

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

Part 5: Subsea umbilicals

ICS 75.180.10

National foreword

This British Standard reproduces verbatim ISO 13628-5:2002 and implements it as the UK national standard.

The UK participation in its preparation was entrusted by Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries, to Subcommittee PSE/17/-/4, Drilling and production equipment, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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Part 5: Subsea umbilicals

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systèmes de production immergés —*

Partie 5: Faisceaux de câbles immergés



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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 3.

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 part of ISO 13628 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13628-5 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

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: 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*

Annex D forms a normative part of this part of ISO 13628. Annexes A, B, C and E are for information only.

Introduction

This part of ISO 13628 is based on API Spec 17E, second edition, September 1998, and API RP 17I, first edition August 1996.

Users of this part of ISO 13628 should be aware that further or differing requirements may 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 engineering solutions for the individual application. This may be particularly applicable if there is innovative or developing technology. If an alternative is offered, the vendor should identify any variations from this part of ISO 13628 and provide details.

In this part of ISO 13628, where practical, US Customary units are included in parentheses for information.

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

Part 5: Subsea umbilicals

1 Scope

This part of ISO 13628 specifies requirements and gives recommendations for the design, material selection, manufacture, design verification, testing, installation and operation of subsea control systems, chemical injection, gas lift, utility and service umbilicals and associated ancillary equipment for the petroleum and natural gas industries.

This part of ISO 13628 applies to umbilicals containing electrical conductors, optical fibres, thermoplastic hoses and metallic tubes, either alone or in combination.

This part of ISO 13628 applies to umbilicals that are for static or dynamic service, and with routings of surface-surface, surface-subsea and subsea-subsea.

This part of ISO 13628 does not apply to the associated component connectors, unless they affect the performance of the umbilical or that of its ancillary equipment.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 13628. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13628 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 527 (all parts), *Plastics — Determination of tensile properties*

ISO 1402, *Rubber and plastics hoses and hose assemblies — Hydrostatic testing*

ISO 4080, *Rubber and plastics hoses and hose assemblies — Determination of permeability to gas*

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 4672:1997, *Rubber and plastics hoses — Sub-ambient temperature flexibility tests*

ISO 6801, *Rubber or plastics hoses — Determination of volumetric expansion*

ISO 6803, *Rubber or plastics hoses and hose assemblies — Hydraulic-pressure impulse test without flexing*

ISO 7751, *Rubber and plastics hoses and hose assemblies — Ratios of proof and burst pressure to design working pressure*

ISO 8308, *Rubber and plastics hoses and tubing — Determination of transmission of liquids through hose and tubing walls*

IEC 60228, *Conductors of insulated cables*

IEC 60502-1, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV), — Part 1: Cables for rated voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)*

IEC 60502-2 *Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV), — Part 2: Cables for rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)*

IEC 60793-1-1, *Optical fibres — Part 1: Generic specification — General*

IEC 60793-2, *Optical fibres — Part 2: Product specifications*

IEC 60794-1-1, *Optical fibre cables — Part 1-1: Generic specification — General*

IEC 60794-1-2, *Optical fibre cables — Part 1-2: Generic specification — Basic optical cable test procedures*

ASTM A 370, *Standard test methods and definitions for mechanical testing of steel products*

ASTM A 450/A 450M, *Standard specification for general requirements for carbon, ferritic alloy and austenitic alloy steel tubes*

ASTM E 562, *Standard test method for determining volume fraction by systematic manual point count*

ASTM G 48, *Standard test methods for pitting and crevice corrosion resistance of stainless steels and related alloys by the use of ferritic chloride solution*

BS 5099, *Specification for spark testing of electric cables*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this part of ISO 13628, the following terms and definitions apply:

3.1.1

ancillary equipment

accessory to the umbilical system which does not form part of the main functional purpose

EXAMPLES Weak link, buoyancy collar and I-tube or J-tube seals.

3.1.2

bend limiter

device for limiting the bend radius of the umbilical by mechanical means

NOTE It typically comprises a series of interlocking metallic or moulded rings, applied over the umbilical.

3.1.3

bend stiffener

device for limiting the bend radius of the umbilical by providing a localized increase in bending stiffness

NOTE The stiffener is usually a moulded device, sometimes reinforced, depending on the required duty, applied over the umbilical.

3.1.4**bird-caging**

phenomenon whereby armour wires locally rearrange with an increase and/or decrease in pitch circle diameter as a result of accumulated axial and radial stresses in the armour layer(s)

3.1.5**bundle**

laid-up functional components and associated fillers in the umbilical prior to sheathing

NOTE

Typical functional components in a bundle include hoses, tubes, electric cables, optical fibre cables.

3.1.6**carousel**

storage container which can be rotated by a drive about a vertical axis

NOTE

It incorporates an inner core structure and an outer peripheral structure, both of which support the umbilical. The umbilical is stored at nominally zero tension. Carousels which do not have a structure on their outer periphery to support the umbilical are often known as turntables.

3.1.7**caterpillar**

cable engine in which the umbilical is held between belts which transfer motive power to the umbilical

3.1.8**characterization data**

data relating to a component or an umbilical giving an indication of performance but not giving specific acceptance/rejection criteria

3.1.9**chinese finger**

type of gripper or stopper used to hold the umbilical via its outer diameter, comprising a number of spirally interwoven wires attached to a built-in anchorage arrangement

3.1.10**core**

generic term used to describe an individual electrically insulated conductor

3.1.11**crab lay**

installation deployment activity whereby the installation vessel moves sideways along, or at the end of, the installation route

3.1.12**design life**

service life multiplied by an appropriate safety factor

3.1.13**design working pressure****DWP**

maximum working pressure at which a hose or tube is rated for continuous operation

3.1.14**design working load**

maximum working load multiplied by an appropriate safety factor

3.1.15**end termination**

mechanical fitting attached to the end of an umbilical which provides a means of transferring installation and operating loads, fluid and electrical services to a mating assembly mounted on the subsea facility or surface facility

3.1.16

factory acceptance test

FAT

series of tests carried out on the complete umbilical system after manufacture is complete, to verify the integrity of the umbilical

3.1.17

functional components

components included within an umbilical which are required to fulfil the operational service needs

EXAMPLES Hoses, tubes, electric/optical fibre cables.

3.1.18

functional specification

document that specifies the totality of needs expressed by features, characteristics, process conditions, boundaries and exclusions defining the performance of a product or service including quality assurance requirements

3.1.19

host facility

fixed or floating facility to which the umbilical is mechanically and functionally connected and which provides the functions and services to be transmitted through the umbilical

EXAMPLES Platform, buoy, floating production system.

3.1.20

hydrogen getter

medium, within an optical fibre system, that chemically neutralizes hydrogen

3.1.21

lay-up

cabling

operation of assembling electrical cores or optical fibres into a cable, or hoses, tubes, electric cables, optical fibre cables into a bundle, or sub-bundle

3.1.22

loadout

transfer of an umbilical or umbilical system from a storage facility onto an installation/shipping vessel either by transfer spooling or by lifting the product stored on its installation/shipping reel

3.1.23

manufacturer's written specification

specification for the umbilical, the umbilical components and their manufacture, generated by the manufacturer in compliance with requirements specified by the purchaser and this part of ISO 13628

NOTE The specification may comprise a multiplicity of documents (design plan, inspection and test plan, test procedures, etc.).

3.1.24

maximum working load

maximum working tensile load that the umbilical can continuously withstand during handling and/or in the installed configuration without suffering damage or loss of performance

NOTE As the bending radius of the umbilical decreases, the maximum working load decreases.

3.1.25

messenger wire

device installed or pre-fitted into an I-tube or J-tube for transferring the primary pulling device, usually a rope, into the tube to provide means of pulling an umbilical through the tube

3.1.26**minimum bend radius**

radius to which a functional component may be bent during processing, reeling and unreeling, storage and installation, service and recovery without damage

NOTE 1 Typical functional components which may be bent include electrical/optical fibre cable, hose, tube, umbilical, etc.

NOTE 2 Minimum bend radius is measured from the centre of the bend to the functional component outer diameter on the inside of its bend, which may vary with the load applied to the component or umbilical.

3.1.27**minimum breaking load**

minimum tensile load that the umbilical can sustain before mechanical failure occurs when the load is applied with the umbilical in a straight condition

3.1.28**moonpool**

open access between a vessel deck and the sea, through which equipment and/or product is deployed

3.1.29**multi-coupler**

multiway connector arrangement comprising two stabplate sub-assemblies, one of which is made of a number of hydraulic and/or electric and/or optical coupler halves, each carrying a separate service, which mate simultaneously with corresponding coupler halves on the other sub-assembly when the two sub-assemblies are brought together

3.1.30**pull-in head**

device used for terminating the end of an umbilical so that it can be loaded/offloaded from a vessel and pulled along the seabed and/or through an I-tube or J-tube

NOTE In some designs the terminated armours may be used to anchor the umbilical at the top of the I-tube or J-tube. It normally comprises a streamlined cylindrical housing into which the umbilical armouring is terminated and within which the ends of the functional components are contained. It is usually capable of rapid disassembly to access the components for post-pull-in tests and monitoring. A form of pull-in head may also be used at the subsea end of the umbilical.

3.1.31**reel**

device for storing umbilicals or components comprising two flanges, separated by a barrel, with the barrel axis normally being horizontal

3.1.32**service life**

specified time during which the umbilical system shall be capable of meeting the functional requirements

3.1.33**S-N data**

data obtained by plotting cyclic stress level versus number of cycles to failure

3.1.34**splice, verb**

join together component lengths or sub-components to achieve the required production length

3.1.35**subsea termination interface**

mechanism which forms the transition between the umbilical and the subsea termination or subsea umbilical distribution unit

NOTE The interface comprises typically an umbilical armour termination, bend stiffener, hose and/or tube end fittings. If the umbilical contains electric cables, then electrical penetrator(s) and/or electrical connectors may also be incorporated.

3.1.36

subsea umbilical distribution unit

mechanism for mechanically, electrically, optically and/or hydraulically connecting an umbilical independently to more than one subsea system

NOTE In this context, hydraulic fluids includes production system service fluids and produced fluid, control fluid and gas lift lines.

3.1.37

subsea umbilical termination

mechanism for mechanically, electrically, optically and/or hydraulically connecting an umbilical or jumper bundle to a subsea system

NOTE In this context, hydraulic fluids include production system service fluids and produced fluid, control fluid, well service fluid and gas lift lines.

3.1.38

umbilical, noun

group of electric cables, optical fibre cables, hoses, tubes, either on their own or in combination with each other, cabled together for flexibility and oversheathed and/or armoured for mechanical strength

3.1.39

umbilical joint

means of joining together two lengths of umbilical to effect a repair or to achieve the required production length

3.1.40

umbilical system

umbilical, complete with end terminations and other ancillary equipment, installed between a fixed platform, a floating production facility or a land-based station, and a fixed platform, a floating production system or a subsea system, providing control, data communication and transportation of production system service fluids and/or utility supplies

3.1.41

unaged representative sample

sample of umbilical, or its internal components, which has not previously been subjected to loadings, stresses and/or elevated temperature

EXAMPLES Electric cables, hoses, tubes and optical fibres.

3.1.42

utility umbilical

umbilical for the provision of electric/hydraulic power, process fluids and data communications installed between two fixed platforms, between a fixed platform and a floating facility, or between a fixed platform/floating facility and a land-based station

3.1.43

virgin material

virgin stock

new and unused material as supplied by the material manufacturer

NOTE Virgin material or virgin stock does not comprise or contain regranulated, recycled, reprocessed, reused or other similar material.

3.1.44

weak link

device which is used to ensure that the umbilical parts or severs at a specified load and location

3.2 Abbreviated terms

For the purposes of this part of ISO 13628, the following abbreviations apply:

AC	alternating current
AVE	apparent volumetric expansion
DC	direct current
DWP	design working pressure
FAT	factory acceptance test
FIR	full indicated reading
<i>d</i>	inside diameter
KP	kilometre point
LAT	lowest astronomical tide
NDE	non-destructive examination
<i>D</i>	outside diameter
OTDR	optical time-domain reflectometer
QA	quality assurance
ROV	remotely operated vehicle
σ_y	specified minimum yield stress
TAN	titrated acid number
TVE	true volumetric expansion
UV	ultra-violet
<i>t</i>	wall thickness

4 Functional requirements

4.1 General requirements

4.1.1 Umbilical

The umbilical, and its constituent components, shall have the following characteristics:

- capable of withstanding all design loads and load combinations and perform its function for the specified design life;
- capable of storage and operation at the specified temperatures during the design life;
- materials: compatible with the environment to which they are exposed and in conformance with the corrosion control and compatibility requirements;
- electric cables: capable of transmitting power and signals with the required characteristics;

- e) optical fibres: capable of transmitting signals at the required wavelengths within the attenuation requirements;
- f) hoses and/or tubes: capable of transmitting fluids at the required flowrate, pressure, temperature and cleanliness levels;
- g) capable of venting, in a controlled manner, if permeation through components can occur;
- h) capable of being recovered and reinstalled as defined in the manufacturer's written specification.

4.1.2 End terminations and ancillary equipment

End termination interfaces with the umbilical components are a critical area and should be addressed during the design review stage.

End terminations and ancillary equipment shall, as a minimum, meet the same functional requirements as the umbilical. If applicable, the following shall be demonstrated.

- a) The end termination shall provide a structural interface between the umbilical and the support structure.
- b) The end termination shall provide a structural interface between the umbilical and bend limiter/bend stiffener device.
- c) The end termination shall not downgrade the service life of the umbilical or the system performance below the functional requirements.
- d) Corrosion protection shall meet the design life requirement.
- e) Contingency or planned recovery of the end termination to the surface during installation shall not downgrade the service life or system performance of the umbilical.

4.2 Project-specific requirements

The purchaser shall specify the functional requirements for the umbilical.

Functional requirements not specifically required or specified by the purchaser but which may affect the design, materials, manufacturing, testing, installation and operation of the umbilical shall be specified by the manufacturer.

NOTE 1 Annex A provides a basis for such specifications.

NOTE 2 If the purchaser does not specify a requirement and its absence does not affect any of these activities, the manufacturer may assume there is no requirement.

5 Quality assurance

Equipment manufactured in accordance with this part of ISO 13628 shall conform to a certified quality assurance (QA) programme. The manufacturer shall develop written specifications that describe how the QA programme will be implemented.

6 Design requirements

6.1 General

The umbilical and its constituent components shall be designed to meet the functional and technical requirements of this part of ISO 13628. The need for analysis shall result from a risk evaluation for the umbilical. The factors that shall be considered are, amongst others, the environmental and service conditions for the umbilical and the consequences of non-performance.

6.2 Design methodology

The design methodology shall include, as a minimum, the following:

- a) description of the theoretical basis, including calculation procedures and methods for evaluating the umbilical design parameters and the criteria to be satisfied in order to meet the functional requirements specified in clause 4;
- b) documentation of the design life assessment methodology, subject to the requirements of 6.3;
- c) verification of the theoretical basis via prototype tests on component samples and on samples of the complete umbilical as specified in 7.6, 7.8.7, 7.9.7 and 10.2. The verification shall include the capacity of all umbilical structural layers. Simplified conservative analysis methods for checking of non-critical layers, such as anti-wear layers, shall be 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 to account for the geometry of metallic structural components, including stress concentrations at and within the end-termination interface, clamped accessories, contact with rigid surfaces, manufacturing tolerances, and load-induced gaps;
- e) manufacturing and design tolerances, manufacturing-induced stresses, welds and other effects which influence structural capacity.

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

If the umbilical design is outside the envelope of previously validated designs, then the manufacturer shall perform prototype tests to verify the design methodology for this new design. The prototype tests shall validate fitness-for-purpose for those design parameters which are outside the previously validated envelope.

6.3 Analysis

6.3.1 General

The manufacturer shall, as part of the design evaluations, consider the results of any installation, dynamic service and structural analysis that may have been carried out in relation to the umbilical design.

The output of the analyses shall be used to demonstrate that the umbilical is suitable for installation and will remain fit for service during its design life.

The analysis results shall be verified either during the design verification testing or during factory acceptance testing. In lieu of physical testing of the components/umbilical, representative historical data may be offered by the manufacturer to verify the models or calculations used.

6.3.2 Definition of load classes

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

- a) **functional loads** are all loads acting on the umbilical during manufacture, installation and operation, including those loads such as the following which act on the umbilical in water (with the exception of wind, wave or current loads):
 - 1) loads due to weight and buoyancy of the umbilical, its contents and attachments, both temporary and permanent;
 - 2) pressure within hoses and tubes;

- 3) thermal expansion and contraction loads;
 - 4) external pressure;
 - 5) testing pressures, including installation, commissioning and storage pressures;
 - 6) external soil or rock reaction forces for trenched, buried or rock-dumped umbilicals;
 - 7) static reaction and deformation loads from supports and protection structures;
 - 8) temporary installation or recovery loads, including applied tension and crushing loads, impact loads and guidance-induced loads;
 - 9) residual installation loads in the umbilical structure during service;
 - 10) displacements due to pressure- and tension-induced rotation;
 - 11) interaction effects of laying-up or clamping the umbilical;
 - 12) loads due to rigid or flexible pipe crossings, or spans;
 - 13) loads due to positioning tolerances during installation;
 - 14) loads from inspection and maintenance tools.
- b) **environmental loads** are those loads induced by external forces caused directly or indirectly by all environmental parameters acting on the umbilical, including those induced by waves, currents and vessel motion;
- c) **accidental loads** are those loads caused directly or indirectly by unplanned activities, including, but not limited to, the following:
- 1) dropped objects;
 - 2) trawl board impact;
 - 3) anchor line failure;
 - 4) fire and explosion;
 - 5) compartment damage or unintended flooding;
 - 6) failure of thrusters;
 - 7) dynamic positioning failure of the installation vessel;
 - 8) external over-pressure;
 - 9) internal over-pressure;
 - 10) failure of turret drive system.

6.3.3 Load combinations and conditions

The umbilical design shall be shown to meet the requirements under all the design load combinations which act on the umbilical. Variation of the loads with respect to time, load effects from the umbilical system and its supports, including effects from the environment and soil conditions, shall be analysed.

The design load conditions that shall be analysed are factory-acceptance testing, installation and operation.

Design checks shall be carried out for any temporary conditions specified by the purchaser and shall be subject to the same design criteria as the design load conditions.

The design load cases to be analysed shall be derived from the loading conditions for the following load combinations:

- a) functional;
- b) functional and environmental;
- c) functional, environmental and accidental.

The load combinations considered should attempt to accurately portray the relevant loading conditions which will be applied to the umbilical. For example, during deployment it is normal practice to pressurize to a lower level than working pressure, purely for monitoring purposes, and thus the combined load case for this condition may be significantly different to that encountered under the working condition(s). Similarly, for dynamic applications, the operation of the wellhead control system may be suspended in severe sea states, thereby obviating the load case of normal working pressure combined with high axial and superimposed bending loads. In practice it is unlikely that all load combinations could be evaluated. The design analysis should therefore be a selective process if the critical and controlling load cases form the basis of the evaluation. Non-controlling and non-critical cases are not normally considered.

6.3.4 Installation analysis

This analysis shall be used to establish the loadings imposed on the umbilical during installation including those imposed due to internal monitoring pressure, vessel motion, installation equipment, clamping loads, trenching operations, rock dumping, crushing, seabed stability and pull-in operations.

The analysis shall be used to establish the following parameters which shall be considered during the design of the umbilical:

- a) allowable limits in the offset between the touch-down point of the umbilical on the seabed and the vessel as a function of sea-state and current;
- b) the variation of tension and curvature along the umbilical as a function of sea-state and current;
- c) tension and curvature time domain plots for a number of points along the umbilical, including the points established as having the maximum values of tension and minimum radii of curvature;
- d) allowable vessel motions to avoid overstressing the umbilical;
- e) residual tension from trenching;
- f) the maximum period of time, as a function of sea-state, that the laying vessel can maintain position prior to failure occurring within the umbilical;
- g) impact forces due to rock dumping;
- h) lateral deformations due to crushing loads during storage and passage through cable haulers in combination with any internal pressure monitoring and lay tension loads.

If the installation involves an I-tube or J-tube pull, the maximum pull-in force on the umbilical, taking into account the friction both on the seabed and within the I-tube or J-tube, shall also be determined.

The umbilical design loads, minimum bend radii and allowable crushing load shall be within the limits established by the installation analysis.

6.3.5 Dynamic service analysis

This analysis shall be used to establish the umbilical loadings arising from self weight, currents, wave motion effects at the surface, vessel/buoy motions, umbilical configuration, etc.

The analysis shall be used to establish the following information:

- a) the variation of tension and curvature along the installed umbilical as a function of sea-state and current;
- b) tension and curvature time series plots for a number of points along the umbilical, including the points established as having the maximum values of tension and minimum radii of curvature.

When considering the fatigue life performance, due consideration shall be made for the probabilistic nature of fatigue life. Particular attention should be paid to vortex-induced vibrations in umbilicals that are in dynamic service, as well as sections of umbilical that extend from the bottom of I-tubes to the seafloor. A suitable safety margin shall be maintained between calculated fatigue life and the required service life.

As bend stiffeners and ancillary equipment may affect the umbilical loading, they should be designed to keep the umbilical within its allowable operational limits.

NOTE A typical safety factor is 10, although this figure depends on the level of analysis, and any necessary assumptions that need to be made.

6.3.6 Structural analysis

This analysis shall be used to establish a design for the umbilical and its constituent components that shall be capable of withstanding the design loads and conditions envisaged during manufacture, load-out, recovery, repair and installation, and also for withstanding the operational conditions throughout the design life.

Details relating to structural analyses of umbilical components are provided within the individual component design subclauses.

The analysis shall demonstrate and justify that the metallic and non-metallic materials used within the umbilical system are designed to satisfy the application requirements of the material throughout the umbilical design life. If possible, this shall be performed using recognized standards and applicable factors of safety.

The design process shall consider the following:

- a) deterioration of material properties and degradation as a result of ageing throughout the service life;
- b) materials selection, including corrosion of metallic elements, cathodic attack and delamination of bonded elements;
- c) seabed stability, including the need for additional ballasting and impact on other installation activities;
- d) fatigue of armour wires, bend stiffeners, polymers and pressure-retaining components;
- e) minimum breaking loads;
- f) effects of environmental conditions (for example UV radiation, temperature, ozone and long-term exposure to seawater and permeated fluids);
- g) cumulative strain of copper conductors, armour wires, metallic tubes and fibres throughout the manufacture, handling and installation processes;
- h) strain on optical fibres.

7 Component design, manufacture and test

7.1 General

The umbilical components shall be designed and manufactured to meet the umbilical functional and technical requirements. Conformance shall be demonstrated by verification and acceptance testing.

For new component designs which are similar to previously verified designs and whose performance can be predicted with a high level of confidence, design verification tests may be included with some or all of the component acceptance tests. For unusual designs, or designs significantly different from previously verified designs, design verification testing shall be undertaken as a separate programme.

If the component design is similar to a previously validated design and the umbilical is to be installed under similar environmental and service conditions, design verification may be substituted by previous historical design verification data.

Verification and acceptance tests to be performed should also be considered for the end terminations and midline connectors and ancillary equipment, if applicable.

NOTE Verification and acceptance tests to be performed during and on completion of component manufacture specified in this clause are summarized in annex B.

7.2 Electric cable

7.2.1 General

Electric cables shall be capable of continuous operation with the insulated conductors operating in a fully flooded seawater environment.

7.2.2 Operating voltage

7.2.2.1 Power cables

Power cable voltage ratings shall be selected from the range 0 V up to the standard rated voltages $U_0/(U \cdot U_m) = 3,6/(6 \times 7,2)$ kV rms, where U_0 , U and U_m are as defined in IEC 60502-1 and IEC 60502-2.

7.2.2.2 Signal cables

Signal cables shall be designed to transmit electrical control and communication signals in the voltage range 0 V rms to $U_0/(U \cdot U_m) = 0,6/(1,0 \times 1,2)$ kV rms, where U_0 , U and U_m are as defined in IEC 60502-1 and IEC 60502-2.

7.2.3 Construction

7.2.3.1 General

Splices necessary to achieve the final length requirements shall be carried out in accordance with the qualified procedures specified in the manufacturer's written specification. Splices shall be subject to the same qualification and acceptance criteria as the insulated conductors and the cables.

Electric cores and cables should be manufactured as continuous lengths.

In a multi-core cable, the construction shall ensure that the cores can be readily separated for termination purposes and do not adhere or do not bond to the sheath, fillers, binder tape or adjacent cores.

If necessary, armouring or other forms of protection should be provided.

As cable cores are in many cases sealed by boot-seal methods, the surface of the insulation shall be round, smooth and free from marks, indentations and surface defects which may affect sealing.

On a design-specific basis, consideration shall be given to conductor strain relief due to compressive and tensile forces and the potential for damaging crushing forces that may arise in the laid-up components and/or deepwater service.

7.2.3.2 Configuration and type of conductor

The conductors shall be fabricated from high-conductivity copper wire and shall comply with the relevant conductivity and material requirements of IEC 60228. The conductors shall be manufactured from annealed circular copper wire.

If stranded, each conductor shall comprise a minimum of seven strands. The minimum nominal cross-sectional area shall be 2,5 mm² (0,004 in²). The nominal cross-sectional area for the conductor shall meet the functional requirements of clause 4.

7.2.3.3 Power cables

Power conductors shall be insulated, twisted and/or sheathed and may be screened and oversheathed in accordance with the manufacturer's written specification.

The chosen insulation material shall be of virgin stock applied as a continuous seamless circular single/multiple extrusion, and shall meet the requirements of IEC 60502-1 and IEC 60502-2. The minimum allowable insulation thickness shall meet the requirements of recognized and applicable national or International Standards for submarine service which shall be cited in the manufacturer's written specification.

7.2.3.4 Signal cables

The signal conductors shall be insulated, twisted and/or sheathed, and may be screened and oversheathed in accordance with the manufacturer's written specification. The signal cables shall be designed to meet the electrical signal transmission characteristics of the communications system adopted.

The chosen insulation material shall be of virgin stock applied as a continuous seamless circular single/multiple extrusion, and shall meet the requirements of IEC 60502-1 and IEC 60502-2. The minimum allowable insulation thickness shall meet the requirements of recognized and applicable national or International Standards for submarine service which shall be cited in the manufacturer's written specification.

7.2.3.5 Conductor coding

The insulated conductors shall be identified either by colour or by numbers. If numbers are employed, these shall be printed at regular intervals not exceeding 100 mm (4,0 in) along the length of each core. The numbers and/or colours employed shall be cited in the manufacturer's written specification.

Coding shall be stable under heat ageing and shall not cause a failure to satisfy the requirements of clause 4.

7.2.3.6 Lay-up

Twisting of individual cores shall be undertaken using helical cabling equipment.

For an intermediate lay-up operation, the cabled cores shall be bound with a helically applied overlapping tape to ensure bundle stability and a circular cross-section.

The lay-up operation shall minimize compressive forces between the cores to minimize the extent of deformation of the insulation.

7.2.3.7 Fillers

To achieve a circular consolidated arrangement, fillers shall be included in the interstices of the laid-up cores and the bundled components bound together using a binder tape, or the laid-up cores shall be consolidated by means of an extruded polymer applied directly over the cores so as to directly fill the interstices. The filler and binder tape materials shall be compatible with other materials in the cable, in particular the electrical insulation. The materials shall be as stated in the manufacturer's written specification.

7.2.3.8 Screening

If required, the cable shall be screened with plain or tinned annealed copper tape, or a two-component tape comprising a thin film of copper bonded to a polymer-based substrate. The thickness and number of layers and minimum cross-sectional area shall be as stated in the manufacturer's written specification. The screen shall be electrically continuous throughout the cable length, and should be applied in such a manner that its electrical continuity shall not be broken throughout its design life.

Metal tape screens, for electric cables or individual power cores, shall provide 100 % coverage of the enclosed electrical cores. They shall be applied helically with an overlap. The screen shall not be applied directly over the twisted cores.

If present, a drain wire shall have a minimum of three strands and the total cross-sectional area shall not be less than 0,35 mm² (0,000 5 in²). It shall be incorporated in such a way that the drain wire remains in contact with the metallic part of the screen.

7.2.3.9 Sheath

The electric cable sheath shall be of a polymeric material incorporating protection against UV radiation and ozone, and shall be as stated in the manufacturer's written specification. The chosen material shall be continuously and concentrically extruded over the laid-up cores to produce a uniform cross-section. The material shall be compatible with sea-water and the specified service fluids throughout manufacture, installation and service, and shall not degrade the quality of other materials with which it may be in contact in the lay-up.

The coefficient of friction between the sheath and the sheaths of other electric cables and/or other components shall be minimized.

As cable sheaths are in many cases sealed by boot-seal methods, the surface of the insulation shall be round, smooth and free from marks, indentations and surface defects which may affect sealing.

7.2.3.10 Identification

The cables shall be uniquely identified in accordance with the manufacturer's written specification. As a minimum the marking shall include:

- a) manufacturer;
- b) unique component reference (e.g. "Cable 3");
- c) batch number;
- d) voltage rating.

Embossed printing is not permitted.

7.2.3.11 Termination interface

The design of the electric cables shall recognize that the cables will be terminated in some form of waterblocking arrangement(s), which shall function throughout the design life.

NOTE This part of ISO 13628 does not provide detailed specifications of electrical terminations for use subsea.

7.3 Performance requirements — Electric cable

7.3.1 Conductor resistance

The DC resistance for each conductor shall not exceed the value defined in IEC 60228.

7.3.2 Insulation resistance

The DC insulation resistance for each electrical core shall not be less than the value defined in the manufacturer's written specification, which shall not be less than 500 M Ω km at 500 V DC.

7.3.3 Screening layer resistivity (non-metallic layers)

For power cable incorporating semiconducting screening layers, the resistivities shall not exceed the following values:

- a) Conductor screen: 1 000 $\Omega \cdot \text{m}$;
- b) Core screen: 500 $\Omega \cdot \text{m}$.

7.3.4 Performance characteristics

7.3.4.1 Signal

The following characteristics for each signal conductor pair shall be defined between upper and lower limits at frequencies within the operating bandwidth of the proposed system:

- a) attenuation;
- b) characteristic impedance;
- c) inductance;
- d) capacitance.

These transmission characteristics, and cross-talk limits between pairs of conductors, shall be as stated in the manufacturer's written specification.

7.3.4.2 Power

The power cable design shall consider:

- a) voltage rating;
- b) current rating;
- c) number of phases;
- d) maximum ambient temperature;
- e) maximum voltage drop.

7.4 Structural analysis — Electric cable

Structural analysis, taking account of data generated from the umbilical structural analysis specified in 6.3.6, shall be undertaken to verify the acceptability of the electric cable design for tensile, compressive and fatigue loadings upon the conductors.

7.5 Manufacture — Electric cable

7.5.1 Conductor stranding

The stranding process shall ensure that individual strands and the stranded conductor shall not be subject to compressive and tensile loadings which can introduce kinks or reduction in conductor or strand cross-sectional area.

The tension applied to the strands during the stranding operation shall be uniformly controlled during the manufacturing process and checked at regular intervals in accordance with the manufacturer's written specification.

Multi-stranded conductors shall be of the concentric lay construction and planetary lay-up in a continuous helix. Other constructions shall not be employed. During the stranding operation, the stranded conductor shall show no propensity to corkscrew or exhibit any other out-of-balance effects.

7.5.2 Insulation extrusion

During extrusion, the following process parameters shall be continuously measured and recorded:

- a) extruder barrel/head temperatures;
- b) melt pressure/temperature;
- c) screw speed/power requirements;
- d) haul-off speed.

The insulation shall be extruded as one continuous length without defects, and shall be subject to inspection and spark-testing during the extrusion process in accordance with the manufacturer's written specification. Repairs to the insulation shall not be permitted.

The insulation thickness and the outside diameter shall be measured continuously, at a minimum of two positions 90° apart, and recorded continuously.

After extrusion, the insulated conductors shall be stored in a dedicated area under cover and protected against direct sunlight, dust and other potential contaminants.

7.5.3 Lay-up

Only cores in individual electric cables and composite electric cables which have been laid up in a continuous helix shall be used in umbilicals manufactured in accordance with this part of ISO 13628. Other lay-up processes are acceptable but shall be qualified for the application.

During the cabling operation, the conductors shall not be subject to tensile and compressive loadings which introduce kinks or reduction in conductor or strand cross-sectional area.

If necessary, filler material shall be incorporated to form a compact and reasonably circular bundle. These fillers may be included in the interstices of the laid-up cores or, alternatively, the interstices may be filled as part of a subsequent sheathing operation.

During lay-up, the twisted cores shall be subject to frequent visual inspection to ensure consistent cabling of the cores and fillers.

If a binder tape is incorporated in the construction, it shall be applied at a uniform tension level which shall not prevent relative movement between individual cores when the cable is flexed.

On completion of lay-up, the cabled cores and/or cabled electric-cable elements shall be stored in a dedicated area under cover and protected against direct sunlight, dust and other potential contaminants.

7.5.4 Sheath extrusion

There shall be no holes or discontinuities in the extruded sheath. Repairs to a sheath are permissible and shall be performed in accordance with the manufacturer's written specification.

The insulation thickness and the outside diameter shall be measured continuously, at a minimum of two positions 90° apart, and recorded continuously.

7.6 Verification tests

7.6.1 Visual and dimensional checks

Electrical cores shall be 100 % visually examined and shall be free from damage, conductor kinks or faults. This shall include examination of materials for possible contamination, verification of dimensions and construction. Conductors shall be examined in accordance with IEC 60228.

7.6.2 Conductor resistance test

A DC conductor resistance test shall be performed on two samples of each insulated conductor, each sample being at least 1 m (3,28 ft) long. One sample shall be taken from each end of a completed electric cable. The measured DC conductor resistance of each conductor, corrected to 20 °C (68 °F), shall not exceed the value specified in IEC 60228 by more than 2 %.

7.6.3 Resistivity of screening layers

The resistivity of the semiconducting screening layers in the completed power core shall not exceed the values specified in 7.3.3.

7.6.4 Insulation resistance

A DC insulation resistance test shall be performed on two samples of insulated conductors, each sample being at least 1 m (3,28 ft) long. One sample shall be taken from each end of a completed electric cable.

The individual insulated conductors shall be immersed in town mains water. Insulation resistance shall be measured. The specimens shall then be subjected to a minimum hydrostatic pressure of 3,5 MPa (500 psi), or maximum hydrostatic pressure at service depth, whichever is greater, or higher in accordance with the hydrostatic pressure at maximum service depth, for a minimum period of 22 h and then insulation-resistance tested while still under pressure. Insulation resistance shall be measured. The value of insulation resistance shall not be less than the value defined in 7.3.2.

If an insulated conductor incorporates a metal screen over its entire length, this test may be undertaken by carrying it out under ambient conditions, without immersion in water.

7.6.5 High voltage DC test

A high voltage test shall be performed on two samples of insulated conductor, each sample being at least 1 m (3,28 ft) long. One sample shall be taken from each end of a completed electric cable.

The individual insulated conductors shall be immersed in town mains water. Insulation resistance shall be measured. The specimens shall then be subjected to a hydrostatic pressure of 3,5 MPa (500 psi), or higher in accordance with the hydrostatic pressure at maximum service depth, for a minimum period of 22 h. The DC test voltage for signal conductors shall be 3 kV, and for power conductors shall be 5 kV or three times U_0 whichever is greater. Each insulated conductor shall withstand the DC voltage between conductor and water at each of the pressure levels, for a period of not less than 5 min. At the end of each period, the leakage current shall be measured and shall not exceed the value stated in the manufacturer's written specification.

If an insulated conductor incorporates a metal screen over its entire length, this test may be undertaken by carrying it out under ambient conditions, without immersion in water.

This test may be combined with the insulation resistance test specified in 7.6.4, using the same samples, provided the insulation resistance test is performed first.

7.6.6 High voltage AC test

On completion of the high voltage DC test specified in 7.6.5, a high voltage AC test shall be performed on the insulated conductors subject to the same hydrostatic pressure.

The test shall be performed with an alternating voltage of sine waveform having a frequency in the range 40 Hz to 62 Hz, unless otherwise stated in the manufacturer's written specification. The value of the applied test voltage shall be as shown in Table 1. The voltage shall be applied between conductor and water. It shall be increased at the rate defined in 7.6.9, and maintained at the full value for 5 min without breakdown of the insulation.

If an insulated conductor incorporates a metal screen over its entire length, this test may be undertaken by carrying it out under ambient conditions, without immersion in water.

Table 1 — AC test voltages

Voltage designation of cable		Test voltage (rms) V
Signal cables	$\leq U_0/(U \cdot U_m) = 0,6/(1,0 \times 1,2)$ kV	1 500
Power cables $\leq U = 600$ V	$\leq 6 \text{ mm}^2$ (0,009 3 in ²)	1 500
	> Above 6 mm ² (0,009 3 in ²)	3 000
Power cables > $U = 600$ V	$\leq U_0/(U \cdot U_m) = 3,6/(6 \times 7,2)$ kV	7 500
See IEC 60502-1 and IEC 60502-2 for definition of U_0 , U and U_m .		

7.6.7 Complete voltage breakdown

On completion of the high voltage tests, four further samples at least 1 m (3,28 ft) in length shall be subjected to a complete DC breakdown test. Two samples shall be taken from each end of a completed electric cable.

Each of the samples shall be tested in a manner identical to that in 7.6.5, with two samples being tested at ambient hydrostatic pressure, and two being tested at the higher pressure used in the test defined in 7.6.5. The DC voltage shall be increased at a rate of 0,1 kV/s until breakdown occurs. The test results shall be recorded for each sample. If no voltage breakdown occurs before application of $3 \times U_0$ the insulated conductor shall be considered suitable.

7.6.8 Partial discharge test

For cables rated above $U_0/(U \cdot U_m) = 1,8/(3 \times 3,6)$ kV, a partial discharge test in accordance with IEC 60502-1 and IEC 60502-2 shall be performed. The discharge magnitude shall not exceed 10 pC.

7.6.9 Rate of application of test voltages

Unless otherwise specified for all voltage tests, the rate of increase from the initial applied voltage to the specified test voltage shall be uniform and shall not be more than 100 % in 10 s, nor less than 100 % in 60 s. The initial applied voltage shall not be greater than 500 V.

7.6.10 Inductance characteristics

A sample of completed electric cable, of 10 m (32,8 ft) minimum length, shall be measured for inductance. The inductance of each conductor pair in the cable shall be measured at fixed frequencies as specified in the manufacturer's written specification. The measured values shall comply with the requirements specified in 7.3.4, which shall include limits for deviation between actual and specified values.

7.6.11 Capacitance characteristics

A sample of completed electric cable, of 10 m (32,8 ft) minimum length, shall be measured for capacitance. The capacitance of each conductor pair in the cable shall be measured at fixed frequencies as stated in the manufacturer's written specification. The capacitance of each power unit shall be measured at the transmission frequency with respect to ground, unless stated otherwise in the manufacturer's written specification. The measured values shall comply with the requirements specified in 7.3.4. The specification shall include limits for deviation between actual and specified values.

7.6.12 Attenuation characteristics

The test shall be performed on signal cables and on power cables if signals are to be superimposed on the power conductors.

A sample of completed electric cable, of 10 m (32,8 ft) minimum length, shall be evaluated for attenuation. The attenuation of each conductor pair shall be measured or derived at the frequencies specified in the manufacturer's written specification and a curve of attenuation versus frequency shall be produced. The measured values shall be in accordance with the requirements specified in 7.3.4.

7.6.13 Characteristic impedance

A sample of completed electric cable of 10 m (32,8 ft) minimum length, shall be measured for characteristic impedance. The characteristic impedance of each pair shall be measured or derived at the frequencies specified in the manufacturer's written specification and a curve of impedance versus frequency shall be produced. The results shall be in accordance with the requirements specified in 7.3.4 which shall include limits for deviation between actual and specified values.

7.7 Component acceptance tests — Electric cable

7.7.1 Visual and dimensional inspection

During the manufacturing processes, each conductor and core shall be 100 % visually examined and shall be free from damage, kinks, faults or contamination. Raw materials shall also be screened for contamination. Core lay-up, taping, sheathing, fill and sheathing, screening, etc. shall be visually examined. Manufacturing parameters shall be periodically monitored in accordance with, and shall comply with, the manufacturer's written specification. Examination of conductors shall comply with the requirements of IEC 60228.

7.7.2 Spark test

All cores shall be spark-tested during insulation extrusion and all sheathing extrusions should be tested if the extrudate is applied directly over a screen or metallic armour layer. There shall be no indication of faults during the extrusion process in order to pass this test. During the process of insulation and sheath extrusion, the minimum voltage levels shall be in accordance with BS 5099 for the insulation and sheath thicknesses.

NOTE Cores incorporating semiconducting layers are not capable of being spark-tested.

7.7.3 DC conductor resistance test

This test shall be performed on the complete conductor lengths, as a minimum at the following manufacturing stages:

- a) after insulation extrusion;
- b) after lay-up of the cores;
- c) after completion of the electric cable.

The measured DC conductor resistance of each conductor, corrected to 20 °C (68 °F), shall not exceed the value in IEC 60228 by more than + 2 % when corrected for lay-loss.

7.7.4 Insulation resistance test

This test shall be performed on the complete conductor lengths in accordance with the procedure and acceptance value specified in 7.6.4 after insulation extrusion. The test shall also be repeated without the requirement for immersion in town mains water under pressure after lay-up, and on completion of manufacture of the electric cable.

7.7.5 High voltage DC test

This test shall be performed on the completed conductor length in accordance with the procedures and acceptance values specified in 7.6.5 after insulation extrusion. The test shall also be repeated without the requirement for immersion in town mains water under pressure after lay-up, and on completion of manufacture of the electric cable.

7.7.6 Inductance characteristics

On completion of cable manufacture, the inductance characteristics shall be measured in accordance with the procedure and acceptance values specified in 7.6.10 as follows:

- a) on a sample of minimum length 10 m (32,8 ft) removed from the completed length; or
- b) on the completed length, provided the overall length does not introduce spurious results.

7.7.7 Capacitance characteristics

On completion of cable manufacture, the capacitance characteristics shall be measured in accordance with the procedure and acceptance values specified in 7.6.11 as follows:

- a) on a sample of minimum length 10 m (32,8 ft) removed from the completed length; or
- b) on the completed length, provided the overall length does not introduce spurious results.

7.7.8 Attenuation characteristics

On completion of cable manufacture, the attenuation characteristics shall be measured or derived in accordance with the procedure and acceptance values specified in 7.6.12 as follows:

- a) on a sample of minimum length 10 m (32,8 ft) removed from the completed length; or
- b) on the completed length, provided the overall length does not introduce spurious results.

7.7.9 Characteristic impedance

On completion of cable manufacture, the characteristic impedance shall be measured in accordance with the procedure specified in 7.6.13 as follows:

- a) on a sample of minimum length 10 m (32,8 ft) removed from the completed length; or
- b) on the completed length, provided the overall length does not introduce spurious results.

7.7.10 Cross-talk

For cables containing independent conductor pairs, if cross-talk has to be minimized, the cross-talk between conductor pairs at the rated voltage, current and the rated frequency range shall be measured on the complete cable length for the appropriate mode.

The measured values shall not exceed the values stated in the manufacturer's written specification.

7.7.11 Time-domain reflectometry

A time-domain reflectometry trace shall be obtained for each conductor from both ends. The width of the pulse shall be sufficient to allow the complete conductor length to be scanned. The graphs produced shall detail all the major points, such as start and finish of the conductor, splices if present, etc. The results of this test shall be used to characterize a conductor within an electric cable or electric cable element, and do not constitute acceptance/rejection criteria.

7.7.12 Delivery to umbilical manufacturer

Should completed cables be transported from the cable manufacturer's facility to the umbilical manufacturer's facility, the following tests shall be performed on all electrical cores following delivery and prior to lay-up:

- a) DC conductor resistance as specified in 7.7.3;
- b) insulation resistance as specified in 7.7.4 ;
- c) high voltage DC test as specified in 7.7.5, for high voltage screened power cables.

7.8 Optical fibre cable

7.8.1 General

Optical fibre cables shall be capable of continuous operation immersed in a seawater environment.

7.8.2 Fibre type and coding

The fibre type shall be of either single-mode or multimode design. The design shall be as given in the manufacturer's written specification. Individual fibre identification shall be by means of fibre colouring.

7.8.3 Cable construction

The fibres shall be contained within a package which shall prevent water and minimize hydrogen contact with each fibre. The carrier package for mechanical protection and its contents shall be designed to block water ingress in the event that the optical fibre cable in the umbilical is severed.

Additional protection against hydrogen shall be incorporated in the form of a hydrogen getter (3.1.20).

The cable shall be designed to provide mechanical protection for the fibres against tensile and crushing loads.

NOTE Tensile protection can be by means of either a central strength member and/or external armouring of either metallic form or textile yarn. Mechanical protection can be by means of encapsulation in either a polymeric or metallic tube with or without external armouring.

7.8.4 Construction

7.8.5 Termination interface

The design of the optical fibre cables shall recognize that the cables will be terminated in some form of waterblocking arrangement, which shall function throughout the design life.

The long-term stability at the termination interface shall not be impeded by the materials of construction or the design.

NOTE This part of ISO 13628 is not applicable to the design of optical fibre terminations for subsea use.

7.8.6 Performance requirements

7.8.6.1 Optical attenuation

The optical attenuation for each fibre at specified wavelengths shall meet the requirements given in clause 4.

7.8.6.2 Fibre strain

The umbilical and optical fibre cables shall be designed so that potentially damaging strain levels are not imposed on the optical fibres.

7.8.6.3 Cable jointing

7.8.6.3.1 Cable

If production lengths dictate, optical fibre cable lengths may be joined together. The joint shall be either a cable splice incorporating fibre splices in accordance with the manufacturer's written specification, or a splice box whereby the individual pigtails can be configured to allow splices to be performed and the jointed fibres to be accommodated free of tensile and bending stresses. Whichever method is employed, water and hydrogen shall be prevented from coming into contact with the fibres.

7.8.6.3.2 Fibre jointing

Jointing of the fibres shall be allowed, with the use of high strength qualified fusion splicing techniques. The acceptance level of splice loss attenuation shall be as defined in the manufacturer's written specification. Splices shall be individually subject to tensile testing, to the load level defined in the manufacturer's written specification.

The splice region shall be suitably protected and the optical performance, after splicing, shall meet the requirements of clause 4.

7.8.7 Verification tests

7.8.7.1 Transmission and optical characteristics

Transmission and optical characteristics of the optical fibres shall be verified in accordance with IEC 60793-1 and IEC 60793-2.

7.8.7.2 Mechanical characteristics

Mechanical characteristics of the optical fibres shall be verified in accordance with IEC 60794-1-1 and IEC 60794-1-2.

7.8.7.3 Environmental resistance

The environmental resistance of the optical fibre cable to seawater, hydrogen and service fluids shall be verified in accordance with the manufacturer's written specification.

7.8.7.4 External pressure test

A sample of the optical fibre cable of minimum length not less than 1 m (3,28 ft) shall be subject to an external hydrostatic pressure test for a period of 14 d at a pressure equivalent to the maximum installation depth for the umbilical. The specimen's optical fibres shall be joined in series and periodically monitored in accordance with the manufacturer's written specification. Any changes in attenuation measured shall not cause degradation in system performance over the design life of the system.

Following completion of the test, the sample shall be stripped down and examined for any evidence of structural or fibre change which may compromise the design life of the system.

7.8.7.5 Fibre splicing

Fibre splicing shall be verified in accordance with the manufacturer's written specification.

7.8.8 Component acceptance tests

7.8.8.1 Visual and dimensional inspection

During the manufacturing process, each optical fibre cable shall be 100 % visually examined and shall be free from damage, kinks or irregularities. Cable lay-up, carrier tube fabrication, sheathing and armouring processes shall be subject to visual examination. Manufacturing parameters shall be periodically measured, and be in accordance with the manufacturer's written specification.

7.8.8.2 Optical time-domain reflectometry (OTDR)

Each fibre within the cable shall be subject to an OTDR test from each end, at wavelengths specified within the manufacturer's written specification.

Graphs produced shall detail all the major points, such as start and end of the cable and splices (if present). Attenuation values shall meet the requirements of the manufacturer's written specification.

7.8.9 Delivery to umbilical manufacturer

If the completed cable is transported from the cable manufacturer's facility to the umbilical manufacturer's facility, an OTDR test as specified in 7.8.8.2 shall be performed on all fibres following delivery and prior to lay-up. Attenuation values shall meet the requirements of the manufacturer's written specification.

7.9 Hoses

7.9.1 General

Hoses shall be capable of continuous operation immersed in a seawater environment.

7.9.2 Hose sizing

All hoses shall be referenced by nominal bore and DWP.

NOTE Preferred hose bore sizes and DWP are tabulated in annex C.

Tolerances on nominal bore shall not exceed the values given in Table 2, and the inside and outside diameters of the hose shall be concentric within the limits in Table 3.

The completed hose outside diameter D shall be within $\pm 4\%$ of the value specified in the manufacturer's written specification.

Table 2 — Nominal bore and wall thickness tolerances

Nominal bore		Tol. %	Liner wall thickness	
mm	(in)		t mm	(in)
6,0 to 10,0	(0,233 to 0,394)	+ 5,0 – 3,0	$\pm 0,2$	(0,007 9)
10,1 to 20,0	(0,395 to 0,787)	+ 3,0 – 2,0	$\pm 0,2$	(0,007 9)
20,1 to 38,1	(0,788 to 1,5)	+ 2,0 – 1,5	$\pm 0,25$	(0,009 8)

If the hose liner is specifically designed to withstand external hydrostatic pressure and this necessitates increasing the thickness of the liner to resist collapse, larger wall thickness and concentricity tolerances are permissible. Such tolerances shall be as stated in the manufacturer's written specification.

Table 3 — Concentricity

Nominal bore		Concentricity, FIR	
mm	(in)	mm	(in)
Up to 25,4	(1,0)	1,0	(0,040)
Over 25,4	(1,0)	1,5	(0,060)

7.9.3 Hose construction

7.9.3.1 General

The hose shall comprise three component parts: the liner, the reinforcement and the sheath. When subject to pressure in an unrestrained state, the hose construction shall show no significant propensity to loop, or rotate about its axis.

7.9.3.2 Hose liner

The liner shall be a continuous, seamless, circular and concentric extrusion, manufactured from virgin thermoplastic material, and shall be compatible with the intended service fluids.

Multi-layer liners may be acceptable if application requirements cannot be satisfied by a single-layer construction. For instance in situations where there are high external pressures, then the use of an internal support may be incorporated.