel motion data requirements listed under riser parameters (above).	
°C = degree Centigrade; °F = degree Fahrenheit; g = gram; K = Kelvin; kg = kilogram; kJ = kilojoule; kN = kilonewton; KOH = potassium hydroxide; kPa = kilopascal; l = litre; m = metre; MBR = minimum bend radius; mg = milligram; MPa = megapascal; ppm = parts per million; TAN = titrated acid number; TF = through flowline; W = Watt NOTE “ppm” is a deprecated unit.	

Annex B
(informative)

Bend stiffeners and bend restrictors

B.1 Scope

Annex B gives guidelines on minimum requirements for the design, material selection, manufacture, testing and marking of non-integral bend stiffeners and bend restrictors for use in flexible pipe applications. The scope of these guidelines is as specified in Clause 1. If no specific guidelines are given in this annex, reference should be made to the requirements specified for the flexible pipe. Bellmouths are not covered in this annex. See ISO 13628-11 for guidelines on bellmouths.

B.2 Definitions

The definitions for bend restrictors and bend stiffeners are as specified in 3.7 and 3.8, respectively. Bend limiters is used in this annex as a generic term for both bend stiffeners and bend restrictors. The term manufacturer as used in this annex refers to the bend limiter supplier.

B.3 Functional requirements

B.3.1 The manufacture should demonstrate that the bend limiter meets the functional requirements specified for the flexible pipe in 5.2.1, as applicable.

B.3.2 Bend stiffeners are typically used only for dynamic applications, and bend restrictors are typically used only for static applications.

B.3.3 The manufacturer should define, in consultation with the purchaser and/or flexible pipe manufacturer, the design requirements for the bend limiter. The purchasing guidelines of Table B.1 may be used for specifying the design requirements.

B.3.4 The design loads for the bend stiffener should be defined in terms of effective tensions and angle variations from the mean. The combinations of tension and angle which are analysed should be sufficient to cover all possible load cases, with reference to the load cases specified for the flexible pipe in Clause 6. The design loads for bend restrictors should be defined in terms of bending moments, shear forces, and, if applicable, impact loads.

B.3.5 The designer of the bend limiter should specify all necessary mounting components.

B.4 Design requirements

B.4.1 The design methodology for bend limiters should be documented and verified by tests or finite-element analyses. The design methodology should be verified by an independent verification agent.

B.4.2 The design methodology should account for the effects of wear (abrasion), corrosion, manufacturing processes, shrinkage, creep and ageing (due to mechanical, chemical and thermal degradation), unless the design is documented to not suffer from such effects. The design methodology should also account for effects of non-linear material properties, in particular, non-linear Young’s Modulus for bend stiffener material.

B.4.3 For bend stiffeners, the design methodology should consider the following failure modes:

a) disbonding or rupture in interface with metallic elements;

b) rupture or cracking in elastomeric material;

c) long-term material performance (ageing);

d) fatigue;

e) end-fitting or support-flange mounting failure.

B.4.4 The design methodology for bend restrictors should consider failure modes c) and e) of B.4.3. The design should ensure that bending moments and shear forces transferred along the length of the bend restrictor do not damage the pipe at either end of the bend restrictor.

B.4.5 The bend limiter should be designed to meet the requirements of B.3 without permanent deformation or loss of mechanical properties. As a minimum, the manufacturer should demonstrate that the design meets the specified requirements under all possible combinations of temperature and flexible pipe bend stiffness. Ovalization of the bend stiffener tip should be documented to not affect the performance of the bend stiffener.

B.4.6 The manufacturer should demonstrate that for all possible load case combinations, the bend limiter is designed to the MBR requirements of 6.3.1 and the design requirements (permissible utilization factors) of Table 6.

B.4.7 The bend limiter design should be compatible with all relevant dimensions of the flexible pipe and end fitting. The design should meet any tolerances for bend limiter internal diameter that are specified by the manufacturer or purchaser.

B.4.8 The tolerances used for all components of the bend limiter should be documented not to increase stress or strain levels above specified allowable values.

B.4.9 If the bend limiter is to be attached to a support structure such as an end fitting, the bend limiter should be designed to safely transfer loads to the support structure. Bend restrictors may be connected at a location remote from the end fitting, requiring clamping directly to the pipe, and in this case the clamping system design should ensure that no damage occurs to the pipe. The design of the bend limiter should ensure that it is restrained axially.

B.4.10 For dynamic applications, fatigue life calculations or testing should be performed. The predicted fatigue life should be at least ten times the service life.

B.5 Materials and manufacture

B.5.1 The bend limiter primary components are typically manufactured from polymer material (elastomeric material for bend stiffeners) and meet the performance requirements specified in B.4. The polymer material may be reinforced.

B.5.2 The polymer material property requirements should include the following as a minimum, for the specified range of design temperatures:

a) tensile strength: ISO 868;

NOTE For the purposes of this provision, ASTM D2240 and ASTM D2583 are equivalent to ISO 868.

b) elongation at break: ISO 527-1 and ISO 527-2;

NOTE For the purposes of this provision, ASTM D638 is equivalent to ISO 527-1 and ISO 527-2.

c) tear strength: ASTM D790;

d) Young's Modulus: ASTM D790;

e) stress-strain curve: ASTM D624;

f) hardness: ISO 868;

NOTE For the purposes of this provision, ASTM D2240 and ASTM D2583 are equivalent to ISO 868.

g) impact strength: ISO 527-1 and ISO 527-2;

NOTE For the purposes of this provision, ASTM D638 is equivalent to ISO 527-1 and ISO 527-2.

h) heat distortion temperature: ISO 75-1 and ISO 75-2;

NOTE For the purposes of this provision, ASTM D648 is equivalent to ISO 75-1 and ISO 75-2.

i) density: ISO 1183 (all parts).

NOTE For the purposes of this provision, ASTM D792 and ASTM D1505 are equivalent to ISO 1183 (all parts).

B.5.3 All materials of the limiter should be resistant to seawater, chemical exposure, ultraviolet exposure and temperature limits, as applicable, for the specified service life.

B.5.4 If applicable, the bend limiter supplier should test and document the effects of water absorption, hydrolysis, creep and temperature on the elastomeric material used for the primary parts of the limiter and confirm the suitability of the material for the specified application.

B.5.5 All metallic components should be protected against corrosion in the specified environment by either material selection, suitable coating, cathodic protection system or a combination for the specified service life.

B.5.6 The manufacturer's specification should define process control requirements for all steps in the manufacture of the bend limiter. The manufacturer's quality plan should specify inspection points, inspection methods and acceptance criteria. Results of all inspections should be recorded. The manufacturer should record every non-conformance verified during manufacture.

B.5.7 The manufacturing procedure for the bend stiffener should ensure bonding of the elastomeric material to internal metallic components. The bond should be demonstrated to be stronger than the performance requirement throughout the service life.

B.5.8 The injection process used in the manufacture of the bend limiter should not leave any voids in the structure that affect its functionality.

B.5.9 Injected material samples should be taken at regular intervals from the production run and subjected to tests including tensile strength and hardness. The results of the tests should be to the manufacturer's specifications.

B.5.10 All components of the bend limiter should be visually examined. In addition, sufficient dimensional measurements should be recorded to ensure that the bend-limiter dimensions are within manufacturer specified tolerances.

B.5.11 Bend restrictors may be subjected to factory acceptance tests. The acceptance tests should, as a minimum, check the MBR under no-load and maximum-load conditions. The results of all tests should be to the manufacturer's specifications, which should meet the design requirements of B.4. Factory acceptance tests are generally not performed on bend stiffeners because of the difficulty in applying realistic loads without the flexible pipe present.

B.6 Documentation

B.6.1 The manufacturer should supply to the purchaser the following documents at the specified times:

a) design report: prior to manufacture;

b) manufacturing quality plan: prior to manufacture;

c) as-built documentation: with supplied pipe.

B.6.2 The design report should provide sufficient documentation to verify that the requirements of this annex have been met. In addition, the design report should include results from all load case analyses, detail description of bend limiter, including drawings and material specification documentation.

B.6.3 The manufacturing quality plan should specify all quality control procedures, including inspection points and test procedures as required to control the manufacturing activities.

B.6.4 The as-built documentation should include drawings, design data, dimensional inspection reports, material certificates and any non-conformance reports and resolutions.

B.7 Marking and packaging

B.7.1 The marking of the bend limiter should make the component permanently identifiable for the specified service life. As a minimum, the marking should specify manufacturer and purchaser names, serial number, manufacturing date and operating MBR. If space is limited, the markings may be reduced to a unique serial number.

B.7.2 Packaging of the bend limiter should ensure its safety in all transport stages prior to installation.

Table B.1 — Purchasing guidelines for bend limiters

Parameter	Bend restrictor	Bend stiffener	Value/Details
General information			
Client:	X	X	
Location:	X	X	
Project:	X	X	
Date:	X	X	
Flexible pipe data			
External diameter and tolerances (m):	X	X	
Structural properties and variations due to temperature, pressure and other effects:	X	X	
Storage and operating MBR (m):	X	X	
Outer sheath material:	X		
End fitting/support structure dimensions and tolerances:	X	X	
Interface requirements			
Termination device:	X	X	
Corrosion protection system:	X	X	
Static offset angle:	X	X	
Bender limiter design limitations/requirements			
Bend limiter external diameter (m):	X	X	
Support point maximum bending moment (kNm):	X	X	
Geometrical restrictions? ☐ Yes ☐ No	X	X	
Maximum contact pressure (MPa):	X		
Internal fluid temperatures (ma. internal design condition) (°C):	X	X	
External environment data			
Medium (air, seawater):	X	X	
Water depth (m):	X	X	
Minimum design temperatures (°C):	X	X	
Maximum design temperatures (°C):	X	X	
Sunlight exposure? ☐ Yes ☐ No	X	X	
Load cases			
Design:	X	X	
Fatigue:	X	X	
Impact (accidental):	X	—	
Service Life:	X	X	
°C = degree Celsius; kNm = kilonewton metre; m = metre; MPa = megapascal			

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