Specification for Subsea Production Control Umbilicals

API SPECIFICATION 17E
SECOND EDITION SEPTEMBER 1, 1998

American
Petroleum
Institute

Specification for Subsea Production Control Umbilicals

Exploration & Production Department

API SPECIFICATION 17E
SECOND EDITION SEPTEMBER 1, 1998

American Petroleum Institute

SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Authoring Department [telephone (202) 682-8000]. A catalog of API publications and materials is published annually and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the director of the Authoring Department (shown on the title page of this document), American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

FOREWORD

This Specification is under the jurisdiction of the API Exploration and Production Department Subcommittee on Standardization of Subsea Production Systems.

American Petroleum Institute (API) Specifications are published as aids to the procurement of standardized equipment and materials, as well as instructions to manufacturers of equipment or materials covered by an API Specification. These Specifications are not intended to obviate the need for sound engineering, nor to inhibit in any way anyone from purchasing or producing products to other specifications.

The formulation and publication of API Specifications and the API monogram program is not intended in any way to inhibit the purchase of products from companies not licensed to use the API monogram.

API Specifications may be used by anyone desiring to do so, and diligent effort has been made by the Institute to assure the accuracy and reliability of the data contained therein. However, the Institute makes no representation, warranty or guarantee in connection with the publication of any API Specification and hereby expressly disclaims any liability or responsibility for loss or damage resulting from their use, for any violation of any federal, state, or municipal regulation with which an API Specification may conflict or for the infringement of any patent resulting from the use of an API Specification.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API Specification is solely responsible for complying with all the applicable requirements of that Specification. The American Petroleum Institute does not represent, warrant or guarantee that such products do in fact conform to the applicable API Specification.

This specification shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

Requests for permission to reproduce or translate all or any part of the material published herein should be addressed to the Director, API Exploration and Production Department.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to the director of the Exploration and Production Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

CONTENTS

Figures

CONTENTS

Page

Specification for Subsea Production Control Umbilicals

1 SCOPE

This specification provides standards for the design, manufacture, design verification and factory acceptance testing of permanently installed subsea control, chemical injection, SSIV and utility umbilicals for both static and dynamic applications for use in marine environments for the offshore production of hydrocarbons. The umbilicals may carry electrical services only, hydraulic or chemical functions only, or a combination of these. Other functions such a gas lift and optical fiber data communications may also be included.

The hose types contained within the umbilicals are of the fiber reinforced thermoplastic construction. The specification also covers the design requirements for low power, low frequency power and communication electric cables designed for the control of subsea production systems.

This specification may be referenced in Purchaser/Functional Specifications for umbilical systems as the detailed standard for the design, manufacture and testing of umbilicals. In compiling such Functional Specifications, sufficient prescriptive information shall be included such that the maximum benefit shall be derived from this specification. Appendix A provides information to be considered in the compilation of a Purchaser/Functional Specification such that the Manufacturer can demonstrate by design calculations, material selection, verification tests, factory acceptance and historical data tests that the umbilical will meet the functional requirements.

Installation of umbilicals is outwith the scope of this specification, however the design of the umbilicals shall take account of installation guidelines applicable to umbilicals contained within API RP17I.

2 References

2.1 STANDARDS

This specification references the following standards. The latest edition of each at placement of order with the manufacturer shall apply.

In the event of conflict between the referenced standards and this specification, then this specification shall take precedence.

API

RP17I	*Installation Guidelines for Subsea Umbilicals*

ASTM[1]

D664	*Test Method for Acid Number of Petroleum Products by Potentiometric Titration*
D974	*Test Method for Acid and Base Number by Colour Indicator Titration*

BS[2]

443	*Specification for Testing Zinc Coatings on Steel Wire and for Quality Requirements*
1441	*Specification for Galvanized Steel Wire for Armoring Submarine Cables*
1442	*Specification for Galvanized Mild Steel Wire for Armoring Cables*
5099	*Specification for Spark Testing of Electrical Cables*
5540	*Evaluating Particulate Contamination of Hydraulic Fluids*

IEC[3]

228	*Conductors of Insulated Cables*
502	*Extruded Solid Di-electric Insulated Power Cables for Rated Voltages from 1 kV up to 30 kV*

ISO[4]

527	*Plastics, Determination of Tensile Properties*
1402	*Rubber and Plastics Hoses and Hose Assemblies—Hydrostatic Testing*
4080	*Rubber and Plastics Hoses—Determination of Gas Permeance*
4406	*Hydraulic Fluid Power–Fluids—Method for Coding Level of Contamination by Solid Particles*
4672	*Rubber and Plastics Hoses—Sub-ambient Temperature Flexibility Tests*
6801	*Rubber and Plastics Hoses—Determination of Volumetric Expansion*
6803	*Rubber or Plastics Hoses and Hose Assemblies—Hydraulic Pressure Impulse Test Without Flexing*
7751	*Rubber and Plastics Hose Assemblies—Ratios of Proof and Burst Pressure to Design Working Pressure*
8308	*Rubber and Plastics Hoses and Tubing—Determination of Transmission of Liquids Through Hose and Tubing Walls*
9001	*Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation and Servicing*

[1]American Society for Testing and Materials100 Barr Harbor Drive West Conshohocken, Pennsylvania 19428-2959.

[2]British Standards Institute 389 Chiswick High Road, London, W4 4AL UK.

[3]International Electrochemical Commission1 rue de Varembe, Geneva, Switzerland.

[4]International Organization for Standardization11 West 42nd Street, New York, New York 10036.

SAE[5]

J516 *Coupling Thread Sizes*

Note: Standards referenced in this specification may be replaced by other international and national standards that can be shown to meet or exceed the requirements of the referenced standard. Manufacturers who choose to use other standards in lieu of standards referenced herein shall be responsible for documenting and verifying the equivalency of the standards.

3 DEFINITIONS

3.1 ancillary equipment: accessory to the umbilical system which does not form part of the main functional purpose. (Weak link, buoyancy collar, I/J-tube seal, etc.).

3.2 API monogram: registered mark of the American Petroleum Institute.

3.3 armor: two or more layers of contra-helically applied galvanized steel wires surrounding the laid-up functional components of an umbilical. The wires may be individually jacketed with a thermoplastic polymer, or alternated with plastic rods of the same diameter. The armor provides mechanical strength, protection and ballast for the umbilical bundle. For some applications, where tensile capability and torque balance are not critical, one layer only of armor may be acceptable.

3.4 attenuation: reduction in level of the transmission signal at the transmission frequency. Measured in decibels (dB).

3.5 bend limiter: device for limiting the bend radius of the umbilical, usually by mechanical means, typically comprising a series of interlocking metal rings designed to lock at a pre-defined radius.

3.6 bend stiffener: device for providing bending strain relief for the umbilical by providing localized increase in stiffness. Usually a molded device, sometimes reinforced depending on the required duty, applied over the umbilical. Sometimes referred to as a bend strain reliever.

3.7 bend stiffness: resistance of an umbilical to bending from a straight condition to a radius. Bending stiffness in an umbilical is analogous to the structural stiffness of a rigid steel beam or steel pipe (modulus of elasticity x second area moment of inertia), except it can vary with temperature and pressure levels within hoses. There can also be a significant level of hysteresis, due to the materials of construction. Quantified as the product of applied bending modulus x resultant bend radius of the umbilical. Expressed as $kN.m^2$.

3.8 bore: internal diameter of the hose liner, used dimensionally to denote hose size.

[5]SAE International Society of Automotive Engineers, 400 Commonwealth Dr. Warrendale, Pennsylvania 15096-001.

3.9 breaking tenacity: term expressing the breaking force of hose reinforcement yarn per unit linear density and expressed in mN/tex, where one tex is the mass in grams of 1,000 meters of yarn.

3.10 built-in end fitting: attachment secured directly to the end, or close to the end of an umbilical, to enable the umbilical to be mechanically anchored so as to resist tensile loads and/or bending moments. The attachment may incorporate a bend stiffener and is typically located at a I/J-tube hang-off or vessel exit point.

3.11 bundle: laid-up functional components (hoses, electric cables, optical fiber cables) and associated fillers in the umbilical prior to sheathing.

3.12 cable: generic term used to describe a group of electric cores or optical fibers bundled together. The electrical cores may be taped and/or jacketed to maintain stability and mechanical protection. The fibers may be bundled loosely in a tube or individually in a slotted carrier which is oversheathed for mechanical protection. (See Appendix C Figures 2 and 3).

3.13 capacitance: measurement of the ability of an electrical cable to store electrostatic charge when potential differences exist between the conductors. Measured in Farads.

3.14 characteristic impedance: AC voltage/current ratio at any point along a transmission line. Measured in Ohms.

3.15 coaxial cable: cable for the transmission of signal data of low to high frequency. The conductor pair is arranged concentrically with an annulus of di-electric material between the conductors.

3.16 components: hoses and electrical cables incorporated in umbilicals. May also include optical fiber cables.

3.17 conductor: rod of conductive metal. In an electric cable a conductor refers to a conductive material, such as copper in either stranded or solid form used to transmit electrical power and/or electrical communications.

3.18 core: generic term used to describe an individual electrically insulated conductor. (See Appendix C, Figure 1).

3.19 coupling: device used to splice two hose lengths together. (See Appendix B, Figure 4).

3.20 crimping: method of attaching a coupling or end fitting to a hose by compressing the coupling/fitting abutment with a radially applied load generally by means of a segmented die arrangement. (See Appendix B, Figure 1). Also applies to an abutment which is non-circular in cross-section (e.g. hexagonal), and is compressed by means of a two-part die of the same cross-sectional form, but with reduced dimensions.

3.21 cross-talk: trespass of electrical energy from one electrical circuit to another. Measured as a power ratio in two configurations:

a. Differential Mode - measured between cores in a pair.
b. Common Mode - measured between cores and screen.

Expressed in decibels (dB).

3.22 DC conductor resistance: linear resistance of an electrical conductor to a direct current. Measured in Ohms.

3.23 DC loop resistance: DC conductor resistance of a pair of conductors connected in series. Measured in Ohms.

3.24 design life: specified period of time during which the umbilical shall fulfill its performance requirements.

3.25 design plan: schedule of design and qualification activities identifying the stages at which Manufacturer, Purchaser, Third Parties or Independent Inspectorates are involved and, additionally, identifying the specifications involved, procedures, acceptance criteria and instructions that are relevant.

3.26 drain wire: conductor placed in contact with an electrical screen to improve and maintain the electrical continuity of the screen. (Generally used in conjunction with metallized plastic film screens).

3.27 dynamic analysis: An analysis undertaken of an umbilical system that will be subject to continuous dynamic excitation to help ensure that the system is designed, installed and operated safely and reliably. The results of analysis, typical histories of forces, moments, displacements, stresses, curvatures, deformations may be used in the design phase for checking and refining the proposed system design and determining proper installation procedures. The analysis may be combined with the interaction analysis of other subsea systems such as adjacent dynamic umbilical systems and/or dynamic production risers. Used to determine the motion envelope of the umbilical with respect to other elements (risers, anchor chains, buoys, etc.).

3.28 end fitting: attachment secured directly to the end of hose incorporating one half of a metal-metal seal, used to enable connection of the hose to another piece of equipment.

3.29 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 installation or surface facility.

3.30 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 QA requirements.

3.31 hose: flexible pressure containing pipe which can perform functions similar to a rigid pipe and withstand repeated flexure at small radii without adverse effects.

3.32 hose assembly: length of hose with an end fitting attached at each end.

3.33 hose liner: inner most component of a hose providing the diaphragm seal for containing and conveying fluids. Sometimes referred to as the core tube. (See Appendix C, Figure 5).

3.34 hose reinforcement: or more layers of high tenacity synthetic fiber applied around the hose liner to provide the design pressure rating requirements. (See Appendix C, Figure 5).

3.35 inductance: constant relating the electromagnetic force induced within the electrical cable to the current variation with time. Measured in Webers per ampere and has an SI derived unit of Henry.

3.36 inspection and test plan: schedule of inspection and test activities identifying the stages at which Manufacturer, Purchaser, Third Parties, or Independent Inspectorates are involved and, additionally, identifying the specifications involved, procedures, acceptance criteria and instructions that are relevant.

3.37 insulation: layer of di-electric material covering an electrical conductor.

3.38 insulated conductor: conductor †insulated with †a suitable di-electric material.

3.39 insulation resistance: resistance of the conductor insulation when applied with a constant DC potential across the cable insulation. Measured in Ohms.

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

3.41 jumper bundle: group of electric cables or hoses on their own or with combinations of each other bundled or cabled together to provide a flexible connection between subsea systems, or between a subsea termination/subsea distribution unit and a subsea system.

3.42 lay-up: operation of assembling electrical cores or optical fibers into a cable, or hoses, electric cables, optical fiber cables into a bundle, or sub-bundle. Also known as cabling.

3.43 linear density: mass per unit length of yarn expressed in tex, where one tex is the mass in grams of 1,000 meters of yarn. E.g. A yarn designated 330 tex has a mass of 330 g per 1,000 m length.

3.44 manufacturer: manufacturer of the umbilical and/or its component parts.

3.45 manufacturer's written specification: specification for the umbilical and the umbilical components and their manufacture, generated by the Manufacturer in response to Purchaser specified requirements. The specification may comprise a multiplicity of documents (Design Plan, Test Procedures, Inspection and Test Plan, etc.).

3.46 maximum working load: maximum working tensile load that the umbilical can withstand continuously during loadout, deployment 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.

3.47 maximum working pressure: maximum pressure at which the hose is rated for continuous operation.

3.48 may: Indicates a possible course of action.

3.49 minimum bend radius: minimum bend radius to which a functional component (hose, electric cable, etc.), or umbilical may be bent during processing, reeling and unreeling, storage and during installation, service and recovery. It is measured from the inside of the bend. (See Appendix B, Figure 3).

3.50 minimum breaking load: minimum tensile load that the umbilical can sustain before mechanical failure occurs when the load is applied with the umbilical in the straight condition.

3.51 oscillatory lay-up: method of laying-up, whereby the components to be cabled together are rotated around the axis of the cabled product, typically 360°-720°, followed by a reversal in the direction of rotation for a similar level of angular rotation, after which the rotation sequence is repeated. Also known as "SZ" lay-up. (See Appendix D, Figure 2).

3.52 oversheath: additional extruded thermoplastic covering used to build-up the outside diameter of an electric cable, or a hose. Used to provide additional protection and/or to increase the diameter to meet geometrical requirements during bundle or sub-bundle lay-up.

May also be locally applied to an umbilical to meet a specific installation or operational requirement, e.g. abrasion protection

3.53 pair: cable for the transmission of electrical power or low frequency signals consisting of two insulated conductors twisted together with a constant lay length. The cable may be screened to reduce cross-talk. (See Appendix C, Figures 2 and 3).

3.54 permeability: characteristic of a material which allows liquid or gas to diffuse through it.

3.55 planetary lay-up: method of laying-up, whereby the elements (electrical cores, components, etc.), to be cabled together are continuously rotated in the same direction around the axis of the cabled product such that the elements are incorporated in the form of continuous helixes. The method necessitates rotating the element lengths to be laid-up which is typically undertaken by a revolving carriage into which the individual lengths are located on their processing reels. (See Appendix D, Figure D1).

3.56 power cable: cable designed to transmit electrical energy at electrical transmission voltages up to and including standard rated voltages $U_o/U(U_m)$ =3.6/6 (7.2) kV rms.

3.57 pressure decay test: test to determine the amount by which the pressure falls in a hose after having being raised to a particular level and then isolated from the pressurizing source. Used to demonstrate the characteristics of a hose due to creep of the hose materials of construction and the hydraulic integrity of a hose.

3.58 proof pressure test: constant pressure, higher than its maximum working pressure, applied to a hose/assembly for a short duration to demonstrate its integrity without causing destruction or deterioration.

3.59 quad: cable for the transmission of electrical power or low frequency signals consisting of four insulated conductors twisted together in a symmetrical arrangement with a constant lay length. The cable may be screened to reduce cross-talk. (See Appendix C, Figures C2 and C3).

3.60 quality assurance: planned, systematic and preventative actions which are required to ensure that materials, products or services will meet specified requirements.

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

3.62 roving: layer of fibers, usually in string form, helically applied around bundled components to act as a bedding layer or around an armor layer to provide protection to the galvanizing, and if required, color identification (see Appendix E, Figures E2 and E3).

3.63 screen: conducting layer applied around laid-up electrical cores to minimize electrical interference from another circuit or around individual power cores to provide a uniform radial electrical field in a power cable or power cable arrangement. Also referred to as a shield.

3.64 shall: indicates mandatory requirement.

3.65 should: indicates preferred course of action or is recommended as good practice.

3.66 sheath: covering of an electric cable, a hose, a bundle, a sub-bundle or an outer armor layer by a layer of polymeric, impervious, or non-impervious material to provide mechanical protection and/or to meet geometrical requirements as part of the umbilical lay-up (see Appendix E, Figures E1 and E3).

3.67 signal cable: cable for the transmission of electrical control and communication signals up to and including standard rated voltages Uo/U = 0.6/1kV rms. Sometimes called a telecommunication (telecom) cable and frequently screened.

3.68 spark test: on-line process test to locate faults in the insulation or sheath covering.

3.69 SN curve: curve derived by plotting the cyclic stress and the corresponding number of fatigue cycles to failure for a given material or structure as a function of different stress levels.

3.70 splice: joining together of component lengths or subcomponents to achieve the required production length.

3.71 subsea termination interface: mechanism which forms the transition between the umbilical and the subsea termination or subsea umbilical distribution unit. The interface comprises typically an umbilical armor termination, bend stiffener, hose end fittings. Where the umbilical contains electric cables, electrical penetrator(s) and/or electrical connectors may also be incorporated.

3.72 subsea umbilical distribution unit: mechanism for mechanically, electrically and/or hydraulically independently connecting the umbilical independently to more than one subsea system. (In this context, hydraulically includes production system service fluids and produced fluids).

3.73 subsea umbilical termination: mechanism for mechanically, electrically and/or hydraulically connecting an umbilical or jumper bundle to a subsea system. (In this context, hydraulically includes production system service fluids and produced fluid, control fluid, well service fluid and gas lift lines).

3.74 swaging: method of attaching an end fitting to a hose by application of an axial force to the front of the end fitting. The fitting abutment is forced into a die of a smaller diameter. (See Appendix B, Figure B2).

3.75 system operating pressure: highest internal pressure at which a hose, attached end fittings/couplings and associated hydraulic connectors are intended to be used in service. It shall not exceed the maximum working pressure and is invariably determined by the performance characteristics of equipment connected to the umbilical system.

3.76 topside umbilical termination: enclosure located on a platform or floating production facility usually directly above or adjacent to the I/J-tube riser system to provide the means of connecting the umbilical functional lines to the topside supply/return lines.

3.77 torque balance: umbilical design which shows little or no propensity to rotate about its axis under the action of a tensile load.

Note: It is not always possible for an umbilical to show no propensity to rotate between zero and its maximum working load. The degree of torsional loading shall be such that the umbilical does not induce significant twist during installation deployment, and for a dynamic umbilical during service, which could result in loops or abnormal configurations.

3.78 town mains water: water from a town water supply, suitable for drinking. May also be referred to as potable water.

3.79 triad: cable for the transmission of electric power or low frequency signals consisting of three insulated conductors twisted together in a symmetrical arrangement with a constant lay length. The cable may be screened to reduce cross-talk. Sometimes referred to as a triple. (See Appendix C, Figures C2 and C3).

3.80 time domain reflectometry: fault finding test to locate breaks in, or significant change in impedance in electrical conductors by pulse reflection techniques.

3.81 U: rated rms power-frequency voltage between two insulated conductors, for which cables and accessories are designed.

3.82 U_m: maximum rms power-frequency voltage between each insulated conductor and screen or sheath, for which cables and accessories are designed. It is the highest voltage that can be sustained under normal operating conditions at any time and at any point in a system. It excludes temporary voltage variations due to fault conditions and the sudden disconnection of large loads.

3.83 U_o: rated rms power-frequency voltage between each insulated conductor and screen or sheath, for which cables and accessories are designed.

3.84 ultimate tensile strength: tensile force at which the umbilical parts.

3.85 umbilical: group of electrical cables, hoses, either on their own or with combinations of each other (or optical fiber cables), cabled together for flexibility and oversheathed and/or armored for mechanical strength. (See Appendix E, Figures E1 and E2).

3.86 umbilical system: umbilical complete with end terminations and other ancillary equipment (weak link, buoyancy collars, etc.), installed between a fixed platform, or a floating production facility, or a land based station, and a fixed platform or a floating production facility, a subsea system providing control, data communication and transportation of production system service fluids and/or utility supplies.

3.87 unaged hose: recently manufactured hose which may or may not have been subjected to manufacturing pressure tests and has not been incorporated in an umbilical, or subject to damaging pressures.

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

3.89 virgin material: thermoplastic raw material as supplied by the material manufacturer. Virgin material does not comprise or contain re-granulated, recycled, reprocessed, reused or other similar material.

3.90 visual examination: examination of raw material, components, part completed components, finished and part-finished product for visible defects in material and workmanship.

3.91 volumetric expansion: increase in internal volume of a hose when pressurized, expressed as a change in volume per unit length at a specified pressure.

3.92 weak link: device which is used to ensure that the umbilical parts at a specified load and location.

3.93 will: indicates an intention of action.

4 ABBREVIATIONS

AC	Alternating Current
BS	British Standard
cm	Centimeter
DC	Direct Current
EPC	Ethylene Propylene Co-polymer
EPDM	Ethylene Propylene Diene Rubber
EPM/EPR	Ethylene Propylene Rubber
ft	Feet
FPS	Floating Production System
FIR	Full Indicated Reading
g	Gram
ID	Internal Diameter
lEC	International Electrotechnical Commission
in	Inch
ISO	International Standards Organization
JIC	Joint Industries Council
kN	Kilonewton
kV	Kilovolt
lb	Pound
m	Meter
mm	Millimeter
OD	Outside Diameter
pC	Picocoloumb
PE	Polyethylene
psi	Pound per square inch
QA	Quality Assurance
QC	Quality Control
rms	Root Mean Square
SAE	Society of Automotive Engineers
SSIV	Subsea Isolation Valve
TAN	Titrated Acid Number

5 ELECTRICAL CABLE DESIGN

5.1 GENERAL

This section defines the principle design parameters for electrical cables. These parameters shall be considered during the design of cables for use in electrical and, composite umbilicals containing hoses and electric cables.

The design and construction of an electrical core, electric cable and composite electrical cable element shall take account of the hydrostatic pressure that they will be subject to throughout their design life. The long term stability at the termination interface shall not be impeded by the materials of construction and the construction design. Materials of construction shall be resistant to micro-organisms present in the storage and installed environments.

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

The design of electrical terminations for use subsea is outwith the scope of this specification. The design of the electric cables shall, however, recognize that the cables will be terminated in some form of waterblocking arrangement (connector, penetrator, etc.), which shall function throughout the design life.

5.2 OPERATING VOLTAGE

5.2.1 Power Cables

Power cable voltage ratings shall be selected from the range 0 V rms up to the standard rated voltages $U_o/U(U_m)$ = 3.6/6 (7.2) kV rms.

5.2.2 Signal Cables

Signal cables shall be designed to transmit electrical control and communication signals in the voltage range 0 V rms to U/U_o = 0.6/1.0 kV rms.

5.3 CONSTRUCTION

5.3.1 General

Electric cores and cables shall be manufactured as continuous lengths, where possible. Splices necessary to achieve the final length requirements may be allowed and shall be carried out in accordance with the qualified procedures specified in the Manufacturer's written specification.

In a multi-core cable, the construction shall ensure that the cores can be readily separated for termination purposes and do not adhere or are bonded to the sheath, fillers, binder tape or adjacent cores. When opened out from the cable, the cores shall be as circular as possible.

5.3.2 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 228. The conductors shall be manufactured from plain or tinned annealed circular copper wire and shall be either solid or stranded.

If stranded, the conductors shall have a minimum of 7 strands. The minimum nominal cross-sectional area shall be 2.5 mm^2. The nominal cross-sectional area for the conductor shall be in accordance with the Manufacturer's written specification.

5.3.3 Power Cables

The power conductors shall be insulated, sheathed, and may be oversheathed, twisted and screened. The method of construction shall be as stated in the Manufacturer's written specification. Conductor and insulation screening shall be incorporated where required in accordance with the requirements of IEC 502. The power cables may be of the following type as illustrated typically in Appendix C, Figures 1 and 2:

a. Single core
b. Twisted pair
c. Twisted triple
d. Twisted quad
e. Twisted multi-core

5.3.4 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 communication system adopted and may be of the following type as illustrated typically in Appendix C, Figure 3:

a. Coaxial cable
b. Twisted pair
c. Twisted triad
d. Twisted quad
e. Twisted multi-core

Where signal and power cables are incorporated in the same umbilical, or signal cables are laid-up without power cables and electrical interference may be present, screening shall be incorporated in each signal cable.

5.3.5 Composite Electric Cable Element

To facilitate geometrical requirements in the lay-up of the umbilical bundle, or electrical termination requirements, signal cables and power cores may be cabled together and/or oversheathed to form a composite cable element as illustrated typically in Appendix C, Figure 4.

5.3.6 Insulation

The insulation material for a conductor shall be suitable for operation immersed in seawater at ambient pressure for the specified design life. Materials that have been used successfully include:

a. Polyethylene (PE), insulation grade low or medium density
b. Cross-Linked Polyethylene (XLPE)
c. Ethylene Propylene Rubber (EPM/EPR)
d. Ethylene Propylene Co-polymer (EPC)
e. Ethylene Propylene Diene Rubber (EPDM)

The chosen insulation material shall be of virgin stock applied as a continuous seamless circular single/multiple extrusion and shall meet the requirements of lEC 502. The minimum allowable insulation thickness shall meet recognized national or international standards which shall be specified in the Manufacturer's written specification. Where no recognized standards are applicable for the chosen insulation material, then the thickness shall be in accordance with the Manufacturer's written specification.

5.3.7 Conductor Coding

The insulated conductors shall be identified either by color or by numbers. Where numbers are employed, these shall be printed at regular intervals not exceeding 100 mm along the length of each core. The numbers and/or colors employed shall be specified in the Manufacturer's written specification.

Coding should be stable under heat aging and should not degrade the quality of the insulation material.

5.3.8 Lay-Up

Twisting of individual cores shall be undertaken using planetary cabling equipment. After the final lay-up, the cores may be bound with tape or a fill and sheath extrudate applied to maintain stability. Where several lay-up operations are involved, each subsequent lay shall be contra-helically applied. 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 or flats on the insulation.

5.3.9 Screening

If required, the cable shall be screened with plain or tinned annealed copper tape, or a metallized polyester tape. 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 service life. The characteristics of the screen shall be specified in the Manufacturer's written specification.

Metal tape screens shall provide a minimum of 100% coverage of the enclosed electrical cores. They shall be applied helically with an overlap in accordance with the Manufacturer's written specification. The screen shall not be applied directly over the twisted cores.

Where a drain wire is used as part of the cable, it shall be multi-stranded copper wire of suitable nominal diameter. It shall be incorporated in the signal cable in such a way that the drain wire remains in contact with the metallic side of the screen tape. The drain wire shall have a minimum of 3 strands and the total cross-sectional area shall not be less than 0.35 mm^2.

5.3.10 Fillers

To achieve a circular consolidated arrangement, synthetic fiber fillers may be included in the interstices of the laid-up cores and the bundled components bound together using a binder tape applied at a constant helix angle. Alternatively, the laid-up cores may be consolidated by means of an extruded polymer applied directly over the cores so as to directly fill the interstices with polymer material. The filler and binder tape material shall not degrade other materials in the cable, in particular the electrical insulation. The material shall be as stated in the Manufacturer's written specification.

5.3.11 Sheath

The electric cable and composite electric cable element sheath shall be of a virgin thermoplastic material, such as Polyethylene, incorporating protection against ultra-violet radiation and shall be as stated in the Manufacturer's written specification. The chosen material shall be continuously and concentrically extruded over the bundled cores to produce a uniform cross-sectional area. The material shall be compatible with the service fluids 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 hoses shall be minimized.

5.3.12 Identification

The cables shall be uniquely identified in accordance with the Manufacturer's written specification.

Embossed printing shall not be permitted.

5.4 DESIGN PERFORMANCE REQUIREMENTS

5.4.1 General

The performance characteristics for the electric cables should take account of the requirement for the characteristics to be compatible with the interfacing electric/electronic systems. The Manufacturer's written specification should take account of these requirements.

5.4.2 Temperature Range

The electric cable shall be capable of operating within the normal temperature range of -15°C to +40°C. For some installed conditions (I/J-tube risers in warm climates, close proximity to production risers in an enclosed environment, etc.), it may be possible for the electric cable to be subjected to a temperature higher than the specified maximum. In this event, the maximum temperature shall be specified in the Manufacture's written specification. The electric cable shall be capable of operating continuously at service temperature for the design life.

Note: Continuous or frequent exposure to elevated temperatures may impact the design life of the electric cable.

5.4.3 Conductor Resistance

The DC resistance for each conductor shall not exceed the value defined in IEC 228.

5.4.4 Insulation Resistance

The DC insulation resistance for each electrical core shall not be less than the values defined in the Manufacturer's written specification which shall not be less than 500 MegOhm.km at 500V DC.

5.4.5 Screening Layer Resistivity (Non-Metallic Layers)

For power cables incorporating semi-conducting screening layers, the resistivities shall not exceed the following values:

a. Conductor screen: 1,000 Ohm.m
b. Core screen: 500 Ohm.m

5.4.6 Attenuation

The signal attenuation for each signal conductor pair shall not exceed that defined in the Manufacturer's written specification over the frequency range within the operating bandwidth of the proposed system. The attenuation characteristics shall have a specified value over this frequency range in decibels per kilometer (dB/km).

5.4.7 Characteristic Impedance

The characteristic impedance of each conductor pair shall be defined between upper and lower limits at frequencies within the operating bandwidth of the proposed system and shall not exceed those values specified in the Manufacturer's written specification.

5.4.8 Inductance/Capacitance

The inductance and capacitance of each conductor pair at specified frequencies shall not exceed those values specified in the Manufacturer's written specification.

5.4.9 Cross-Talk

Cross-talk limits between conductors shall be as stated in the Manufacturer's written specification for the appropriate mode.

5.4.10 Service Environment

Electric cables shall be designed for exposure to service fluids, ultra-violet radiation, air ozone and seawater for the specified design life.

Note: Following exposure to a submarine environment, electrical characteristics may be subject to change and installed systems should be designed to tolerate such changes.

6 HOSE DESIGN

6.1 GENERAL

This section defines the principle design parameters for hose and hose assemblies. These parameters shall be used to specify and describe the performance and characteristics of a hose design, end fitting design and coupling design for joining hose lengths in the umbilical or in a repair/production joint.

Hoses shall be manufactured as continuous lengths where possible. Splices necessary to achieve the final length requirements may be allowed and shall be carried out in accordance with the qualified procedures specified in the Manufacturer's written specification.

The design and construction of hoses and attached end fittings shall take account of the external hydrostatic pressure, when unpressurized, that they will be subject to throughout their design life. Materials of construction shall be resistant to micro-organisms present in the storage and installed environments.

6.2 HOSE SIZING

All hoses shall be referenced by nominal bore and maximum working pressure. Hoses should be selected from the bore sizes and maximum working pressure tabulated in Table 1. Tolerances on nominal bore shall not exceed the values defined in Table 2 and the inside and outside diameter of the hose shall be concentric within the limits in Table 3.

The completed hose OD shall be within ± 4% of the value specified in the Manufacturer's written specification.

Table 1—Preferred Hose Sizes/Pressure Ratings

Nominal Bore mm (in)	Maximum Working Pressure Bar (psi)	Minimum Burst Pressure Bar (psi)	Thread Type
6.3 (1/4)	207 (3,000)	828 (12,000)	7/16 - 20
9.5 (3/8)	207 (3,000)	828 (12,000)	9/16 - 18
12.7 (1/2)	207 (3,000)	828 (12,000)	3/4 - 16
15.9 (5/8)	207 (3,000)	828 (12,000)	7/8 - 14
19.0 (3/4)	207 (3,000)	828 (12,000)	11/16 - 12
25.4 (1)	207 (3,000)	828 (12,000)	15/16 - 12
31.8 (1 1/4)	207 (3,000)	828 (12,000)	15/8 - 12
38.1 (1 1/2)	207 (3,000)	828 (12,000)	17/8 - 12
6.3 (1/4)	345 (5,000)	1379 (20,000)	7/16 - 20
9.5 (3/8)	345 (5,000)	1379 (20,000)	9/16 - 18
12.7 (1/2)	345 (5,000)	1379 (20,000)	3/4- 16
15.9 (5/8)	345 (5,000)	1379 (20,000)	7/8 - 14
19.0 (3/4)	345 (5,000)	1379 (20,000)	1 1/16 - 12
25.4 (1)	345 (5,000)	1379 (20,000)	1 5/16 - 16
6.3 (1/4)	517 (7,500)	2069 (30,000)	7/16 - 20
9.5 (3/8)	517 (7,500)	2069 (30,000)	9/16 - 18
12.7 (1/2)	517 (7,500)	2069 (30,000)	3/4- 16
6.3 (1/4)	690 (10,000)	2759 (40,000)	7/16 - 20
9.5 (3/8)	690 (10,000	2759 (40,000)	9/16 - 18
12.7 (1/2)	690 (10,000)	2759 (40,000)	3/4 - 16

Table 2—Nominal Bore and Wall Thickness Tolerances

Nominal Bore		Tolerance (%)		Liner Wall Thickness
mm	ins	Plus	Minus	mm
6.0 - 10.0	0.233 - 0.394	5.0	3.0	± 0.2
10.1 - 20.0	0.395 - 0.787	3.0	2.0	± 0.2
20.1 - 38.1	0.788 - 1.5	2.0	1.5	± 0.25

Table 3—Concentricity

Nominal Bore		Concentricity, FIR	
mm	ins	mm	ins
Up to 6.3	(1/4)	0.8	0.030
Over 6.3	(1/4)	1.0	0.040
Over 25.4	(1)	1.5	0.060

6.3 CONSTRUCTION

6.3.1 General

The hose shall comprise three component parts; the liner, the reinforcement and the sheath. (See Appendix C, Figure C5). When subject to pressure in an unrestrained state, the hose construction shall show no significant propensity to loop, or rotate about its axis.

The long term sealing and retention of the end fittings/couplings shall not be impeded by the hose materials of construction. All materials used shall be suitable for long term immersion in seawater and shall be in accordance with the Manufacturer's written specification.

6.3.2 Liner

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

Multi-layer liners may be acceptable where application requirements cannot be satisfied by a single layer construction.

The material in its extruded form shall not introduce particulate contamination of the hose bore, either by extraction (oligomers, etc.), or by reaction with the control fluid such that fluid cleanliness cannot be maintained.

6.3.3 Reinforcement

The reinforcement shall comprise one or more layers of synthetic fiber, applied around the liner. Aramid fiber is one example of a material that should be suitable for this application.

6.3.4 Sheath

The sheath shall comprise a continuous, seamless, circular extrusion, manufactured from a thermoplastic material incorporating protection against ultra-violet radiation. Typical materials that meet these requirements are polyamides and ether based polyurethanes.

The sheath shall provide for the passage of permeated fluids where the particular fluid/hose liner combination may give rise to permeation. Typical methods include pin-pricking of the sheath or collection of the permeated fluid at the hose ends. The sheath material shall be compatible with the interstice filler material and the sheathing material of other services within the umbilical throughout its design life. The sheath shall be designed to protect the reinforcement and liner from abrasion, erosion and mechanical damage.

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

6.3.5 Identification

As a minimum, the following information shall be marked along the complete length of a hose at regular intervals not exceeding 1 m:

a. Manufacturer
b. Batch number
c. Nominal bore size
d. Maximum working pressure
e. Manufacturer's part number
f. Unique function reference (e.g. Line 6)

6.3.6 End Fittings and Couplings

Each hose assembly shall incorporate end fittings of the female JIC 37° swivel type unless otherwise stated in the Manufacturer's written specification.

Couplings used to join two hose lengths within an umbilical shall be the one piece unthreaded type. Couplings used to join hose lengths within a rigid umbilical joint shall be of the threaded type and/or the one piece unthreaded type.

The fitting or coupling within a rigid joint shall be constructed from a material with corrosion resistant properties equal to or better than Stainless Steel 316L, and shall be permanently attached to the hose end. The attachment of the abutment part of the fitment shall be performed using a qualified swaging procedure. Crimping should not be employed where Stainless Steel 316L is the material of construction. The thread size for each fitting shall conform to SAE J516 where JIC 37° fittings are used. For other fitting designs, the thread size shall be as per the Manufacturer's written specification.

Couplings used within an umbilical shall be constructed from a material with corrosion resistant properties equal to, or better than UNS 6625 and shall be permanently attached either by a qualified crimping or swaging procedure or other qualified procedure as per the Manufacturer's written specification.

End fittings or couplings in a rigid joint shall either be protected by a water barrier, or have the facility for linking to a cathodic protection system.

Where there is a risk of an end fitting or coupling nut unscrewing as a result of induced torque, vibration, etc. then an appropriate interlock feature shall be included to prevent the nut rotating.

6.4 DESIGN PERFORMANCE REQUIREMENTS

6.4.1 Temperature Range

The hose assembly shall be capable of operating within the normal temperature range of -15°C to +40°C. For some cold weather applications, it may be possible for the hose to experience temperatures lower than the specified minimum (during storage, loadout and installation and for the topside hose during service). Additionally, for some installed conditions (I/J-tube risers in warm climates, close proximity to production risers in an enclosed environment, etc.), the hose could be subjected to a temperature higher than the specified maximum. In either event, the maximum or minimum temperature shall be specified in the Manufacturer's written specification. The hose shall be capable of operating continuously at service temperature for the design life.

Note: Continuous or frequent exposure to elevated temperatures may impact the design life of the hose and/or the hose assembly.

6.4.2 Test Pressure Ratios

Table 4 below indicates the required ratio of proof and burst pressures to the maximum working pressure for thermoplastic hoses in accordance with ISO 7751.

Table 4—Test Pressure Ratios

Proof Pressure		Burst Pressure
A	B	
2	1.5	4

Note: *Applicable on completion of hose manufacture and normally used once. Applicable following shipment of individual hose lengths and inclusion of hoses into an umbilical.*

For higher maximum working pressure ratings than those specified in Table 4, lower burst pressure ratios may be acceptable which shall be in accordance with the Manufacturer's written specification. These higher working pressure hoses shall be design verified in accordance with Section 9.

6.4.3 Collapse Pressure

The hose assembly, when bent to the minimum bend radius, shall be capable of withstanding a minimum applied external pressure with the hoses filled with installation/service fluid at zero internal pressure without collapsing. The minimum value of external collapse pressure shall be 150% of the difference in static head due to hydrostatic pressure at maximum design depth less the static head at that depth due to the installation/service fluid,

6.4.4 Change in Length

The hose shall be designed such that the change in length when the hose is pressurized from atmospheric pressure to its maximum working pressure shall be within the range -1.5% to +2%.

6.4.5 Minimum Bend Radius

The minimum bend radius to which the hose can be bent without down rating or affecting its performance shall be as stated in the Manufacturer's written specification.

6.4.6 Service Fluids

The Manufacturer shall specify the hose materials of construction to be used for the specified service fluids. The Manufacturer shall either undertake compatibility testing on the specified service fluids, as defined in Section 11, or provide documentary evidence of previous tests which demonstrate compatibility for the specified design life.

The Manufacturer, in conjunction with the Purchaser/User, shall review the fluids to be incorporated in the hoses designated for well service duty, and the potential for chemical reactions within the umbilical lines when the service fluids are introduced. In the event the control system fluid is not used, the potential for micro-biological activity within the lines shall be reviewed.

The fluid cleanliness of each hose shall be in accordance with the Manufacturer's written specification.

Design life compatibility shall be demonstrated. The maximum continuous temperature that can be experienced by a hose assembly throughout the design life should also be addressed as part of the compatibility evaluation.

6.4.7 Service Environment

The hose, end fittings and couplings shall be designed for exposure to service fluids, ultra-violet radiation, air, ozone and seawater for the specified design life.

7 UMBILICAL DESIGN

7.1 GENERAL

This section defines the principle design parameters for umbilicals and sets forth other criteria to be considered in their design. Umbilicals shall be manufactured as continuous lengths where possible. Joints necessary to achieve the final length requirements may be allowed and shall be carried out in accordance with the qualified procedures specified in the Manufacturer's written specification.

The design and construction of umbilicals shall take account of the external hydrostatic pressure that they will be subject to during installation and throughout their design life. Materials of construction shall be resistant to micro-organisms present in the storage and installed conditions.

Only components which satisfy the requirements of Sections 4 and 6 are to be used in the construction of umbilicals manufactured to this specification.

The umbilical functional requirements and level of redundancy required shall be as specified in the Manufacturer's written specification.

Where sheathing is employed, repairs to the sheath may be allowed and shall be undertaken in accordance with the Manufacturer's written specification.

7.2 CONSTRUCTION

7.2.1 Cross-Sectional Arrangement

The umbilical shall be designed to incorporate the functional requirements and meet the mechanical properties specified in the Manufacturer's written specification. Consideration shall be given to the following points:

a. The cross-section shall be circular and should be as compact as possible.

b. The cross-section should be as symmetrical as possible. This may be achieved by the use of additional components or fillers.

c. In the case of umbilicals containing electric cables, the cables should be placed towards the center of the umbilical bundle. Alternative cross-sectional arrangements with electric cables or electric cable sub-bundles around the outside of the bundle are permissible. In this case, the design of the electric cables and sub-bundles shall take into account the additional tensile and compressive loadings which may be imposed on the electrical conductors so that the design life is not compromised.

d. If fillers are used in the interstices of the umbilical, the filler material should be selected with consideration of the crushing forces on the bundle due to manufacture, installation and service. The material should also be compatible with seawater.

Typical material types that should be suitable for many applications include polyethylene/polyamide rods/tubes, profiled sections and polypropylene fibers.

e. Umbilicals for dynamic service and for most static applications require allowance for movement during installation and service. To alleviate this effect, consideration should be given to the coefficient of friction between components within the bundle.

Note: The requirements of a) and b) are not always coincident. See Appendix E, Figure E3 for typical umbilical cross-sectional arrangements.

7.2.2 Lay-Up

Individual functional components (electric cables, hoses, optical fiber cables, fillers, etc.) shall be laid-up to form the umbilical bundle or sub-bundle. Several lay-up operations may be necessary to achieve the final bundle configuration.

Lay-up shall be undertaken either by planetary cabling or by oscillatory cabling. After each lay-up operation, the cabled components shall be bound with a helically applied tape to ensure bundle stability and a circular cross-section prior to subsequent lay-up or sheathing. The binder tape shall be applied with a constant helix angle as specified in the Manufacturer's written specification.

Where oscillatory cabling is employed, the lay-angle, angular rotation between reversals and the electric cable design shall be addressed so as to minimize tensile and compressive loadings which may be imposed on the electrical conductors during lay-up, reeling, unreeling, installation and dynamic service.

Where planetary cabling is employed and several lay-up operations are involved, each subsequent lay-up shall be applied in the opposite direction to the previous lay-up.

The bundle lay-up procedure should be carried out with the hoses pressurized. The pressure level used shall be in accordance with the Manufacturer's written specification which shall be sufficient to prevent distortion of the hose. All subsequent manufacturing operations should be carried out with the hoses pressurized to the same nominal pressure.

7.2.3 Sub-Bundles

Sub-bundles which may comprise electric cables, hoses or combinations of electric cables and hoses shall be designed and dimensionally sized to provide a circular configuration. The sub-bundle should be designed to be as symmetrical as possible about its center axis.

Filler components in the form of extruded tubes, rods, fibers or profiled sections may also be included to achieve consolidation and the required configuration. They shall be suitably selected to provide compression resistance and maintain the circular cross-section when the umbilical is subjected to radial compression and to avoid the possibility of the sub-components damaging each other.

To maintain stability after laying-up the sub-components, a binder tape shall be applied at a constant helix angle.

For geometrical and/or mechanical requirements (e.g. interfacing with an electrical penetrator), the bundled and taped sub-components may be oversheathed in a thermoplastic material which shall be as stated in the Manufacturer's written specification. The chosen material shall be continuously and concentrically extruded over the binder tape. The material shall not degrade the quality of other materials with which it may be in contact within the sub-bundle or future adjacent components.

Where geometrical and/or mechanical requirements do not dictate an extruded sheath is required, then the sheath can be the binder tape provided the design and application of the tape provide adequate stability and mechanical protection for the sub-bundle during subsequent processing stages, installation, and service in the case of dynamic umbilical designs.

7.2.4 Inner Sheath

An inner sheath shall be applied over the taped bundle to provide mechanical protection, increase bundle stability and provide a bedding for the armor wires. The sheath material shall be:

a. For static applications, either a continuously extruded thermoplastic material or a layer of helically applied synthetic fiber roving.

Typical materials that should be suitable for most static applications are polyethylene, ether based polyurethanes, polyamides, polypropylene fibers or other materials with comparable properties. The material shall be compatible with the environmental conditions and shall provide sufficient resistance to abrasion and stress cracking during loadout and installation.

b. For dynamic applications, a continuously extruded thermoplastic material only.

Typical materials that can be considered for most applications are polyethylene, ether based polyurethanes and polyamides. The material shall be compatible with the environmental conditions and shall provide resistance to abrasion and stress cracking under dynamic conditions.

The inner sheath shall be free of contaminants, faults and other defects. Where appropriate, the sheath shall include for resistance to ultra-violet light. The sheath shall be of a thickness sufficient to ensure proper distribution of radial compression between the armor wire and the bundle. The thickness of the sheath, and the tolerance for thickness and concentricity, shall be specified by the Manufacturer.

The sheath extrusion process shall be in accordance with the Manufacturer's written specification. It shall be selected by the Manufacturer to suit the subsequent armoring process and to ensure that the bundle components can move freely and independently of each other, during bending and flexing.

7.2.5 Armoring

Umbilicals which contain electrical conductors shall be armored or shall include a suitable strain member. For umbilicals which are to be torque balanced and/or require to be capable of accepting high tensile loading, the armoring shall consist of two or more contra-helically applied layers of steel armor wires. These shall be applied under uniform tension and designed to limit rotation as umbilical tension varies from zero to the maximum working axial load. For dynamic umbilicals, the armoring may also serve to provide ballast to achieve the necessary stability during dynamic operation. For multi-layer armor and/or ballast packages, additional layers shall be applied in the opposite direction to the adjacent layer(s). The size and lay lengths of the armor wires shall be specified by the Manufacturer to provide the necessary tensile strength, axial elongation, bending stiffness and weight.

For some applications where ballast and/or mechanical protection are required, and high tensile loading and/or torque balance are not critical requirements, no armor or a single layer of armor wires may be acceptable.

Note: An unarmored or single layer armor construction will normally only be applicable to a short umbilical with low installation loading applied to the umbilical and its terminations, for example, a jumper bundle.

A layer of suitable material may be placed between the layers of armor wire to minimize fretting during bending or flexure.

The armor wires shall be carbon steel, circular in cross-section unless otherwise specified and shall meet the requirements of:

a. BS 1441/BS 1442, galvanized to meet the requirements of BS 443, or

b. Steel wires as in a), overjacketed with a polymeric material to reduce weight in air/water and/or umbilical tensile strength.

Alternative wire sizes and cross-sections other than those specified in BS 1441/BS 1442 may be employed.

If required, thermoplastic filler rods may be used in place of armor wires to minimize the tensile strength and/or weight of the umbilical. The fillers shall be distributed uniformly with the steel wires and their use shall not introduce torsional imbalance.

The number and size of the armor wires, and fillers if used, shall be such as to provide each armor layer with a nominal coverage of 95% of the pitch circle circumference of the layer.

7.2.6 Outer Sheath

Armored umbilicals shall have a layer or covering over the outermost layer of armor wires which shall be fabricated as:

a. A continuously extruded thermoplastic sheath, or

b. A covering of helically applied polypropylene rovings.

For dynamic applications, a continuously extruded thermoplastic sheath shall be employed in accordance with the requirements of Section 7.2.4 with the added provision that for dynamic applications involving buoys clamped to the umbilical, the sheath material shall exhibit low creep and be resistant to crack propagation.

To provide visual indication of twist during installation, an abrasion resistant, high visibility line of contrasting color shall be applied along the umbilical length. If lengths are joined, the continuous line should align between lengths after joining.

7.2.7 Length Marking.

The umbilical shall be sequentially marked in 100 meter increments with the exception of the first and last 100 meters, which shall be sequentially marked in 10 meter increments. The marks shall be durable throughout storage, loadout and installation of the umbilical and legible to divers or underwater video cameras providing all round (360°) visibility and with a minimum character height of 25 mm (1").

Note: Accurate length measurement is a critical requirement in the manufacture of umbilicals. If the umbilical is too short, then the necessary system connections cannot be made. If the umbilical is too long, this can present difficulties in disposing of excess length on the seabed.

7.3 DESIGN PERFORMANCE REQUIREMENTS

7.3.1 Analytical Analysis

The need for analysis shall be considered as part of the risk reduction procedure for the umbilical. The considerations that are involved include, amongst others, the environmental and service conditions for the umbilical and the consequences of non-performance.

The calculation methodology adopted, and any software packages used for these analyses, shall be independently verified and shall be clearly stated in the Manufacturer's written specification. The design process may be iterative to achieve the optimum design and the Manufacturer should allow for this in the design procedures.

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 pertaining to the umbilical design.

The output of the analyses shall be used to demonstrate that the umbilical is suitable to be installed 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 and the elements of the components and umbilical, representative historical data may be offered by the Manufacturer to verify the models or calculations used.

7.3.1.1 Installation Analysis

These analyses shall be used to establish the loadings imposed on the umbilical during installation including those imposed due to trenching operations, rock dumping, crushing, seabed stability and pull-in operations.

The installation analyses shall consider installation vessel motions and any other information necessary for the calculations that are made available.

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 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

d. Allowable vessel motions to avoid overstressing the umbilical.

e. Residual tension from plowing-in.

f. The maximum period of time, as a function of sea-state, that the laying vessel can be hove-to prior to failure occurring within the umbilical.

If the installation involves an I or J-tube pull, the following additional information shall also be supplied:-

g. Maximum pull-in force on the umbilical, taking into account the friction both on the seabed and within the I or J-tube.

h. Impact forces if subject to rock dumping protection and maximum lateral deformation due to storage loads, cable haulers, etc.

The umbilical design loads, minimum bend radii and allowable crushing load shall be within the limits established by the installation analysis. The Manufacturer shall provide the following information regarding limitations on installation:

a. Minimum acceptable sheave/reel diameters.
b. Minimum acceptable installation curvature.
c. Maximum acceptable tensile loading with respect to curvature.

7.3.1.2 Dynamic Service Analysis

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

The dynamic analysis shall consider end surface motions, proposed umbilical configuration and any other information necessary for the calculations that are made available.

The analysis shall be used to establish the following information:-

a. The variation of tension and curvature along the 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 needs to be made for the probablistic nature of fatigue life. A suitable safety margin shall be maintained between calculated fatigue life and the required in-service design life.

7.3.1.3 Structural Analysis

This analysis shall be used to establish a design for the umbilical construction that shall be capable of withstanding the design loads and conditions as envisaged for the product during manufacture, loadout, installation and also for the operational conditions throughout its design life.

The analysis shall demonstrate that the metallic and polymeric materials used within the construction are designed to recognized standards and applicable factors of safety.

The design process shall consider the following:

a. Deterioration and degradation as a result of aging throughout the service life.
b. Materials selection including corrosion of metallic elements, cathodic attack and delamination of bonded elements.
c. Seabed stability acceptance criteria.
d. Fatigue of armor wires and polymers.
e. Minimum breaking loads.
f. The effects of environmental conditions, i.e. UV attack, temperature, ozone and the exposure to seawater and permeated fluids.
g. Tensile and compressive stresses imposed upon electrical conductors.

7.3.2 Temperature Range

The umbilical shall be capable of operating within the normal temperature range of -15°C to +40°C. For some cold weather applications, it may be possible for the umbilical to experience temperatures lower than the specified minimum (during storage, loadout and installation and for the topside length during service). Additionally, for some installed conditions (I/J-tube risers in warm climates, close proximity to production risers in an enclosed environment, etc.), it may be possible for the umbilical to be exposed to a temperature higher than the specified maximum. In either event, the maximum or minimum temperature shall be specified in the Manufacturer's written specification. It shall, however, be capable of operating continuously at the specified service temperature for the specified design life.

Note: Continuous or frequent exposure to elevated temperatures may impact on the design life of the umbilical.

7.3.3 Maximum Working Load

The maximum working load for the umbilical shall not be less that the value stated in the Manufacturer's written specification.

7.3.4 Minimum Breaking Load

The minimum breaking load, with the umbilical straight, shall be in accordance with the Manufacturer's written specification.

In all cases the specified load level shall be such that under all possible installation and service conditions an adequate margin of safety is demonstrated to exist by analysis.

7.3.5 Minimum Bend Radius

The minimum bend radii to which the umbilical can be bent for storage and service without affecting its performance shall be as stated in the Manufacturer's written specification.

7.3.6 Dynamic Service Life

The umbilical shall be designed to be fatigue resistant for the specified design life with an adequate safety margin derived from analysis when operating in a dynamic mode and subject to the loads, number of flexures and motions as specified in the Manufacturer's written specification.

7.3.7 Seabed Stability

The umbilical shall be designed to be stable when laid on the seabed for the seabed condition and seabed current values specified in the Manufacturer's written specification.

7.3.8 Service Environment

The umbilical and its constituent components shall be designed for immersion in seawater for its design life. Consideration should also be given to storage prior to installation, exposure to service fluids, the seabed and topsides environments in terms of radiation, ozone, temperature, chemicals and any imposed dynamic conditions.

8 TERMINATIONS AND ANCILLARY EQUIPMENT

8.1 GENERAL

The subsea end of a hose, electrical, or composite electro-hydraulic umbilical may be terminated in one half of an underwater mateable connector assembly. Alternatively, the umbilical components may be terminated directly into a subsea control pod or junction box. The surface end of the umbilical will generally have the armor strength member terminated and suspended by a flange connected to the top of a riser "I" or "J"-tube, with the hoses and electrical cables accessible for connection to platform control equipment.

The design of umbilical terminations and ancillary equipment is invariably specific to a particular umbilical system and, as such, detailed specification data is outside the scope of this specification. The following formation is provided for guidance only.

For termination equipment with metallic construction, corrosion protection shall be provided by either independent cathodic protection, or a facility for electrical bonding to a cathodic protection system. In the selection of termination materials, consideration should be given to their corrosion resistance properties.

Where necessary, bend limiters/stiffeners shall be incorporated to prevent damaging forces being applied to the umbilical during loadout, deployment and service.

In reviewing the design requirements for terminations and ancillary equipment, such reviews shall consider the effects of component test parameters on the active elements within the terminations and ancillary equipment.

8.2 TERMINATIONS

8.2.1 Armor Terminations

Armored umbilicals shall be terminated with end terminations with a minimum loading capability equal to or exceeding the maximum working load of the umbilical. The terminations shall be designed for use in a marine environment.

8.2.2 Electrical Terminations

For terminations to be permanently installed subsea (penetrators, connectors, etc.), the design shall take account of the requirement for effective waterblocking at the cable entry, pin to pin conductive connectors and pigtails where applicable. Where bonded and/or non-pressure balanced designs are to be employed, the design shall address the reliability of the bonding and/or sealing mechanism in a submarine environment throughout the design life.

Where electrical connectors will, or could be exposed to extended immersion in a submarine environment without connection to mating halves, suitable blanking arrangements shall be incorporated. Such blanking arrangements shall provide both mechanical protection and prevent electrolytic action between adjacent pins in the event electrical power is applied to the connected electrical cores.

The terminations shall be designed for use in a marine environment. The materials used shall be demonstrated to be suitable in terms of corrosion and compatibility.

The electrical terminations shall be tested in accordance with the Manufacturer's written specification.

8.2.3 Pull-In Head

A pull-in head shall be used to pull the umbilical through the I or J-tube. The pull-in head shall be designed to withstand installation loads without damage to the umbilical or its functional components.

The pull-in head shall be designed to allow uninterrupted travel over rollers/sheaves and through I or J-tube risers without damage or snagging. The Manufacturer shall specify the size relationship between the I or J-tube internal and pull-in head diameters.

The pull-in head shall be designed to house the hose and electrical cable terminations. In some cases, the hoses may be terminated with temporary end fittings and the electric cables sealed to prevent water ingress to allow topside connections to be made following pull-in and routing to the topside junction box.

8.2.4 Topside Hang-Off

A topside hang-off shall be used to secure the umbilical to the top of the I or J-tube riser or other securing locations. The hang-off equipment shall be designed to withstand static or dynamic loads associated with vessel motions and installation forces, and to transfer the breaking load without damaging the umbilical or umbilical components.

Note: The hang-off design shall take account that, once installed, inspection access at the top of the I/J-tube may not be practical and the potential for long term corrosion or creep at the load bearing components shall be addressed.

8.2.5 Subsea Termination Interface

A subsea termination interface shall be used to provide the transition between the umbilical and its subsea termination or subsea umbilical distribution unit.

The design of the bend limiter/stiffener shall take account of the size, weight and center of gravity of the subsea termination and their effect on the umbilical during loadout, deployment and subsea pull-in.

8.2.6 Subsea Umbilical Termination

A subsea umbilical termination shall be used to connect the umbilical mechanically and functionally to the subsea system. Mechanical connection may be achieved by a lock-down arrangement or a chain/strop tie-back to the subsea system. The latter method is preferable when a weak link arrangement is installed between the termination and the subsea system which severs the functional lines when activated.

Functional connection may be achieved by one of the following methods:

a. Direct connection to the subsea system by means of electric and/or hydraulic pigtails. Should this method be employed, the design shall incorporate a pigtail protection arrangement which can be readily removed following deployment of the umbilical and pull-in of the subsea termination to the subsea system.

b. Bulkhead mounting individual electric and/or hydraulic connectors to facilitate subsea connection by jumper assemblies. The design of the termination shall incorporate a bullnose arrangement to provide mechanical protection during umbilical deployment and pull-in of the termination which can be readily removed subsea.

c. Bulkhead mounting stabplate(s) to facilitate connection by a jumper bundle(s) requiring similar mechanical protection requirements as individual bulkhead mounting electric/hydraulic connectors.

d. Bulkhead mounting electric and/or hydraulic connectors for direct connection with a mating half. During deployment, the bulkhead connectors shall be mechanically protected. The means of pull-in, axial and radial alignment of the mating halves shall be as per the Manufacturer's written specification.

Where the design incorporates isolation valves and/or electric shorting/test points requiring access, the design shall be such that these can be readily accessed and operated. The method of access and operation shall be as specified in the Manufacturer's written specification.

8.2.7 Subsea Umbilical Distribution Unit

The subsea umbilical distribution unit shall mechanically and functionally connect the umbilical to several subsea systems in a similar manner to the subsea umbilical termination. Where a significant number of systems are to be connected, the size, weight, center of gravity, deployment and pull-in shall be considered in respect of bend strain relief for the umbilical.

8.3 ANCILLARY EQUIPMENT

8.3.1 Joint Box

A joint box shall be used to join umbilical sub-lengths to achieve overall length requirements or to repair a damaged umbilical. Each umbilical end to be joined shall have an armor termination. These shall be joined using a connecting sleeve or barrel which shall allow for the transmittal of the load from one sub-length to the other. The means of connecting the sleeve or barrel shall allow removal or access for the design life of the umbilical.

The joint box shall be of a streamlined design with a bend stiffener at each end and shall be of compact size to facilitate reeling, storage and installation requirements. To facilitate rapid assembly offshore, the bend stiffener should be of the pre-molded slide-on design.

The joining of the hoses, electric cables and optical fibers within the joint box shall be according to the Manufacturer's written specification.

Joint boxes should not be incorporated in any section of an umbilical that will operate in a dynamic mode.

8.3.2 Weak Link

A weak link is an optional component designed to protect the umbilical, and equipment connected to the umbilical, from excessive line loads. The required load at which the weak link shall be activated shall be defined in Manufacturer's written specification. The weak link shall be designed to have a design life equal to or greater than the umbilical.

For weak link designs which are integral to the umbilical, in order to facilitate installation and retrieval of the umbilical, the weak link shall have an override mechanism which shall be easily removable and replaceable when the weak link is installed on the seabed. With the override mechanism in place, the weak link shall be capable of withstanding the maximum umbilical tensile working load without either being activated or suffering mechanical failure.

If the weak link is activated, the functional lines shall be cleanly severed. Damage to the services shall be minimized by ensuring that the internal umbilical components are not excessively loaded during activation. The design shall facilitate repair of the umbilical after activation.

An alternative weak link design may be employed in the form of a shearing guillotine which acts on jumper hoses or cables installed between the subsea umbilical termination/distribution unit and a subsea system. The jumpers severed shall be replaceable subsea.

Other approaches to the design of weak links (such as stabplates), may be acceptable and should be defined in the Manufacturer's written specification. If a weak link is required, the Manufacturer's written specification shall state the type of weak link design to be used.

Note: If the weak link is activated, its operation shall not prevent the safe shut down of the Wellhead and Christmas Tree equipment under any circumstances. The hydraulic pressure in the parted hydraulic lines shall be capable of reducing to ambient pressure in the umbilical section connected to the Wellhead/Christmas Tree equipment.

8.3.3 Buoyancy Attachments

Depending on the installed configuration, a dynamic umbilical may necessitate buoyancy attachments in the form of collars, tanks, etc. to achieve the necessary configuration and dynamic motions. The method of attachment shall be such as not to induce stress cracking in the umbilical sheath, allow excessive stress relaxation with the compressive zone of the attachment if clamped, or allow excessive strain of the umbilical and its components.

9 QUALITY ASSURANCE

9.1 GENERAL

The Manufacturer shall operate a Quality Assurance System. A Quality Plan produced by the Manufacturer shall form the key document defining all activities relating to the design, manufacture and testing of an umbilical. QA activities shall be undertaken as an integral part of the Manufacturer's organization, working methods and procedures. Verification activities shall be included as an integral part of the design and manufacture of an umbilical and umbilical components. The Quality Assurance System shall comprehensively address the following areas:

a. Umbilical and Component Design
b. Design Verification Testing
c. Manufacturing Processes
d. In-Process Inspection Testing
e. Factory Acceptance Testing

9.1.1 Umbilical and Component Design

Prior to commencement of manufacture, umbilical and component requirements shall be subject to a design review in accordance with the Manufacturer's Quality System. The design review shall take account of the requirements specified in Sections 5, 6 and 7 and any supplementary requirements specified in the Manufacturer's written specification.

9.1.2 Design Verification Testing

Where the design review indicates the requirement for design verification testing, this shall be undertaken in accordance with the Manufacturer's Design Plan. The Plan shall take account of the requirements specified in Section 11 and any supplementary requirements specified in the Manufacturer's written specification.

9.1.3 Manufacturing Process

Materials for components and umbilicals shall be purchased in accordance with written material specifications. The specifications shall include measurable physical, mechanical, chemical and performance characteristics and tolerances with which the materials shall comply.

Each process shall be operated in accordance with a comprehensive operational procedure that has been audited to confirm its accuracy and repeatability. Manufacturing processes shall be monitored in accordance with Inspection and Test Plans which shall take account of the requirements specified in Section 10 and any supplementary requirements specified in the Manufacturer's written specification.

9.1.4 In-Process Inspection Testing

In-process inspection and testing shall be undertaken at each stage of manufacture to confirm that partially completed components and umbilical are in accordance with the Manufacturer's written specification.

9.1.5 Factory Acceptance Tests

Factory Acceptance Tests shall be undertaken on each component and umbilical in accordance with the Manufacturer's Inspection and Test Plan. This shall take account of the requirement specified in Section 12 and any supplementary requirements specified in the Manufacturer's written specification.

9.1.6 Test Schedule

Tests to be performed during and on completion of component and umbilical manufacture specified in Sections 11 and 12 are summarized in Appendix F.

9.2 PROCEDURES AND WORK INSTRUCTIONS

The Manufacturer shall have a suite of comprehensively documented procedures and work instructions relating to all activities for the design, manufacture and test of an umbilical. The procedures and instructions shall cover, but not be limited to the following:

a. Quality assurance and quality control.
b. Design and engineering practice.
c. Engineering control including design change control.
d. Computer aided design.
e. Material, component and umbilical control, handling, preservation and storage.
f. Planning, manufacturing and testing control.
g. Document control.
h. Reporting.
i. Organization and management including control of suppliers.
j. All inspection and testing.

k. Technical query/concession request handling.

l. Supplier control and coordination.

m. Material, components and subcomponents procurement.

n. Packaging and shipping of materials, components, sub-components and umbilicals.

o. Calibration and maintenance of inspection/test equipment.

p. Identification/traceability of incoming materials, components, sub-components and umbilical product.

q. Design verification.

r. Certification.

9.3 EQUIPMENT CALIBRATION

Measuring equipment used for design verification, inspection and factory acceptance testing shall be calibrated in accordance with the Manufacturer's calibration schedule. All calibrations shall be supported with documentation and no test shall be performed using equipment that is outwith its calibration schedule. All reference equipment shall be traceable to National Standards.

9.4 SUPPLIERS

Only Suppliers which are formally approved by the Manufacturer shall be used to provide materials, components and sub-components for incorporation in an umbilical or, services as part of the design, manufacture and test of an umbilical.

Approval should be made on the basis of, but not limited to one or more of the following:

a. Supplier accredited to a Quality Assurance System.

b. Supplier subject to audit by the Manufacturer.

c. Supplier previous history record.

10 MANUFACTURING REQUIREMENTS

10.1 GENERAL

Manufacturing operations shall be performed in accordance with the Manufacturer's written specifications and procedures which shall conform with the requirements of this section. New or unproven processes shall be qualified and the Manufacturer shall maintain documentation for the qualification of such processes.

QA/QC activities during manufacture shall be defined by the Manufacturer's Inspection and Test Plan.

10.2 HANDLING DURING MANUFACTURE

The Manufacturer shall have documented procedures for the handling of raw materials, intermediate and finished components and umbilical during manufacture, packaging, storage and shipment. Such procedures shall address cleanliness, dryness, purity, excessive temperature, protection against mechanical damage and ultra-violet degradation and other potentially damaging facets for each stage of manufacture.

Transfer and handling of completed and partially completed components and umbilical at all stages should be such that no abrasion or other mechanical damage occurs, and contamination cannot be introduced. Spooling of finished or partially finished components and umbilicals onto processing/storage reels and carousels should be performed uniformly, and at no time should product come into contact with anything other than the manufacturing equipment being utilized.

Where applicable, sufficient back-tension shall be applied during spooling to minimize the risk of slack turns developing when the product is removed from its intermediate processing reel.

All processing/storage reels and carousels shall be clean, smooth and free from rough edges and other damaging facets and shall be sufficiently rigid and strong enough to accommodate the entire component or umbilical length without suffering damage or distribution.

The barrel diameter of reels or carousels shall not subject the contents to a bend radius less than that specified in the Manufacturer's written specification.

Reels used for hose pressure decay and proof pressure testing shall be suitably designed to protect the hose on the drums and to accommodate loadings on the barrel and flanges when the hose is pressurized.

Powered take-up on storage reels/carousels should be employed, and all take-up operations shall be monitored to check for non-conformances. Visual inspection shall be in accordance with the Manufacturer's Inspection and Test Plan and frequent visual inspection shall be undertaken at critical stages of manufacture.

When transferring completed or part completed hoses, electric cables and umbilicals between storage centers and/or through equipment as part of the processing operation, the intermediate handling and guidance shall allow uninterrupted transfer without damage to the product or contact with the ground or other extraneous objects.

Caterpillar tensioners or cable haulers shall be designed so as to impart no damaging or permanently deforming forces on the product being transferred.

10.3 EXTRUSION

Extrusion operations shall be carried out in clean, dedicated areas which shall be subject to regular cleaning schedules.

Process equipment shall be regularly inspected internally and externally for cleanliness. Hoppers, pipework, extruders, etc. should be opened and/or stripped down as necessary after extended shut-down, or material change to permit comprehensive visual inspection and to remove bore deposits, extraneous and degraded material.

Cleanliness control, levels and inspection frequencies shall be in accordance with the Manufacturer's Inspection and Test Plan. Particular attention should be paid to the cleanliness of the extrusion head and, if applicable, the maintenance of the filter screen pack which prevents extrusion of particulate matter. The filter screen, if used, shall be mechanically secured into the extrusion head to prevent the by-pass of any extruded material.

Raw elastomeric and thermoplastic material shall be bulk packaged in sealed containers, and where necessary, have moisture resistant liners. If necessary, the hopper shall incorporate a drying facility to prevent moisture regain by the raw polymer. The moisture level within the hopper shall be continually monitored by an on-line moisture analyzer or dew meter. Materials shall be dry and within the material supplier's specification immediately prior to use. Transfer to the extruder shall be in a controlled manner so as not to introduce contamination into the material.

Process parameters shall be sampled in accordance with the relevant extrusion sub-sections.

10.4 ELECTRIC CABLE MANUFACTURE

10.4.1 Conductor Stranding

The electrical conductor is a critical element in an electric cable and the stranding process shall be carefully controlled in a clean area which shall be subject to a regular cleaning routine.

The stranding process shall ensure that individual strands and the stranded conductor shall not be subject to excessive compressive and tensile loadings which can introduce kinks or reduction in conductor or strand cross-sectional area. Where the weight of a strand is large, the pay-off reel should be powered.

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 Inspection and Test Plan.

Multi-stranded conductors shall be of the concentric lay construction and planetary laid-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 any other out of balance effects.

10.4.2 Insulation Extrusion

The conductor insulation is a critical element in an electric cable and the extrusion process shall be carefully controlled and monitored.

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

a. Extruder barrel/head temperatures
b. Melt pressure/temperature
c. Screw speed/power requirement
d. Haul-off speed

The insulation shall be extruded as one continuous length without defects, shut-downs or restarts. It shall be subject to verification in accordance with the Manufacturer's Inspection and Test Plan and spark testing during the extrusion process. Repairs to the insulation shall not be permitted.

The insulation thickness shall be measured and the outside diameter shall be measured continuously at two positions 90° apart, and recorded continuously using a chart recorder. Both insulation thickness and diameter shall be in accordance with the Manufacturer's written specification and shall be traceable to the core length produced.

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

10.4.3 Lay-Up

The laying-up of electrical cores and fillers, if applicable, is a critical element in the manufacture of an electric cable and the process shall be carefully controlled. Only cores in individual electric cables and composite electric cable elements which have been planetary laid-up shall be used in umbilicals manufactured to this specification. During the cabling operation, the conductors shall not be subject to excessive tensile and compressive loadings.

Where necessary, non-metallic fillers of synthetic material shall be incorporated to form a compact and reasonably circular bundle. These 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 uniform consistent cabling of the cores and fillers.

Where a binder tape is incorporated in the construction, it shall be applied at a uniform tension which shall not prevent relative movement between individual cores when the cable is bent or flexed. To facilitate relative movement, an internal lubricant to reduce friction may be included.

On completion of lay-up, the cabled cores and/or cabled electric cable elements shall be stored in a dry, dedicated and controlled area.

10.4.4 Sheath Extrusion

Sheath extrusion may take one of three forms:

a. A combined fill and sheath extrusion whereby interstices between the electrical cores are directly filled with extrudate.

b. A sheathing operation as per a), followed by an oversheath for additional fluid resistance and mechanical protection. (Usually applied in the case of screened electrical cables).

c. A sheath applied directly over cores which have been taped as part of the lay-up operation.

There shall be no holes or discontinuities in the extruded sheath. Screened cables should be subject to spark testing as part of the extrusion process.

Repairs to a sheath are allowable and shall be performed in accordance with the Manufacturer's written specification.

10.5 HOSE MANUFACTURE

10.5.1 Liner Extrusion

The hose liner is a critical element in a hose and the extrusion process shall be carefully controlled and monitored. Transfer of raw material into the extruder shall employ vacuum draw-off from a sealed container system to prevent ingress of contamination.

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 requirement
d. Quench tank vacuum
e. Haul-off speed

The liner shall be extruded as one continuous length without joints or defects in a segregated controlled entry area. The outside diameter shall be measured continuously at two positions 90° apart and the liner wall thickness shall be measured continuously at four positions 90° apart, and continuously recorded. Both wall thickness and diameter measurements shall be traceable to the length of hose produced.

During extrusion the liner shall be subject to frequent visual examination for the detection of visible defects such as color changes, bubbles, or inclusions. The extrusion process shall provide all round (360°) visual observation of the extruded liner. The Manufacturer's written specification shall include accept/reject levels for such defects.

After extrusion, the ends shall be sealed against contamination ingression. Liners awaiting application of reinforcement shall be stored in a controlled dry area under cover and protected against direct sunlight, dust, ultra-violet radiation and other potential contaminants.

10.5.2 Reinforcement Application

The hose reinforcement is a critical element in a hose and the manufacture shall be carefully controlled. The application process shall be carried out in a clean, dedicated area which shall be subject to a regular cleaning procedure. The reinforcement yarn shall be protected against dust and ultra-violet degradation during storage. Yarn bobbins affected by humidity and/or temperature shall be conditioned in accordance with the material supplier's specifications before use.

Linear density and breaking strength tests shall be performed on samples from each batch of reinforcement yarn, to confirm that the material properties are within the limits specified.

The reinforcement yarn shall be wound uniformly onto braiding bobbins taking care to minimize fluff and exclude dirt, oil or other extraneous matter from the package. The tension in each yarn shall be controlled within the specified tension tolerance. The braiding machine shall be regularly subject to removal of loose fibers and fluff from the points of generation.

The tension applied to the reinforcement yarn during manufacture of the hose shall be checked for each bobbin at the commencement of each production run and thereafter in accordance with the Manufacturer's Inspection and Test Plan which ensures that all bobbins are checked at regular intervals.

Where braiding is applied using high speed machines, the effect of high transient tensions and resulting hoop forces shall be addressed to ensure bore size consistency. When braiding long length and/or large diameter liners, powered let-off reels should be employed to prevent high pay-out tensions.

Splices in the reinforcement yarn may be necessary to extend the yarn length prior to its application to the liner. Splices are permitted provided hose performance requirements are still met and shall be made in accordance with the Manufacturer's qualified procedure. The incidence of yarn splices shall be staggered within each braid and between braids so that no two splices coincide. The distance between splices when measured along the axis of the hose shall be stated in the Manufacturer's qualified procedure.

During application of the reinforcement, the braided liner shall be frequently inspected during spooling to ensure that there are no visible defects.

On completion of braiding, the storage reel shall immediately be completely covered with suitable sheeting to protect the reinforcement from airborne contaminants and degradation from exposure to ultra-violet radiation. While awaiting completion, the braided liner shall be stored in a controlled dry area under cover and protected against direct sunlight, dust, ultra-violet radiation and other potential contaminants.

10.5.3 Sheath Extrusion

Extrusion of the hose sheath shall follow the same process requirements as for extrusion of the liner with the exception of the measurement and recording of quench tank vacuum and wall thickness which are not applicable.

The reinforced hose liner shall be kept dry prior to and during passage through the extruder. Care shall be taken to ensure that the reinforced liner is not stretched and the reinforcement is not disturbed during application of the outer sheath.

During sheath extrusion, the product shall be subject to frequent visual inspection to ensure uninterrupted and uniform coverage and no extraneous material is included under the sheath. Repairs to a sheath are allowable and shall be performed in accordance with the Manufacturer's written specification.

Where a hose is intended for use with a fluid (typically methane and methanol) which may permeate the liner, the sheath shall be adequately ventilated to prevent pressure build up between the liner and sheath. The requirement for venting shall be identified in the Manufacturer's Inspection and Test Plan and the venting method shall be in accordance with the Manufacturer's written specification.

10.6 UMBILICAL MANUFACTURE

10.6.1 Lay-Up

The laying-up of components and fillers into sub-bundles and bundles is a critical element in an umbilical and the process shall be carefully controlled. The operation shall be carried out in a clean, dedicated controlled area which shall be subject to a regular cleaning schedule.

For both planetary and oscillatory cabling, the components, sub-bundles and fillers shall not be subject to excessive compressive and tensile loadings. Where the weight of a component or sub-bundle could induce damaging loads, the pay-off reels should be powered.

Binder tapes shall be applied at uniform tensions which shall not prevent relative movement between components when the bundle and/or umbilical is bent or flexed.

During lay-up, the product shall be subject to frequent visual inspection to ensure uniform and consistent cabling of the components and associated fillers.

The bundled components or intermediate bundled components shall be stored on a suitably sized reel and/or carousel in a dry dedicated and controlled area. The spooling tension and/or number of layers shall be such as not to induce damaging deformation to the bundle structure or individual components.

10.6.2 Inner Sheath

The bundle (or sub-bundle) shall be kept dry prior to and during passage through the extruder.

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

a. Extruder barrel/head temperatures.
b. Melt pressure/temperature.
c. Screw speed/power requirement.
d. Haul-off speed.
e. Outside diameter.

Where the inner sheath comprises rovings, these shall be applied under uniform tension. The tension applied to the roving yarns shall be checked for each bobbin at the commencement of each production run and thereafter in accordance with the Manufacturer's Inspection and Test Plan.

During sheath application, the product shall be subject to frequent visual inspection to ensure uninterrupted and uniform coverage and no extraneous material is included under the sheath. Care shall be taken to ensure that the bundle (or sub-bundle) is not stretched and the binder taper is not disturbed during this process.

Repairs to a sheath are allowable and shall be performed in accordance with the Manufacturer's written specification.

10.6.3 Armoring

The armoring of a sheathed or roved bundle is a critical element in an umbilical and the process shall be carefully controlled. The operation shall be carried out in a clean dedicated, controlled area which shall be subject to a regular cleaning routine.

Breaking strength, yield strength and load-extension measurements shall be performed on samples from each batch of armor wire to confirm that the material properties are within the specified limits.

Armor wires shall be wound uniformly onto armor bobbins and subsequently processed in a manner which does not damage or reduce the effectiveness of the galvanizing layer or contaminate with extraneous matter.

During armor application, the bundle and its components shall not be subject to excessive compressive loadings which result in deformation or damage. Bedding tapes shall be applied at uniform tension. The tension applied to the armor wires, shall be checked for each bobbin at the commencement of each production run and thereafter in accordance with the Manufacturer's Inspection and Test Plan.

During armor application, the product shall be subject to frequent visual inspection to ensure uninterrupted and uniform coverage and no extraneous material is included under the armor. Care shall be taken to ensure that the sheathed bundle is not stretched and the sheath disturbed during this process.

Armor wire welds may be included in the armoring system provided they are staggered a minimum of two lay lengths apart and are made in accordance with the Manufacturer's written specification.

10.6.4 Outer Sheath

Application of the outer sheath shall follow the same process requirements as for the inner sheath.

During, or if applied after application of the outer sheath, the longitudinal stripe shall be frequently visually inspected for continuity and evidence of twist in the umbilical.

10.7 STORAGE

On completion of manufacture, umbilicals should be stored on suitably designed and constructed storage reels or carousels. The radius of the inner turns shall not be less than the Manufacturer's minimum bend radius for storage.

Where an umbilical is stored on a reel, the flange diameter shall be greater than the diameter of the outermost layer by at least one umbilical diameter. Spooling of an umbilical onto its storage reel (which could also be the shipping and/or installation reel), shall be undertaken with sufficient back tension to minimize the risk of slack turns developing when the product is removed from the reel.

Whether stored on a reel or carousel, the number of layers shall be such as not to impart damaging forces to the underlying layers. Reels and carousels shall be located on flat stable ground in a safe area away from machinery and/or processes which produce corrosive and/or damaging products and away from constantly used work areas. Where appropriate, suitable barriers shall be erected to minimize the risk of damage as a result of collision by passing vehicles.

Where an umbilical is to be stored for an extended duration, typically in excess of 6 months, and/or periods of temperature extremes, consideration shall be given to the effect on the fluid within the hose lines. If necessary, the fluid shall be replaced by a more appropriate fluid. The requirement to change fluid and fluid type shall be defined in the Manufacturer's written specification which shall also detail frequency of inspection and testing to confirm product integrity.

11 DESIGN VERIFICATION AND CHARACTERIZATION TESTING

11.1 GENERAL

Design verification and characterization tests shall be performed to prove that a particular design of a functional component and/or an umbilical meets the design requirement. For an umbilical, the tests can be undertaken using part of the length from production, or from manufacture of a pre-production length. The pre-production length shall be manufactured using approved manufacturing procedures identical with those intended for the manufacture of the production length. This latter course is recommended in cases of unusual or novel designs, or for severely loaded and dynamic umbilical designs.

For new electric cables, hose and umbilical designs which are similar to previously verified designs and their performance can be predicted with a high level of confidence, then design verification tests may be included with some or all of the factory acceptance tests specified in Section 12. For unusual designs, or designs significantly different from previously verified designs, design verification testing shall be undertaken as a separate program.

If the umbilical design is similar to 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.

Characterization tests are normally undertaken to provide component and umbilical performance characteristics and shall have no accept/reject criteria, unless specifically stated in the Manufacturer's written specification.

All electrical cable and hose designs for use in umbilicals shall be tested on representative samples in accordance with the requirements of this section. The tests shall be satisfactorily completed prior to acceptance of a design in an umbilical. Each sample shall be uniquely and clearly identified by tagging or marking and unless otherwise specified, each test shall be executed and documented according to the standard specified for the test. The criteria for passing each test shall be according to the standard specified for that test unless otherwise specified.

All test procedures shall be documented and all measuring equipment used in the tests shall be calibrated, with supporting documentation. At the conclusion of each test, a test report containing full description of the tests and a full set of test results shall be produced. Witnessing of the tests shall be in accordance with the Design Plan.

Design verification test data is valid from the date of satisfactory completion of the verification test, unless a significant changes in design, operating parameters, material or manufacturing process occur.

Additional design verification and characterization tests may be required to confirm that a design is suitable for a unique or demanding application. If required, these tests including accept/reject criteria, where applicable, shall be specified in the Manufacturer's written specification.

Only those electrical cable and hose designs that have successfully completed all the verification tests may be incorporated in an umbilical.

11.2 TEST FAILURE

For each design of functional component, all of the design verification tests shall be passed. Failure to meet any of the specified requirements shall require modification of some or all of the design criteria, or the re-test of the design. In the event of a re-test, the reason for the failure of the failed sample shall be included as part of the supporting test documentation. The test in which the sample failed shall be repeated satisfactorily for three new samples before the design is verified. In the event of any redesign of the functional component as a result of a failure, the verification tests shall be repeated in full for the new design before the design can be verified.

In the event of failure of the umbilical design to meet the design verification tests requirements, the cause of the failure for each test shall be determined and a detailed test report shall be generated. The Manufacturer shall, additionally, in the test report identify all potential shortcomings if the design is to be put into service.

The Purchaser/User shall review the test report and determine whether the design is acceptable and what additional steps need to be introduced to mitigate any potential problems that may arise when the umbilical is put into service.

11.3 ELECTRIC CABLES

The following tests shall be performed to verify each cable design and provide characterization data.

11.3.1 Visual and Dimensional Checks

Electrical cores from completed electric cables shall be examined visually and shall be free from damage, conductor kinks or faults. This shall include examination of materials for contamination, dimensions and construction. Conductors shall be examined in accordance with IEC 228.

11.3.2 Conductor Resistance Test

A DC conductor resistance test shall be performed on two samples of each insulated conductor, each sample being at least 1 meter long. One sample shall be taken from the trailing end and one from the leading end of a finished electrical cable. The measured DC conductor resistance of each conductor corrected to 20°C shall not exceed the specified values in IEC 228 by more than 2%.

11.3.3 Resistivity of Screening Layers

The resistivity of the semi-conducting screening layers in the completed power cable shall not exceed the values defined in Section 5.4.5.

11.3.4 Insulation Resistance

A DC insulation resistance test shall be performed on two samples of insulated conductors, each sample being at least 1 meter long. One sample shall be taken from the trailing end and one from the leading end of a finished electrical cable.

The individual insulated conductors shall be immersed in town mains water and subjected to a minimum hydrostatic pressure of 34.5 bar (500 psi) for a minimum period of 22 hours and then insulation resistance tested while still under pressure. Insulation resistance shall be measured and calculated in accordance with lEC 502. The value of insulation resistance shall not be less than the value as defined in Section 5.4.4.

Where an insulated conductor incorporates a metal screen over its entire length, this test may be undertaken without immersion in water.

11.3.5 High Voltage DC Test

A high voltage test shall be performed on two samples of insulated conductor, each sample being at least 1 meter long. One sample shall be taken from the trailing end and one from the leading end of a finished electrical cable.

The individual insulated conductors shall be immersed in town mains water and subjected to a hydrostatic pressure of 34.5 bar (500 psi) for a minimum period of 22 hours. The DC withstand voltage for signal conductors shall be 3 kV, and for power conductors shall be 5 kV or three times Uo whichever is greater. Each insulated conductor shall withstand the DC voltage between conductor and water while still under pressure, for a period of not less than 5 minutes. At the end of this period, the leakage current shall be measured and shall not exceed the value stated in the Manufacturer's written specification.

Where an insulated conductor incorporates a metal screen over its entire length, this test may be undertaken without immersion in water.

This test may be combined with the insulation resistance test specified in Section 11.3.4, using the same samples, provided the insulation resistance test is performed first.

11.3.6 High Voltage AC Test

On completion of the high voltage DC test specified in Section 11.3.5, a high voltage AC test shall be performed with the insulated conductors subject to the same hydrostatic pressure.

The test shall be performed with an alternating voltage of sine wave form having a frequency in the range 40-62 Hz unless otherwise stated in the Manufacturer's written specification. The rms value of the applied voltage shall be as shown in Table 5. The voltage shall be applied between conductor and water. It shall be increased at the rate defined in Section 11.3.9, and maintained at the full value for 5 minutes without breakdown of the insulation.

Where an insulated conductor incorporates a metal screen over its entire length, this test may be undertaken without immersion in water.

11.3.7 Complete Voltage Breakdown

On completion of the high voltage tests, two further samples at least 1meter in length shall be subjected to a complete DC breakdown test. One sample shall be taken from the trailing end and one from the leading end of a finished electrical cable.

Each of the samples shall be tested in an identical manner to that in Section 11.3.5. The DC voltage shall be increased at a rate of 1 kV/10 seconds until breakdown occurs. The test results shall be recorded for each sample. If no voltage breakdown occurs before application of three times U_o then the insulated conductor shall be considered suitable. i

Table 5—AC Test Voltages

Voltage Designation of Cable		Test Voltage (rms) V
Signal Cables		1,500
Power Cables- up to and including U=600V	Up to and including 6mm^2	1,500
	Above 6mm^2	3,000
Power Cables - above U = 600V	Up to $U_o/U(U_m)$ = 1.8/3 (3.6)kV	7,500

11.3.8 Partial Discharge Test

For cables rated above $U_o/U(U_m)$ = 1.8/3 (3.6) kV, a partial discharge test in accordance with lEC 502 shall be performed. The discharge magnitude shall not exceed 10 pC.

11.3.9 Rate of Application of Test Voltages

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

11.3.10 Inductance Characteristics

This test shall be performed on both signal and power cables unless otherwise stated in the Manufacturer's written specification.

A sample of completed electric cable, of 10 meters 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 the Manufacturer's written specification which shall include limits for deviation between actual and specified values.

11.3.11 Capacitance Characteristics

A sample of completed electric cable of 10 meters 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 the Manufacturer's written specification which shall include limits for deviation between actual and specified values.

11.3.12 Attenuation Characteristics

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

A sample of completed electric cable of 10 meters minimum length, shall be evaluated for attenuation. The attenuation of each conductor pair in the cable shall be measured or derived at fixed frequencies as specified in the Manufacturer's written specification. The measured values shall not exceed the maximum value specified in Manufacturer's written specification.

11.3.13 Characteristic Impedance

A sample of completed electric cable of 10 meters minimum length, shall be measured for characteristic impedance. The characteristic impedance of each conductor pair in the cable shall be measured and a curve of impedance versus frequency shall be produced over the specified frequency range, unless otherwise specified in the Manufacturer's written specification which shall include limits for deviation between actual and specified values.

11.4 HOSES

The tests specified below shall be performed to verify each hose design and provide characterization data.

If the hose design is intended for use where more than one length of hose will be joined by a coupling, for tests specified in Sections 11.4.4, 11.4.5 and 11.4.6, at least one sample shall contain the coupling design that will be employed. In addition, the test procedure specified in Section 11.4.10 shall be performed if threaded couplings are to be incorporated.

Where no reference is made to an end fitting design, for expediency these may be carbon steel of proprietary design provided the performance does not degrade the test performance requirements.

The tests described below, other than the volumetric expansion test specified in Section 11.4.9 shall be considered to be destructive tests and once completed the test samples shall be destroyed.

11.4.1 Test Fluid

The test fluid shall be the Manufacturer's standard test fluid as specified in the Manufacturer's written specification. The fluid used for each test shall be recorded as part of the test report. Unless otherwise specified, all pressure measurements shall be made at the hose inlet.

11.4.2 Visual and Dimensional Tests

One unaged representative sample of 150 mm minimum length shall be taken from each end of a manufactured hose length. During the dimensional tests, the hose shall be visually examined and be free from damage, irregularities and visual non-conformances in each part of the construction. Measurements of the following parameters of each sample shall be made in accordance with the Manufacturers written procedure:

a. Internal diameter.
b. Diameter over reinforcement.
c. External diameter.
d. Hose concentricity.
e. Liner wall thickness.

The Manufacturer's written specification shall include a hose dimensional specification clearly stating the values and manufacturing tolerances for all the parameters above. The values and tolerances shall not exceed those specified in Section 6.2.

11.4.3 Change in Length Test

One unaged representative sample shall be taken from each end of a manufactured hose length. The sample length shall not be less than 400 mm when measured between the hose end fittings. The test shall be performed on each sample in accordance with the change in length test for hydraulic hoses specified in ISO 1402 at a test pressure equal to the maximum working pressure.

The measured change in length shall be within the range specified in Section 6.4.4.

11.4.4 Leakage Test

One unaged representative sample shall be taken from each end of a manufactured hose length and assembled with the intended material and design of end fitting incorporated at each end of each sample. The sample length shall not be less than 400 mm when measured between the hose end fittings. The test shall be performed on each sample in accordance with the leakage test for hydraulic hoses specified in ISO 1402. There shall be no evidence of leakage during or on completion of the test.

11.4.5 Burst Test

One unaged representative sample shall be taken from each end of a manufactured hose length and assembled with the intended material and design of end fitting incorporated at each end of each sample. Two further samples shall be prepared with a minimum of one splice in the reinforcement of each sample made according to the Manufacturer's written specification. These particular samples shall be clearly marked showing the position of each splice. The sample length shall not be less than 400 mm when measured between the hose end fittings. Test results for samples with splices and samples without splices shall be recorded. This test shall be carried out on each sample in accordance with the burst pressure test for hydraulic hoses specified in ISO 1402 using the standard laboratory temperature. The minimum burst pressure shall not be less than the value specified in Section 6.4.2.

This test may be combined with the change in length test specified in Section 11.4.3 after having first performed the change in length test.

11.4.6 Impulse Test

Two unaged representative samples shall be taken from each end of a manufactured hose length (four samples in total). Two further samples shall be prepared with a minimum of one splice in the reinforcement made according to the Manufacturer's written specification. The splices shall be located nominally in the center of the test sample and their location clearly identified.

End fittings shall be attached to each sample using the same procedure that will be used to attach the fittings that will be employed in service. At least four end fittings shall be of the same design and material of construction as those that will be employed in service. The sample length shall be calculated using the formula specified in ISO 6803.

All hose assemblies shall be subjected to a proof pressure test as specified in ISO 1402 before commencing the impulse test. The test shall be conducted in accordance with the impulse test procedure specified in ISO 6803 at the reduced test fluid temperature of 55 ± 3°C. Compatibility of the test fluid with the hose liner shall be confirmed prior to commencement of the test. The test pressure shall be 1.33 times the maximum working pressure, and the hose shall withstand a minimum of 200,000 cycles without any signs of leakage or failure.

For hoses greater than 25.4 mm (1") nominal bore, or higher working pressures than those specified in Section 6, Table 1, alternative installed test configurations, pressure waveforms and/or number of cycles forming the accept/reject criteria may be acceptable as defined in the Manufacturer's written specification.

11.4.7 Cold Bend Test

One unaged representative sample shall be taken from the end of a manufactured hose length. The sample length shall not be less than 400 mm when measured between the hose end fittings. The test shall be carried out in accordance with the cold flexibility test specified in ISO 4672, Method B, where the test temperature is as specified in Table 6. The sample shall fail the test if any signs of leakage, distortion or cracking are apparent.

11.4.8 Collapse Test

This test shall be performed in accordance with the method specified in Appendix G. The pressure at which the hose collapses shall exceed the value specified in Section 6.4.3.

Table 6—Cold Bend Test Temperature

Climate	Test Temperature
Normal weather	-15°C ± 3°C
Cold weather	-40°C ± 3°C

11.4.9 Volumetric Expansion Test

This test may be performed in accordance with one or more of the following methods:

a. ISO 6801. This method requires measurements to be taken on new and unaged hose.

b. Appendix H. This method requires measurements to be taken on new hose which has been subject to pre-pressurization.

c. The Manufacturer's written specification when specific hose characteristic information is required.

The results from this test shall be used to characterize a hose design and do not constitute accept/reject criteria.

Note: Volumetric expansion measurements made on sample lengths do not correlate directly with hoses in an installed umbilical system. Factors such as frictional losses in long length hydraulic lines, hydrostatic head due to vertical installed umbilical sections, seabed hydrostatic pressure, etc. can all contribute to the differences.

11.4.10 End Fitting Anti-Rotation Test

Two unaged representative hose samples of not less than 600 mm in length shall have swivel female service design fittings attached at one end only.

The other ends shall be terminated with any convenient end fitting which is not detrimental to the outcome of the test. The service design female connections shall be mated using a male-male adapter manufactured from the same material and tightened to the Manufacturer's recommended sealing torque. One end of the mated arrangement shall be clamped, the other end shall have a minimum of 90° twist imparted before being clamped. The direction of twist shall be in the direction required to unscrew the mated fittings at the center of the test arrangement.

Hydrostatic pressure cycling between zero and 1.5 times the maximum working pressure shall be applied 10 times consecutively, at a frequency of less than 1.5 cycles per minute. The time for the test pressure rise and decay shall be a minimum of 10 seconds. On completion of 10 cycles, the pressure shall be held constant at 1.5 times the maximum working pressure for 10 minutes minimum. The sample shall be inspected for signs of leakage and distortion. Any such signs shall result in failure of the test.

11.4.11 Fluid Compatibility

11.4.11.1 General

Compatibility testing shall be performed to demonstrate that the specified service fluids are compatible with the materials of hose construction.

Unless the Manufacturer is able to provide documentary evidence of previously conducted compatibility tests for identical fluid and material combinations, testing shall be required for each of the proposed fluid and material combinations. The fluid/material combinations and the applicable test procedure shall be as stated in the Manufacturer's written specification.

Immersion testing which utilizes plaques or dumbbells shall only be used to determine whether there is gross incompatibility between the hose liner, and sheath material and the fluid. This method may be used for predicting hose sheath compatibility, but for hose liners such testing shall be supported by a program of pressure cycle testing on complete hose samples from which the minimum service life shall be predicted.

Prediction of the minimum service life, determined by compatibility testing, shall be in accordance with the Manufacturer's written procedure.

The Manufacturer shall also demonstrate that the reinforcement sheath material is compatible with seawater and permeated fluid throughout the specified design life. If the Manufacturer is able to produce documentary evidence of satisfactory compatibility based upon actual service experience, compatibility testing of the hose sheath may not be required.

11.4.11.2 Immersion Tests

Immersion tests, involving accelerated aging at elevated temperature and monitoring of physical properties, shall be undertaken as a coarse filter before pressure cycling tests. Specimens shall be stressed by means of dead-weight loads at strain levels as per Manufacturers Written Specification.

Measurement of specimen material properties shall include volume swell, ultimate tensile stress and elongation at break.

11.4.11.3 Pressure Cycling Tests

Pressure cycling tests shall be performed on a minimum of 6 representative hose samples terminated with the same abutment design features as the service end fittings, each approximately 1 meter long, which may be joined in a string for convenience. Prior to testing, the hose assemblies shall be subject to a change in length test as described in Section 11.4.3, followed by a proof test as described in ISO 1402. The hose string shall be immersed in a bath of town mains water, filtered to 5 micron absolute, held at a temperature of 40°C ± 1°C for a period of 12 months. In the event that timescales do not permit a 12 month program, a higher temperature for a shorter duration may be acceptable. The duration and temperature shall be as stated in the Manufacturer's written specification. If elevated temperatures are used then care needs to be taken that the failure mechanism is representative, and that the material temperature limits are not exceeded.

The water shall be renewed monthly.

The hose string shall be filled with the service fluid under investigation and the pressure in the string shall be cycled between zero and the maximum working pressure at a rate of 1 cycle/hour. The pressurization and depressurization periods shall each be of 5 minutes duration ± 10 seconds, and the dwell time at zero pressure shall be 10 minutes ± 10 seconds.

At specified time intervals, samples of hose may be removed from one of the test assemblies and the remaining hose re-terminated and reintroduced into the test program. Removed samples shall be examined and the hose liner physical properties measured and compared with those of control samples from the same batch.

The hose/fluid combination shall pass this compatibility test if:

a. None of the hoses fail during the period of pressure cycling, and,

b. The Manufacturer's written specification predicts the minimum service life is greater than the specified design life.

11.4.12 Permeability

Permeability tests shall be carried out to determine whether the hose liner is permeable to the specified service fluids which contain low molecular weight fractions. The results from this test shall be used to characterize a hose design and do not constitute accept/reject criteria.

Tests on other fluids may be required as specified in the Manufacturer's written specification.

When carrying out permeability testing it should be noted that on some materials the permeation rate is a significant function of both temperature and pressure.

11.4.12.1 Liquids

The permeability of the liner to liquids shall be measured on a sample of tube at least 1 meter long using the test apparatus described in ISO 8308. The nitrogen charge pressure shall be checked daily and adjusted if necessary, and at all other times the "main" and "venting" valves shall be kept tightly closed. The loss of fluid shall be measured daily over a period of at least 30 days, or until the level of fluid in the burette has fallen below the minimum mark if this occurs sooner. A graph of fluid loss against elapsed time shall be plotted. The average gradient of this graph shall be used to determine the characteristic permeation rate for the particular fluid/material combination.

11.4.12.2 Gases

The permeability of the liner to gases shall be measured on a 1 meter long sample of tube in accordance with ISO 4080.

11.5 UMBILICAL

The following tests shall be performed to verify the umbilical design and the design principles employed in its construction and to provide umbilical characterization data.

11.5.1 General

If the umbilical contains electrical cores, the following electrical tests shall be performed as an integral part of the mechanical tests:

a. Continuous monitoring of the conductor paths with each conductor in the umbilical connected in series. The measured DC conductor resistance value shall not exceed the value defined in Section 11.3.2 at the beginning and end of the test.

b. Insulation resistance shall be measured during, and after completion of the mechanical testing. The measured value shall comply with the requirements of Section 5.4.4.

Where tests require the umbilical to be tensile loaded, the mechanical means of anchoring shall employ the same design principles as for the service umbilical system.

11.5.2 Tensile Test

A representative length of the completed umbilical, which takes account of end effects and pitch lengths of the umbilical components, shall be subjected to a two stage tensile loading program.

The first stage shall involve three load cycles to establish the permanent set and residual twist of the umbilical design up to the maximum design working load. Stage two shall involve a further loading to establish the load at which the components within the umbilical cease to function, and the ultimate tensile strength of the umbilical.

Both ends of the sample shall be terminated in such a manner that for armored umbilicals the armor wires are gripped, and for unarmored umbilicals, the internal components are firmly gripped. When loaded into the test rig, the specimen shall have freedom to rotate under the action of the tensile load. During tensile testing, umbilicals containing hoses shall be pressurized to their specified installation pressure (for static umbilicals), or to the value defined in the Manufacturer's written specification (for dynamic umbilicals), during tensile testing. Electrical testing, if applicable, shall be performed in accordance with the requirements of Section 11.5.1 or in accordance with the Manufacturer's written specification.

The tensile load shall be applied in a minimum of 10 increments up to the maximum design working load and at each load level, the load, extension and rotation shall be recorded. On reaching the maximum working load, the load shall be reduced and the same procedure utilized during load-down. The procedure shall be repeated for the second and third cycles.

Following completion of the three load cycles, the load shall be increased until mechanical failure occurs, or minimum breaking load is reached, whichever is the sooner. Any prior functional failure of the umbilical shall be noted. At the conclusion of the testing, the umbilical specimen shall be stripped down and visually examined in the event of premature failure of functional components.

11.5.3 Bend Stiffness Test

A sample of the completed umbilical shall be subject to a series of bending regimes to allow its inherent stiffness to be determined. This is an optional test and the information generated shall not form part of accept/reject criteria unless stated otherwise in the Manufacturer's written specification.

In the case of umbilicals containing hoses, the stiffness shall be obtained for the following conditions:

a. Hoses pressurized to the recommended installation value.
b. All hoses pressurized to a common value as stated in the Manufacturer's written specification.

For static umbilicals, condition a) should apply and for dynamic umbilicals, condition b) should apply.

The bend stiffness shall be measured on a specimen length with a minimum sample length of not less than 2m.

One end of the umbilical shall be anchored with all the components locked to produce a built-in end condition. Transverse load increments shall be applied to the other end, and the deflection shall be measured 30 seconds ± 5 seconds after load application. No more than a further 30 seconds ± 5 seconds shall elapse before applying the next load increment. The load shall be decreased in a similar manner. Bend stiffness shall be calculated using the engineers beam bending theory and the sectional modulus values for the sample length shall be recorded.

11.5.4 Crush Test

A sample of completed umbilical shall be subject to lateral loading to allow its resistance to deformation to be determined.

In the case of umbilicals containing hoses, the resistance to lateral loading shall be obtained for the following conditions:

a. Hoses unpressurized.
b. Hoses pressurized to the recommended installation value.
c. All hoses pressurized to a common value as stated in the Manufacturer's written specification.

For static umbilicals, conditions a) and b) shall apply and for dynamic umbilicals, a), b) and c) shall apply.

The lateral deformation tests specified in a), b) and c) above shall be performed on separate representative umbilical samples which have not been subject to previous testing.

Where umbilicals contain electrical cores, electrical testing shall be in accordance with the requirements of Section 11.5.1, or in accordance with the Manufacturer's written specification.

The test sample shall be loaded between two parallel plates each a minimum of 250 mm in length and located diametrically opposite each other in a compressive loading device. With the hoses pressurized to their specified pressure, the plates shall be moved towards each other at a rate not exceeding 5 mm/min.

The reduction in umbilical diameter between the load plates shall be continuously recorded as a function of the applied load. On reaching the maximum applied load specified in the Manufacturer's written specification or 10% deformation, whichever occurs first, the load shall be decreased at a rate not exceeding 5 mm/min. When the load has reduced to zero, the sample shall be examined and the effects of the applied load on the umbilical and the functional components shall be determined and documented.

11.5.5 Fatigue Testing

Mechanical testing should be undertaken to determine the fatigue resistance of an umbilical. Test regimes shall be chosen to demonstrate that a particular design or design feature is suitable to withstand the repeated flexures sustained by an umbilical during manufacture, transfer spooling, loadout, I/J-tube pull-in, burial and, for a dynamic installation, operational service throughout the design life.

The test regimes shall be as per the Manufacturer's written specification taking account of installation/ service parameters, and the results of design activities and analyses.

Note: Because of the wide range of fatigue conditions to which an umbilical can be exposed, it is not possible to generalize and specify test methods and parameters to cover all eventualities. Instead, the testing is application specific.

Guidance notes on fatigue testing are contained in Appendix I.

11.5.5.1 Components

Fatigue Testing. For static umbilicals hoses should be pressurized to their recommended installation pressure. Hoses in dynamic umbilicals should be pressurized to their maximum service working pressure, unless analysis shows that varying the pressure in some time (or cycle) dependent manner is more representative. However, where an umbilical contains hoses with a multiplicity of working pressures, for expediency a common pressure may be adopted. Electrical cores shall be continuously monitored for DC continuity. Conductor DC resistance and core insulation resistance shall be measured at the beginning and the end of the fatigue test program and at periodic intervals as defined in the Manufacturer's written specification.

12 FACTORY ACCEPTANCE TESTS

12.1 GENERAL

These tests shall be performed during component and umbilical manufacture. Unless otherwise specified, each test shall be executed and documented according to the standard specified for the test. Unless otherwise specified, the criteria for passing each test shall be according to the standard specified for that test.

All test procedures shall be documented and all measuring equipment used in the tests shall be calibrated with supporting documentation. Inspection testing shall be carried out at intermediate stages and on completion of each hose, electric cable and umbilical.

Where raw materials are subject to inspection testing, it is acceptable for more than one batch of raw material to be used in the manufacture of components and umbilicals, provided the characteristics of each batch of material meet the material suppliers specification, and the same material specification is used for each manufactured length.

The tests detailed in this section are the minimum requirement for each manufactured length. If the acceptance criteria for a test are not met, the cause of the failure shall be investigated and a report compiled. In the event of failure of one or more of the inspection tests, raw material, completed or part-completed components and umbilicals may be rejected.

Additional factory acceptance tests may be required to confirm the integrity and performance compliance of components, or umbilical, resulting from additional design or design verification requirements, or assembly of sub-bundles. If required, these tests including accept/reject criteria where applicable, shall be specified in the Manufacturer's written specification.

Following fitment of terminations and ancillary equipment, additional factory acceptance tests shall be undertaken. The tests to be performed shall be based on the tests specified in this section, and the extent of the testing shall be as specified in the Manufacturer's Written Specification.

Note: When performing these additional tests, the effects of test parameters on the ancillary equipment shall be checked. For example, an electrical connector may not be able to withstand the test voltage specified for the electrical cores within the umbilical. Where necessary, test parameters shall be modified to ensure the integrity of the active termination/ancillary elements is not compromised. The modified test parameters shall be specified in the Manufacturer's Written Specification.

12.2 ELECTRIC CABLE MANUFACTURE

12.2.1 Visual and Dimensional Inspection

During the manufacturing processes, each conductor and insulated conductor shall be 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 frequently visually examined. Manufacturing parameters shall be periodically monitored in accordance with the Manufacturer's Inspection and Test Plan and shall comply with the Manufacturer's written specification. Conductor examination shall comply with the requirements of IEC 228.

12.2.2 Spark Test

All cores shall be spark tested during insulation extrusion and all sheathing extrusions should be tested where applied directly over a screen. There shall be no indication of faults in order to pass this test. During the process of insulation and sheath extrusion, the minimum voltage levels shall be as defined in BS 5099 for the applicable insulation and sheath thicknesses.

12.2.3 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 shall not exceed the values in IEC 228 by more than 2% when corrected for lay-loss.

12.2.4 Insulation Resistance Test

This test shall be performed on the complete conductor lengths in accordance with the procedure specified in Section 11.3.4 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.

12.2.5 High Voltage DC Test

This test shall be performed on the completed conductor length in accordance with the procedure specified in Section 11.3.5 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.

12.2.6 Inductance Characteristics

On completion of cable manufacture, the inductance characteristics shall be measured in accordance with the procedure specified in Section 11.3.10 as follows:

a. On a 10 meter minimum length sample removed from the completed length, or;

b. On the completed length provided the overall length does not introduce spurious results.

12.2.7 Capacitance Characteristics

On completion of cable manufacture, the capacitance characteristics shall be measured in accordance with the procedure specified in Section 11.3.11 as follows:

a. On a 10 meter minimum length sample removed from the completed length, or;

b. On the completed length provided the overall length does not introduce spurious results.

12.2.8 Attenuation Characteristics

On completion of cable manufacture, the attenuation characteristics shall be measured or derived in accordance with the procedure specified in Section 11.3.12 as follows:

a. On a 10 meter minimum length sample removed from the completed length, or;
b. On the completed length provided the overall length does not introduce spurious results.

12.2.9 Characteristic Impedance

On completion of cable manufacture, the characteristic impedance shall be measured in accordance with the procedure specified in Section 11.3.13 as follows:

a. On a 10 meter minimum length sample removed from the completed length, or;
b. On the completed length provided the overall length does not introduce spurious results.

12.2.10 Cross-Talk

The cross-talk between conductor pairs at the rated voltage, current and frequency shall be measured on the complete cable length for the appropriate mode.

The measured values shall be less than the maximum values specified in the Manufacturer's written specification.

12.2.11 Time Domain Reflectometry

A time domain reflectometry trace shall be obtained for each conductor. The width of the pulse shall be such as 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, joints, if present, etc. The results of this test shall be used to characterize a conductor within an umbilical and do not constitute accept/reject criteria.

12.3 HOSE MANUFACTURE

12.3.1 Visual and Dimensional Inspection

During the manufacturing processes, the extrudates and braided reinforcement shall be free from damage, faults or contamination. Raw materials shall also be examined for contamination. Manufacturing parameters shall be periodically monitored and shall comply with the Manufacturer's Inspection and Test Plan and shall comply with the Manufacturer's written specification.

As a minimum, the following dimensional checks shall be carried out in accordance with the Manufacturer's written procedure:

a. Liner—ID, OD, concentricity, wall thickness.
b. Reinforcement—OD, pitch (for each layer).
c. Sheath—OD, concentricity.
d. Completed Hose—ID, OD, concentricity.

ID measurements shall be performed using a "go/no go" gage to verify the bore is within the tolerance stated in the Manufacturer's written specification.

12.3.2 Liner Pressure Tests

12.3.2.1 Burst Test

After extrusion, a 1 meter length of liner shall be removed from each end of each extruded length, and subjected to a burst test. The burst pressure shall be not less than 80% of the calculated burst pressure based upon minimum wall thickness, maximum bore diameter and tensile stress at 20% liner material elongation, using standard thin wall cylinder theory.

12.3.3 Test Fluid

For sample testing, the test fluid shall be as per the Manufacturer's written specification. For integrity tests to be performed on each completed hose length, the test fluid shall be one of the following:

a. The specified system control fluid filtered to 5 microns absolute and clean to ISO 4406, Class 15/12 for all lines.
b. Town mains water plus a minimum of 25% mono-ethylene glycol filtered to 5 microns absolute where there is potential for chemical reaction between the control fluid and the intended well service fluid, or where specified in the Manufacturer's written specification.

The test fluid shall remain in the hoses throughout umbilical manufacture, loadout, shipping and installation.

Storage of the test fluid(s) in both the shipping containers and in the hoses shall be such as to prevent freezing occurring. The test fluid(s) shall be new and unused and the introduction of contamination during fluid transfer and pressure/flow rate testing shall be avoided. Completed hose lengths shall be sealed at each end at all times when testing is not in progress.

Note: During testing, the test fluid may be subject to elevated temperatures which may reduce the design life of the hose. At all times, the temperature of the test fluid shall be maintained within the range specified in Section 6.6.1.The use of two different test fluids is not recommended as this can duplicate test equipment requirements during umbilical manufacture, loadout and installation.

12.3.4 Change in Length

On completion of manufacture, an unaged representative sample shall be taken from each end of each manufactured length and subject to a change in length measurement in accordance with the procedure specified in Section 11.4.3.

12.3.5 Burst Test

On completion of manufacture, an unaged representative sample shall be taken from each end of each manufactured length and subject to a burst test in accordance with the procedure specified in Section 11.4.5 with the exception that it is not a requirement for reinforcement splices to be included in any of the test samples.

This test may be combined with the change in length test in Section 12.3.4.

12.3.6 Proof Pressure/Decay Test

On completion of manufacture, a proof test shall be performed. The hose shall be pressurized at a controlled rate up to the proof pressure. The test pressure shall be measured at both ends of the hose and shall be maintained within ± 5% over a minimum period of 30 minutes. At the end of this period where the pressure has been maintained, the pressure source shall be isolated and the pressure decay characteristic monitored over a minimum period of 60 minutes. During this period, the monitored pressure shall provide a clear indication of stabilization. Throughout the proof pressure test period, the ambient temperature shall be continuously monitored. There shall be no evidence of leakage or failure during or at the end of the test period.

A schematic arrangement of the test set-up and typical proof pressure trace are provided in Appendix B, Figure B5.

12.4 UMBILICAL MANUFACTURE

12.4.1 General

During umbilical manufacture, the functional components shall be subject to factory acceptance tests.

12.4.2 Visual and Dimensional Inspection

During the manufacturing processes, the components partially completed and completed umbilical shall be free from damage, faults or contamination. Raw materials shall also be screened for contamination. Manufacturing parameters shall be periodically monitored, and shall comply with the Manufacturer's Inspection and Test Plan and with the Manufacturer's written specification.

12.4.3 Electric Cables

The following tests shall be performed on each complete length of electric cable and electric cable element.

12.4.3.1 Delivery to Umbilical Manufacture

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

a. DC Conductor Resistance as per Section 12.2.3.
b. Insulation Resistance as per Section 12.2.4.

12.4.3.2 Intermediate Assembly

During intermediate assembly (lay-up, sheathing, armoring), there shall be no requirement to perform integrity tests on the electrical cores unless specified otherwise in the Manufacturer's written specification.

12.4.3.3 Completed Umbilical

On completion of umbilical manufacture and prior to fitting of end terminations, the umbilical electrical cores shall be subject to the following factory acceptance tests:

a. DC Conductor Resistance as per Section 12.2.3.
b. Insulation Resistance as per Section 12.2.4.
c. High Voltage DC as per Section 12.2.5.
d. Transmission line characteristics* as per Sections 12.2.6–12.2.9.
e. Cross-talk as per Section 12.2.10.
f. Time domain reflectometry as per Section 12.2.11.

Note: * Such characteristics (inductance, capacitance, impedance), shall only be measured if the overall length is sufficiently short so as not to introduce spurious results.

12.4.4 Hoses

The following tests shall be performed on each complete length:

12.4.4.1 Delivery to Umbilical Manufacturer

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

a. Proof pressure/decay test as per Section 12.3.6 at a test pressure of 1.5 x maximum working pressure.

12.4.4.2 Intermediate Assembly

During intermediate assembly (lay-up, sheathing, armoring), there shall be no requirement to perform integrity tests on the hoses unless specified otherwise in the Manufacturer's written specification.

12.4.4.3 Completed Umbilical

On completion of umbilical manufacture and prior to fitting of end terminations, the umbilical hoses shall be subject to the following factory acceptance tests:

a. Proof pressure/decay test as per Section 12.3.6 at a test pressure of 1.5 x maximum working pressure.
b. Flow Test. The Manufacturer's written specification shall state the nominal flow rate that each hose shall be required to pass. The Manufacturer shall calculate expected pressure

drops for the specified nominal flow rate, and the test shall require that the nominal flow rate is passed through the hose.

A constant high pressure supply shall be connected to one end of each manufactured hose length and the other end shall be vented to atmosphere. The test fluid shall be passed through the hose until the pressure reading at the hose inlet is constant within 5%, and the flow rate is constant within 5%. The flow rate, pressure drop across the hose and fluid temperature shall be recorded. The actual pressure drop and the calculated pressure drop shall be compared and the difference between the two shall not exceed the tolerance value stated in the Manufacturer's written specification.

Note: Reasonable correlation may be expected in turbulent flow, but poor correlation is to be expected under laminar flow conditions. In an umbilical due to lay-up and storage in a curved condition, true laminar flow conditions may not arise.

c. Dynamic Response. This is an optional test performed in accordance with the procedure described in Appendix J or as per the Manufacturer's written specification. The results from this test shall be used to characterize a hose within an umbilical and do not constitute accept/reject criteria.

d. Fluid Cleanliness. Upon satisfactory completion of all other acceptance tests, each hose length specified in the Manufacturer's written specification, if required, shall be flushed with the specified test fluid. The flow rate should be sufficient to ensure turbulent flow and a Reynolds Number of 20,000 should be used when calculating the ideal flow rate. Should this value result in the hose being subject to a pressure greater than the maximum working pressure at the hose inlet, then the highest flow rate possible shall be used subject to not exceeding the maximum working pressure. The fluid temperature shall be monitored continuously to ensure that the hose temperature rating is not exceeded.

Each hose length shall be flushed until the cleanliness level is reached. At the end of this period, three consecutive fluid samples per hose shall be taken at intervals of at least 10 minutes, using the procedure specified in ISO 4406. The cleanliness levels shall meet or exceed the value(s) specified in the Manufacturer's written specification.

Note: For convenience, short hose lengths may be connected together to facilitate the flushing requirements. For hose pressures in excess of 345 bar (5,000 psi) an inlet pressure lower than the hose maximum working pressure may result due to limitations in flushing equipment capacity.

12.4.5 Umbilical Marking—General Requirements

Umbilicals that meet the requirements of this specification and have passed all the tests in this section shall be marked with the following:

a. Part number.
b. Manufacturer's name or trademark.
c. Date of manufacture (month/year).
d. Serial number.
e. API monogram*.

Note: *API lincencees only. Contact API for information on licensing. Marking shall be applied on a nameplate securely attached to the umbilical.

APPENDIX A—INFORMATION TO BE PROVIDED WITHIN A PURCHASER/FUNCTIONAL SPECIFICATION

A.1 Introduction

This Appendix provides guidelines for information to be provided within a Purchaser/ Functional Specification for an umbilical system, which references this API Specification as the detailed standard for the design, manufacture and test of the umbilical to be incorporated in the umbilical system. These guidelines, set out below, are not intended to be mandatory, but are intended as a convenient reference such that the umbilical Manufacturer is provided with sufficient information to ensure the umbilical is correctly designed for its intended functionality.

Note: Functional requirements not specifically required by the Purchaser/ User which may affect the design, materials, manufacturing, testing, installation deployment and operation of the umbilical/umbilical system shall be specified by the Manufacturer in the Manufacturer's written specification.

The Purchaser/User shall specify project specific design requirements and considerations within a Purchaser/ Functional Specification, which shall be based on the following:

A.2 Information To Be Provided

A.2.1 SCOPE OF DEVELOPMENT

The Manufacturer should be aware of the scope of the development for which the umbilical system is intended and where it is incorporated as part of the development. This should be provided by means of narrative description and schematic arrangement drawings.

Additionally, the Manufacturer should also be aware of the proposed installation sequence and method by which the umbilical system will be installed.

A.2.2 SCOPE OF SUPPLY

The scope of supply in respect of the umbilical system should be clearly defined, including but not limited to the following:

a. Number off and lengths, including spare lengths, of each umbilical design.
b. Type of terminations/ancillary equipment required, including repair joint kits, buoyancy attachments, etc.

A.2.3 APPLICABLE CODES, STANDARDS AND REGULATIONS

Other applicable Codes, Standards and Regulations that will apply to the design, manufacture and test of the umbilical/umbilical system or could have an influence should be clearly defined. This should cover National, International and Purchaser/User Specifications. Additionally, any Purchaser/User requirement amendments to this API Specification should be clearly stated.

A.2.4 OPERATING ENVIRONMENT

The relevant operating environment applicable to the design, installation and operation of the umbilical and the umbilical system should be clearly defined. This should address the following:

Location: Geographical data for the installation location.

Water Depth: Design water depth, variations over pipe location and tidal variations.

Seawater Data: Minimum and maximum temperatures.

Air Temperature: Minimum and maximum during storage, installation and operation. (Storage/operation including localized areas where extreme temperatures are to be experienced, e.g. FPS turret with the umbilical adjacent to high temperature flowlines).

Survival Conditions: Conditions which the umbilical may experience as a result of non-planned activities, (extended period for the umbilical suspended from the installation vessel as a result of a breakdown within the installation spread, loss of FPS mooring chain resulting in a modified vessel offset, etc.), which should be catered for within the umbilical system.

Sea-bed Conditions: Description, friction coefficients, seabed scour, sand waves and variations along umbilical route.

Marine Growth: Maximum values and variations along length.

Ice: Maximum ice accumulation, or drifting icebergs and ice floes.

Current Data: As a function of water depth, direction and return period, and including the known effects of local current phenomena.

Wind Data: Direction, speeds, frequencies.

Wave Data: Significant and maximum waves, associated periods, wave spectra as a function of direction and return period.

Further environmental data will be required to carry out installation and service analysis.

A.2.5 SPECIFIC PURCHASER REQUIREMENTS

The following requirements specific to the Purchaser/User field development requirements should be clearly defined.

A.2.5.1 Design Life

The intended design life and not the required Manufacturer's mechanical warranty (guarantee), shall be stated.

A.2.5.2 Umbilical Length

The required umbilical length for each umbilical system including manufacturing tolerance shall be stated.

Note: Installation considerations normally dictate the negative length tolerance shall be zero and the positive length tolerance + 1%.

A.2.5.3 Functional Requirements

The number, type, size duty and duty rating of each component design should be stated.

A.2.5.4 Umbilical Characteristics

Where umbilical characteristics are important to overall system performance, these should be clearly defined.

Note: For static umbilicals, this is normally limited to maximum working load, maximum weight, minimum bend radius if these are likely to impact on the shipment and/or installation equipment.

For dynamic umbilicals, this should address the following:

a. Diameter to weight ratio expressed as $mm.kg.m^{-1}$($in.lb.ft^{-1}$).
b. Buoyancy attachment (no off, location, upthrust).
c. Points applicable to any static length of the umbilical if appropriate.
d. Loads and minimum bend radii at key interfaces (generally resulting from mathematical modeling of the installed configuration in connection with sea currents and vessel motions).

A.2.5.5 Component Characteristics

Where component characteristics are important to overall system performance, these shall be clearly defined.

Note: For hoses, this is normally limited to volumetric expansion and resistance to external hydrostatic pressure as defined by measured collapse pressure. For electric cables/cable elements, this is normally limited to attenuation, characteristic impedance, capacitance, inductance and cross-talk where the umbilical incorporates separate power and signal cores.

A.2.5.6 Service Fluids

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

a. Liquids, including water, oil composition and alcohols.
b. Injected chemical products including alcohols, and inhibitors for corrosion, hydrate, paraffin, scale and wax.
c. Corrosive agents, including bacteria, chlorides, organic acids and sulphur bearing compounds.
d. Aromatic components.
e. Gases, including oxygen, hydrogen, methane and nitrogen.
f. All parameters which define service conditions, including partial pressure of H_2S and CO_2, pH of aqueous phase, TAN (as per ASTM D664 or D974) and water content (produced water, seawater and free water).

A.2.6 ONE-OFF FUNCTIONAL REQUIREMENTS

Functional requirements which have to be met only once, but which are necessary for the installation or operation of the umbilical/umbilical system should be stated.

A.2.7 INTERFACES

Interface areas between the umbilical and mating arrangements should be clearly defined. The connector requirements for both end terminations in the umbilical should be specified. This should include, connector type, welding specification, seal type and sizes.

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

a. Purchaser supplied pull-in and connection tools, terminations and mating test connectors etc.
b. Geometric, dimensional and imposed loading data.
c. Purchaser supplied installation aids and equipment.

A.2.8 INSTALLATION REQUIREMENTS

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

a. For installation by the purchaser, the purchaser should specify any requirements on load restrictions, clamping/tensioner loads, overboarding chute requirements, installation tolerances and any other facility limitations.
b. For installation by the manufacturer, the purchaser should specify any requirements for season, environment, vessel limitations, installation tolerances, restrictions due to conflicting activities, and installation scope (including trenching, burial, testing, inspection, surveying and documentation).

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

APPENDIX B—DRAWINGS

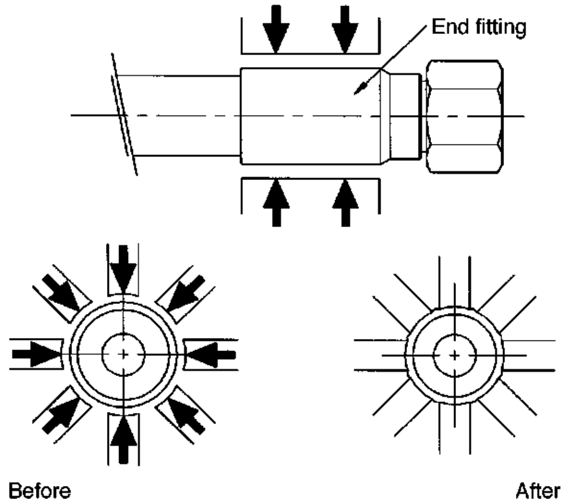


Figure B-1—Typical Method of Crimping

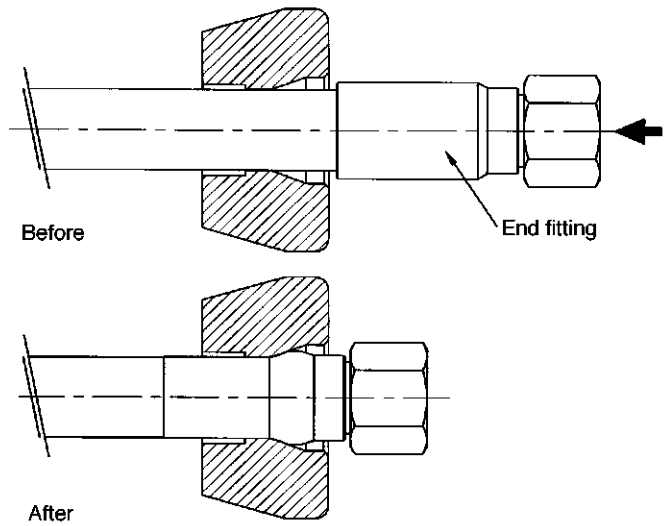


Figure B-2—Typical Method of Swaging

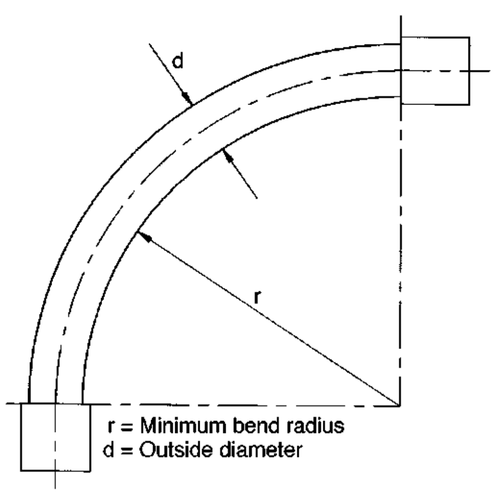


Figure B-3—Minimum Bending Radius

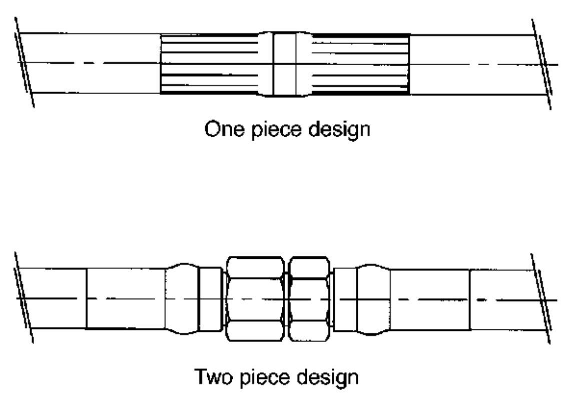


Figure B-4—Typical Hose Coupling Arrangements

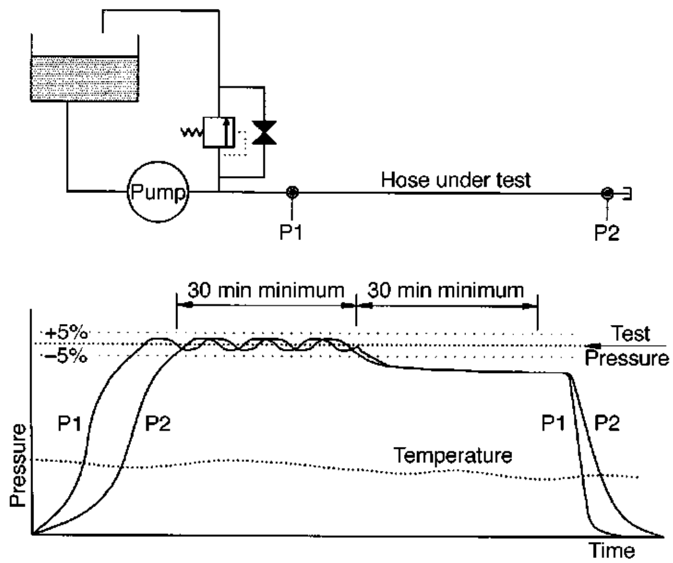


Figure B-5—Proof Pressure/Decay Test Arrangement

APPENDIX C—ELECTRIC CABLE AND HOSE CONSTRUCTIONS

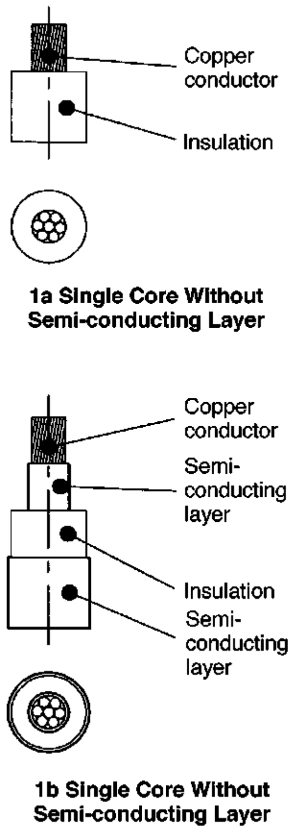


Figure C-1—Typical Power Core Arrangements

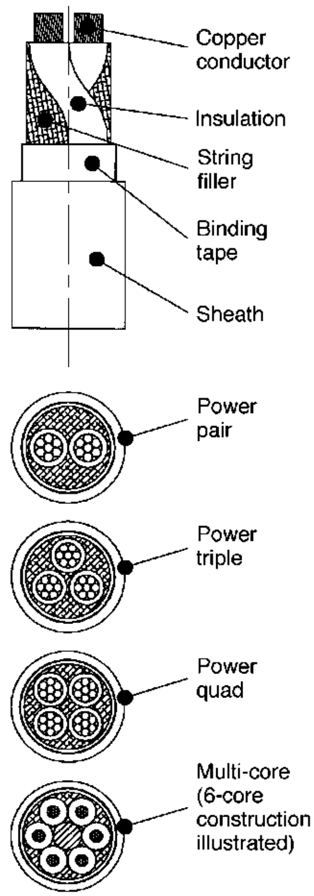


Figure C-2—Typical Power Cable Arrangements

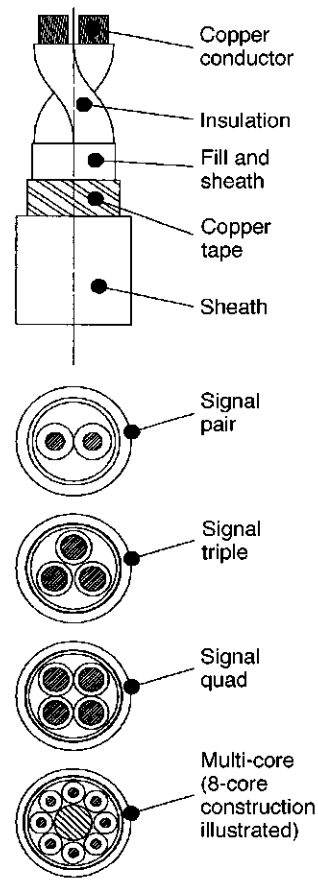


Figure C-3—Typical Signal Cable Arrangements

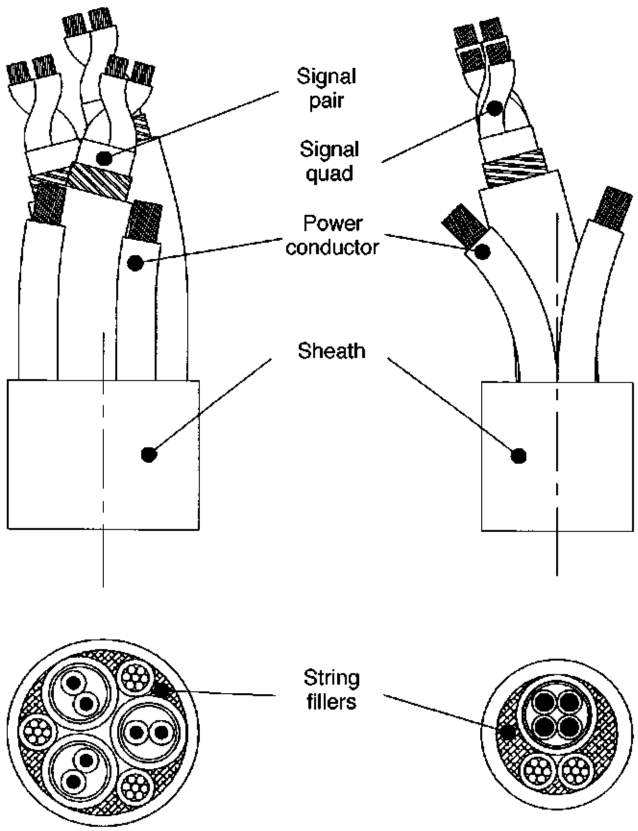


Figure C-4—Typical Electric Cable Elements

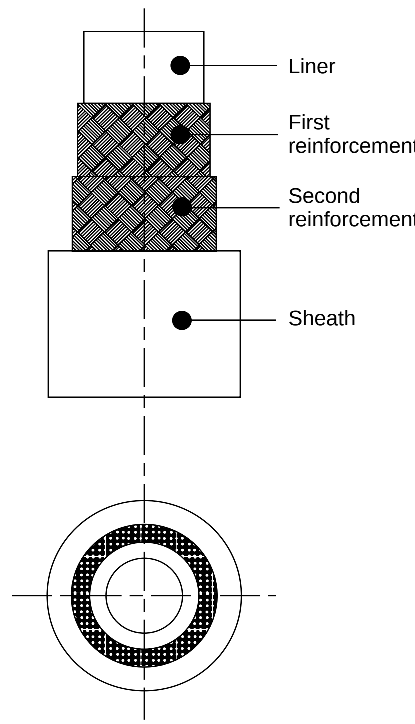


Figure C-5—Typical Thermoplastic Hose Construction

APPENDIX D—LAYING-UP PROCESS ARRANGEMENTS/CABLED PRODUCT FORMS

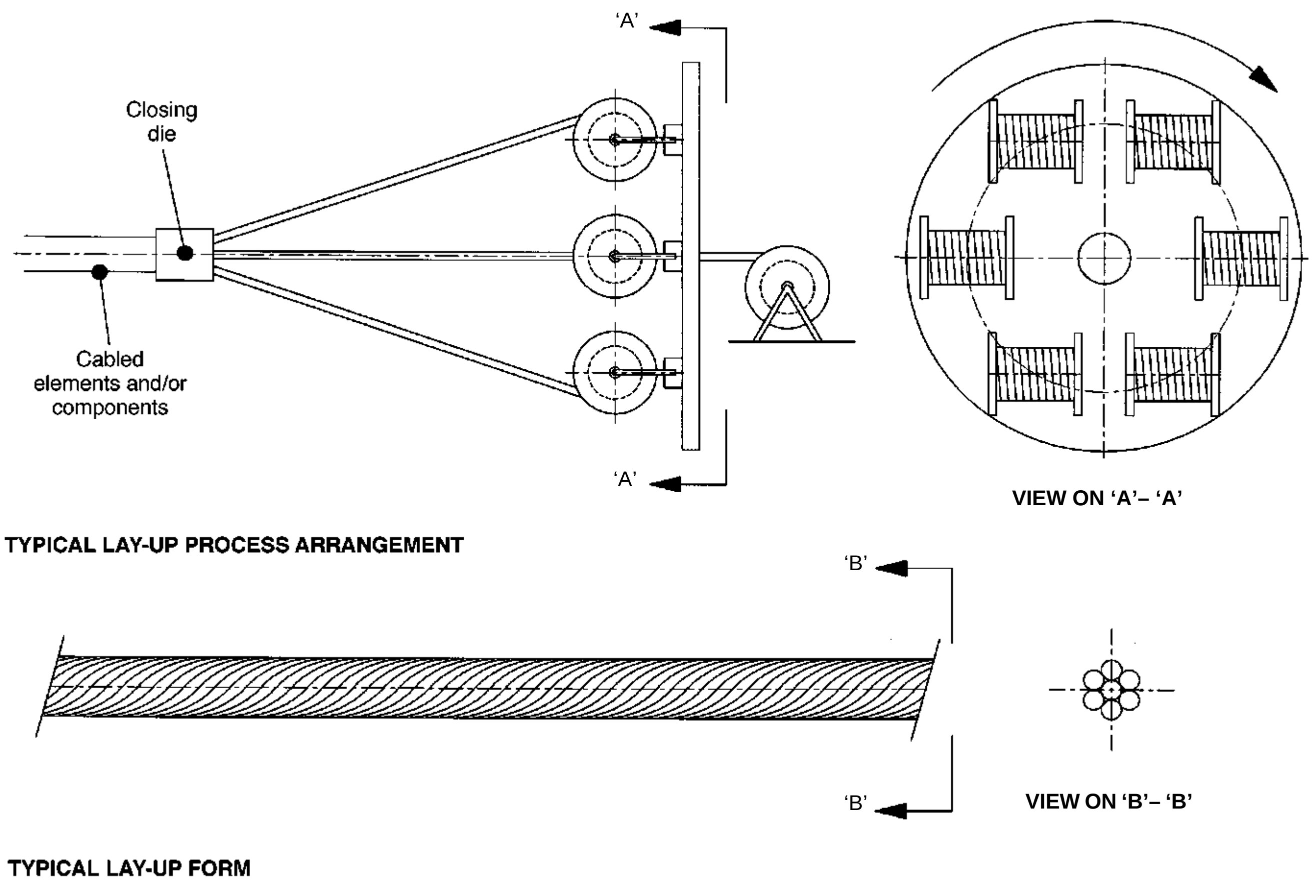


Figure D-1—Planetary Lay-up

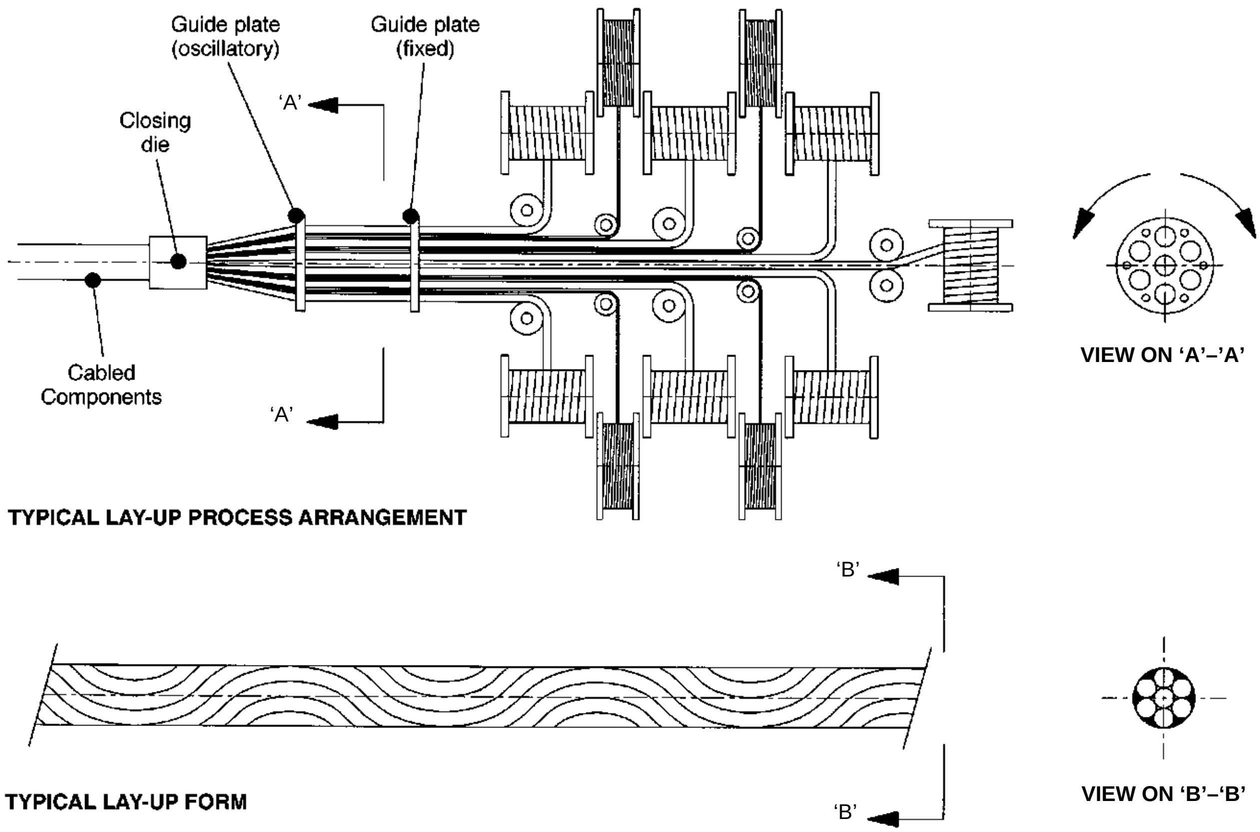


Figure D-2—Oscillatory Lay-up

APPENDIX E—UMBILICAL CONSTRUCTION

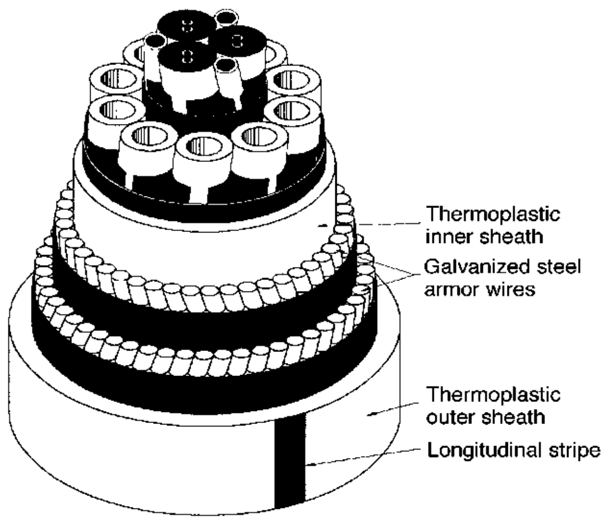


Figure E-1—Typical Umbilical with Inner and Outer Thermoplastic Sheath

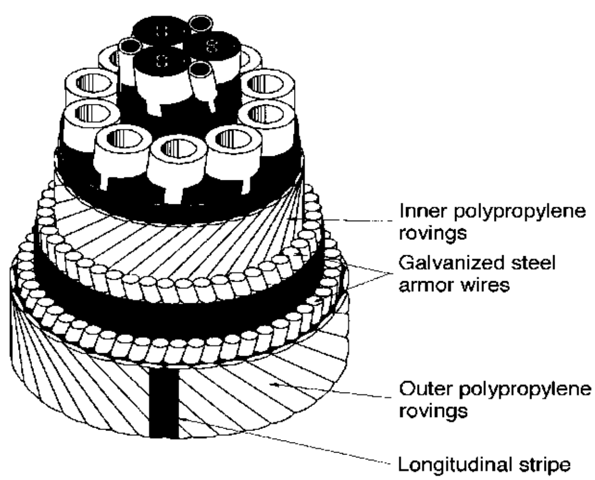
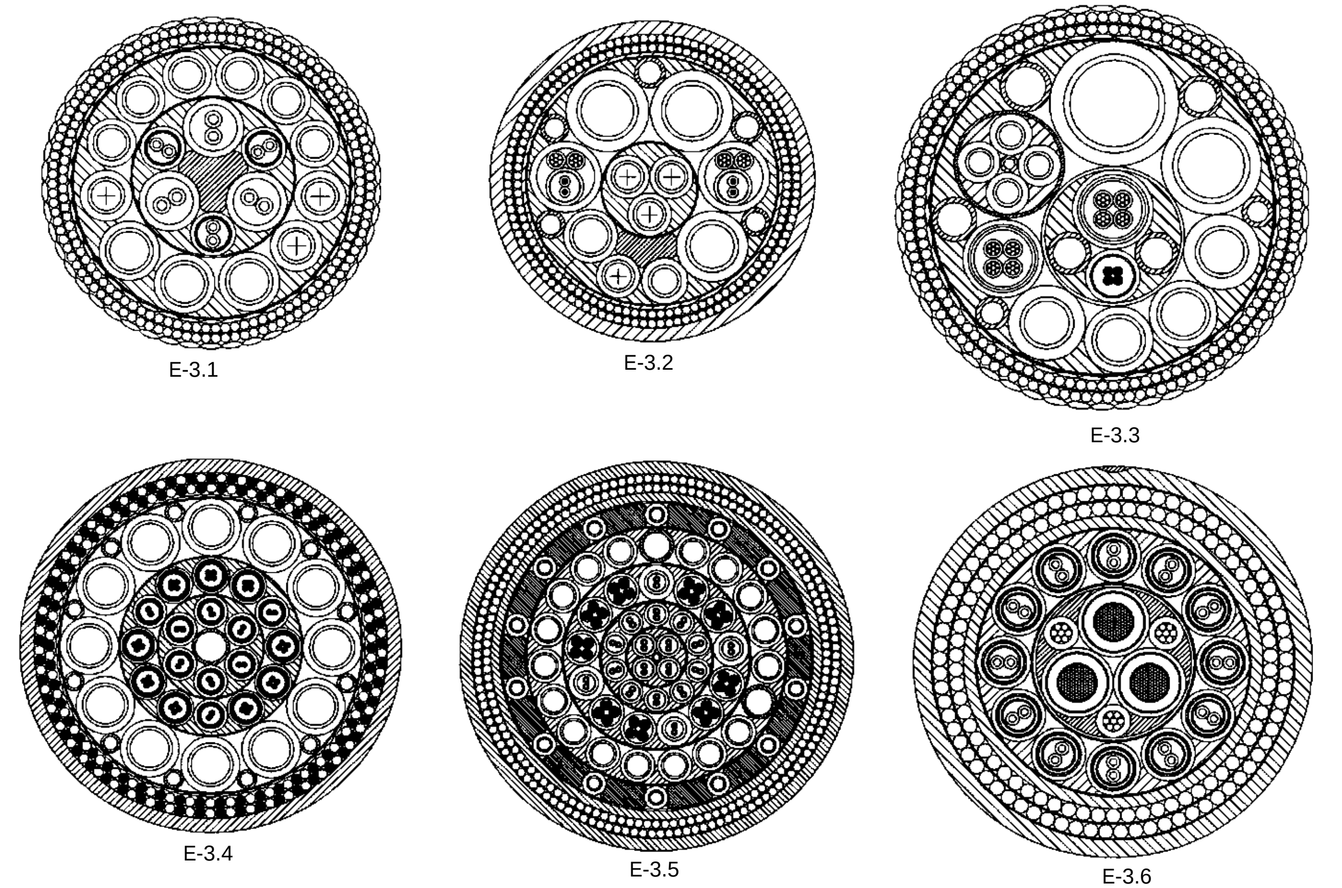
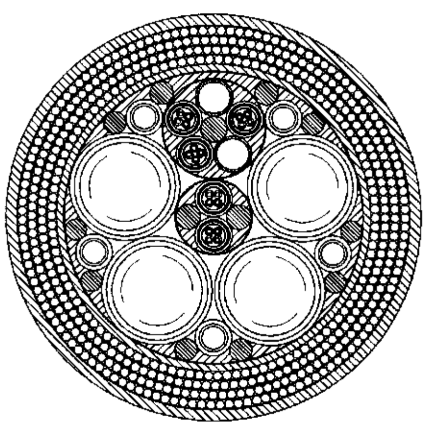


Figure E-2—Typical Umbilical with Inner and Outer Roving Sheath





E-3.7

E-3.1—Central electric cable sub-bundle, shaped central filler, symmetrical arrangement.
E-3.2—Non central electric cable elements, non sheathed hose sub-bundle, relatively symmetrical arrangement.
E-3.3—Near central electric cable sub-bundle, non central electric cable and oversheathed hose sub-bundle, non-symmetrical arrangement.
E-3.4—Central electric cable sub-bundle, alternating plastic armor rods, symmetrical arrangement.
E-3.5—Central electric cable sub-bundle, shaped fillers, symmetrical arrangment.
E-3.6—Electric umbilical with central power core sub-bundle, symmetrical arrangement.
E-3.7—Dynamic umbilical, central electric cable sub-bundle, non central electro/hydraulic sub-bundle, two additional layers of armor wire for ballast.

Figure E-3—Typical Umbilical Cross Sectional Arrangements

APPENDIX F—SCHEDULE OF TESTS TO BE PERFORMED AS PART OF THE MANUFACTURER'S QUALITY ASSURANCE PROGRAM

Table F-1—Electric Cables/Electric Cable Elements

Test To be Performed	Characterization*	Verification	Component Acceptance	Delivery † Acceptance	Umbilical Acceptance
Visual and Dimensional	-	11.3.1	12.2.1	-	-
Conductor Resistance	-	11.3.2	12.2.3	12.4.3.1 a)	12.4.4.3 a)
Resistivity of Screening Layers	-	11.3.3	-	-	-
Insulation Resistance	-	11.3.4	12.2.4	12.4.3.1 b)	12.4.4.3 b)
High Voltage DC	-	11.3.5	12.2.5	-	12.4.4.3 c)
High Voltage AC		11.3.6	-	-	-
Complete Voltage Breakdown	-	11.3.7	-	-	-
Partial Discharge	-	11.3.8	-	-	-
Inductance Characteristics	-	11.3.10	12.2.6	-	12.4.4.3 d)
Capacitance Characteristics	-	11.3.11	12.2.7	-	12.4.4.3 d)
Attenuation Characteristics	-	11.3.12	12.2.8	-	12.4.4.3 d)
Characteristic Impedance	-	11.3.13	12.2.9	-	12.4.4.3 d)
Cross-Talk	-	-	12.2.10‡	-	12.4.4.3 e)
Spark Test	-	-	12.2.2	-	-
Time Domain Reflectometry	10.2.11	-	12.2.11	-	12.4.4.3 f)

Table F-2—Hose Tests

Test To be Performed	Characterization*	Verification	Component Acceptance	Delivery † Acceptance	Umbilical Acceptance
Visual and Dimensional	-	11.4.2	12.3.1	-	-
Change in Length	-	11.4.3	12.3.4	-	-
Leakage	-	11.4.4	-	-	-
Burst–Liner	-	-	12.3.2.1	-	-
Burst–Hose	-	11.4.5	12.3.5	-	-
Proof Pressure/Decay	-	-	12.3.6	12.4.4.1 a)	12.4.4.3 a)
Impulse	-	11.4.6	-	-	-
Cold Bend	-	11.4.7	-	-	-
Collapse	-	11.4.8	-	-	-
Volumetric Expansion	11.4.9	-	-	-	-
End Fitting Anti-Rotation	-	11.4.10	-	-	-
Fluid Compatibility	-	11.4.11	-	-	-
Permeability	11.4.12	-	-	-	-
Flow Test	-	-	-	-	12.4.4.3 b)
Dynamic Response #	12.4.4.3 c)	-	-	-	-
Fluid Cleanliness	-	-	-	-	12.4.4.3 d)

Table F-3—Umbilical Tests

Test To be Performed	Characterization*	Verification	Component Acceptance	Delivery † Acceptance	Umbilical Acceptance
Visual and Dimensional	-	-	12.4.2	-	12.4.2
Tensile	-	11.5.2	-	-	-
Bend Stiffness #	11.5.3	-	-	-	-
Crush	-	11.5.4	-	-	-
Fatigue	-	11.5.5	-	-	-

Note: *These tests shall have no accept/reject criteria unless specifically stated in the Manufacturer's written specification. †These tests are to be undertaken if the components involve transportation from the component manufacturer's facility to the umbilical manufacturer's facility.‡ This test is only undertaken if the power and signal conductors are incorporated as an electric cable element or an electric cable sub-bundle (which can also include hoses) prior to incorporation in the umbilical. # Optional tests to be undertaken if specifically requested by Purchaser.

APPENDIX G—TEST METHOD FOR DETERMINING THE COLLAPSE PRESSURE OF A HOSE WHEN SUBJECT TO EXTERNAL HYDROSTATIC PRESSURE

G.1 Introduction

This test method specifies the procedure of determining the collapse pressure of a hose due to an external hydrostatic pressure. The test is designed to simulate the conditions a hose will experience in service when containing gases, or a liquid of specific gravity less than that of seawater, and to establish the pressure differential at which the hoses will collapse. The test shall be performed on loose hose and not whilst incorporated in an umbilical.

G.2 Test Set-Up

This test procedure requires the following equipment:

a. Hydraulic power supply.
b. Pressure vessel.
c. Burette.
d. Pressure transducer.
e. Strip Chart recorder.

G.3 Test Procedure

Install a sample of hose bent to its specified minimum bend radius into the pressure vessel illustrated and fill the vessel with water taking care to remove any trapped air. The sample length shall not be less than 500 mm between end fittings.

Fill the hose with water until the water reaches the lower graduation on the burette. Start the chart recorder and then raise the pressure in the pressure vessel at a uniform rate of nominally 0.5 bar (7.25 psi)/min. As the pressure increases monitor the increase in fluid volume at a small but discernible rate. When the volume rapidly increases, note this point on the chart recorder and read off the pressure. This is the pressure at which the hose has collapsed.

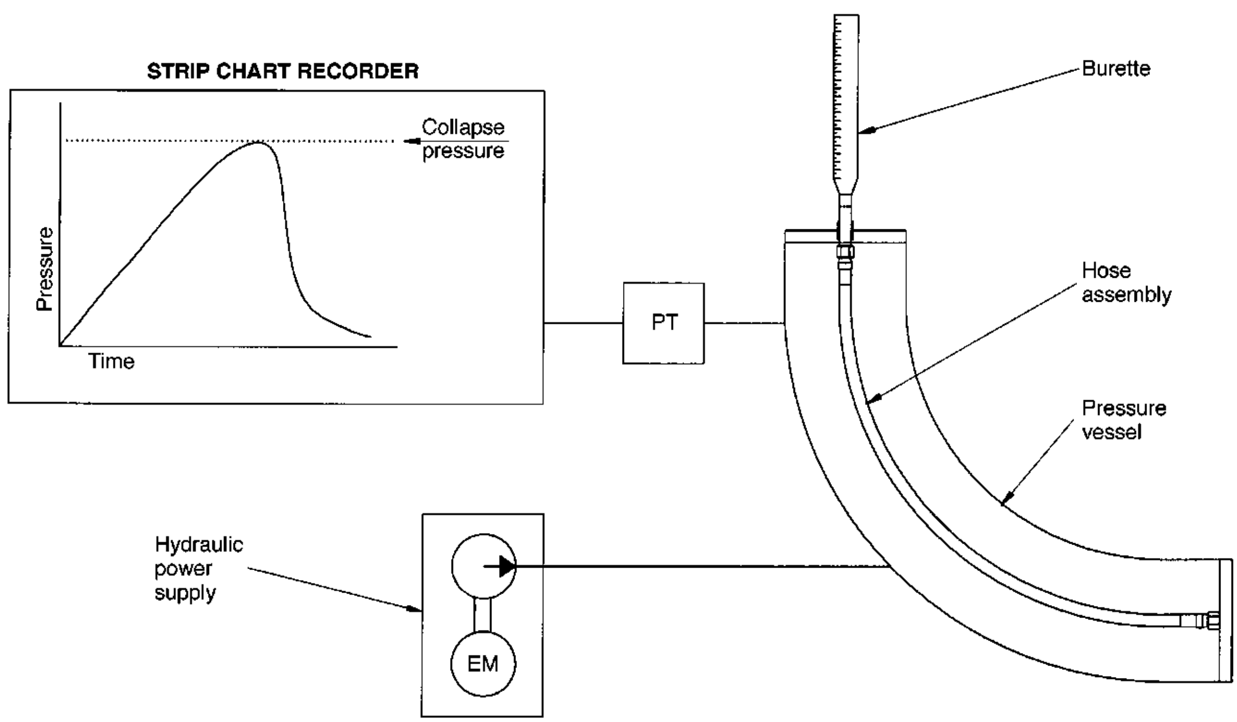


Figure G-1—Schematic Arrangement of Test Rig

Note: Loads, angles, number of cycles and periods are illustrative only. In practice they should be derived from analysis.

APPENDIX H—TEST METHOD FOR DETERMINING THE VOLUMETRIC EXPANSION OF A THERMOPLASTIC HOSE WHEN USED AS HYDRAULIC CONTROL LINE IN AN UMBILICAL

H.1 Introduction

This test method specifies the procedure of determining the volumetric expansion of thermoplastic hoses that are normally pressurized in subsea production control and SSIV umbilicals.

H.2 Test Set-Up

This test procedure requires the following equipment:

a. Hydraulic power supply.
b. Burette.
c. Pressure transducer.
d. Isolation valve.
e. Control valve.
f. Bleed valve.

H.3 Test Procedure

Test samples shall not be less than 3 m in length between end fittings and shall not be tested within 24 hours of completion of manufacture of the hose. Prior to undertaking volumetric expansion measurements, the hose shall be preconditioned by pressurizing the sample with water or other incompressible and compatible fluid to the maximum working pressure. The maximum working pressure shall be maintained for a period of 5 days and during this period, the pressure shall be lowered to atmospheric pressure and returned to the maximum working pressure once per day. After completing the 5 day pressure cycle, the sample shall be tested for volumetric expansion three times within 48 hours using the following procedure, and the pressure ranges selected, starting at the highest pressure.

Define the pressure range for the volumetric expansion measurement, from the maximum working pressure down to nominally 10% of the maximum working pressure. The pressure steps shall be in 70 bar (1,000 psi) decrements down to the nominally 10% maximum working pressure level with two equally spaced decrements in the 10% to 0% pressure range.

Connect the test assembly between the test manifolds taking care not to introduce twist into the hose. The system and test sample shall be filled with water or other incompressible and compatible fluid and purged to eliminate any entrapped air.

1 hour (± 5 minutes) before measuring the volumetric expansion, pressurize the test sample to the maximum working pressure (± 5%) at a uniform rate of pressure rise and ensure the fluid level is set correctly in the burette.

On reaching the maximum working pressure, open control valve (B) and allow the hose to depressurize into the burette in a controlled manner, until the first pressure level is reached. Close the control valve (B) and record the displaced volume in the burette.

Repeat the procedure for the remaining predetermined pressure levels allowing a period of 45 seconds (± 5 seconds) to elapse between each stage of depressurization. If necessary, withdraw fluid so as to maintain the pressure at the selected level. When commencing the final reduction to atmospheric pressure, a set period of 45 seconds (± 5 seconds) shall be observed before closing control valve (B), thus preventing further fluid from entering the burette. The volumetric expansion measurements shall be recorded within 5 seconds of reaching the defined incremental measurement level.

The measured results taken from the burette readings may be expressed as either, True Volumetric Expansion (TVE), or Apparent Volumetric Expansion (AVE), in terms of cm^3/m (in3/ft) or percentage volume change.

AVE is the volume of fluid collected in the burette, **without correction**. That is, by not subtracting from the measured result, the calculated volume change of the test fluid for the same pressure changes. TVE is the value of fluid collected in the burette in **which corrections have been made** so that the measured volume change applies to the hose structure only.

Note: The specifying of a time period to measure the fluid displacement from the hose sample is needed to systematically account for the viscoelastic behavior of the hoses. The bulk of the fluid will escape from the hose in a few seconds. However, the amount still leaving the hose at any reasonable time is not zero. There will be a difference in volumetric expansion measurements measured over short and long time intervals. A set of volumetric expansion measurements made with significantly differing drainage times from data point to data point will have poor repeatability. A slight difference in the slope of the volumetric expansion vs. pressure curves is likely depending on the drainage time used. Therefore, in order to make comparable measurements, and to achieve the best volumetric expansion measurement accuracy, a fixed drainage time must be used.

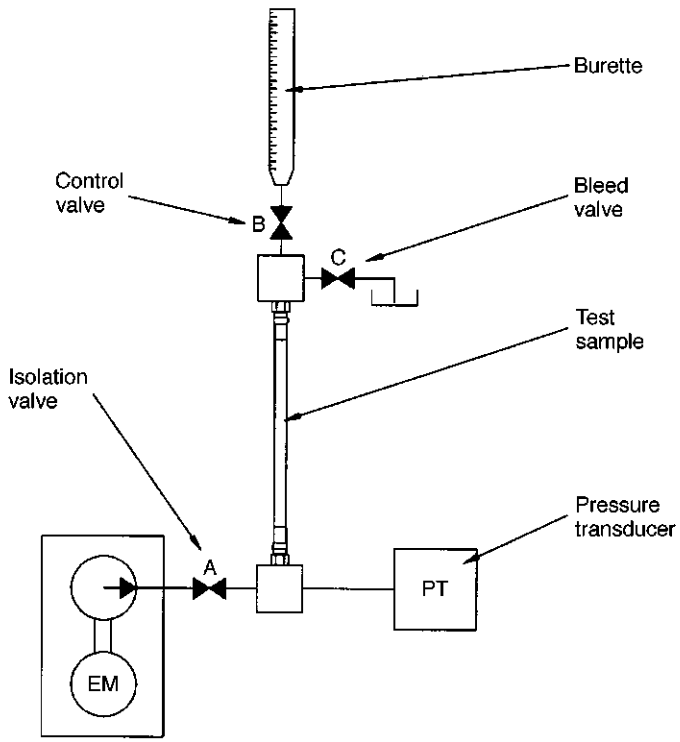


Figure H-1—Schematic Arrangement of Test Rig

APPENDIX I—FATIGUE TESTING

The test regimes shall be as per the Manufacturer's written specification taking account of installation and service parameters. The testing shall be designed so that in conjunction with analysis the required design life will be demonstrable, with a suitable margin of safety.

An umbilical intended for static service after installation shall be verified by demonstrating that the design can withstand the loads and flexures experienced primarily during the installation process. Normally, the most critical area is when the umbilical is over-boarded during installation and may be exposed to high tensile loads and repeated flexure during the deployment. (Reference Fig I-1). It is however important that thorough analysis is carried out to confirm that the most critical area is identified.

The test regime selected shall demonstrate that the umbilical will satisfy these requirements for an agreed duration, and/or minimum number of load cycles as stated in the Manufacturer's written specification.

If it is shown that flexing is the critical regime, testing to determine the fatigue resistance during installation deployment would be based upon a representative sample of umbilical being repetitively flexed to a predetermined radius and straightened while subject to tension by means of an applied load. The applied load and flexing frequency shall be representative of the predicted installation conditions. The sample shall withstand the specified number of flexures without impairing the umbilical functionality, or component failure. Where components have been bundled using the oscillatory method, the region of umbilical that will be subject to flexing shall include changes of direction in the components.

Table Examples of fatigue test configurations which may be suitable for this fatigue condition are illustrated in Figs I-2 and I-3. Alternatively, the Manufacturer may demonstrate the suitability by means of mathematical model analysis which has been verified by comparing the theoretical calculations to the actual physical measurements and/or historical data.

An umbilical intended for dynamic service after installation shall be verified by demonstrating that the design can sustain the loads and flexures that will be imposed on the umbilical throughout its operational life.

Depending on the installed configuration, typically as illustrated in Figs I-4 and I-5 and host vessel motions, the umbilical may be subject to a whole spectral range of flexure conditions which may cover one or more of the following:

a. High axial load with low angles of flexing.
b. Low axial load with high angles of flexing.
c. High axial load with high angles of flexing.
d. Low axial load with low angles of flexing.

Note: For shallow water installations, low axial loads with high angles of flexing at the vessel hang-off are to be expected. For deep water installations, high axial loads with low angles of flexing at the vessel hang-off are to be expected. The other conditions may occur as a result of the installed configuration e.g. mid water buoy. As a result of these factors, a dynamic umbilical may be exposed to a wide range of environmental variables and test regimes shall take account of such variables. The effect of such variables on the axial load within the umbilical and the degree of flexure are normally determined by analysis of the installed system. From this analysis it is possible to develop a test matrix in respect of defined fatigue motions. (See example provided in Table I-1).

Note: The results of the analysis may show a significant number of flex cycles occur at very low levels of angular deflection. At such levels of deflection, the cyclic stress levels in the electrical conductors and armor wires may be so low that they cannot be observed on their SN curves. In these situations, the necessity to perform fatigue testing at such low angles should be considered. The selected test regime should, however, as a minimum, impart the same level of potentially damaging fatigue stresses to the umbilical as it is expected to withstand during its operational life.

To verify the fatigue performance of the umbilical at the vessel exit region, the umbilical should be subject to a bending under tension at a built-in end fitting test. This test is illustrated typically in Fig I-6. Where the in-service built-in end fitting incorporates a bend stiffener or other means of strain relief, a stiffener or strain relief device of the same design should be incorporated in the test sample.

Table I-1—Typical Test Matrix for Flex Fatigue Testing of a Dynamic Umbilical

Test Block	Load (tones)	No of Cycles	Deflection (degrees)	Period (seconds)	Duration (days)
A	5	1.45×10^6	+/-2	4	66.7
B	26	5.1×10^5	+/-3	4	23.5
C	28	4×10^5	+/-4	5	23.0
D	30	2.5×10^5	+/-5	6	17.3
E	32	1.7×10^5	+/-6	8	15.6
F	35	2.15×10^5	+/-8	10	24.7
G	40	2,500	0 -> + 10	10	0.3
H	40	2,500	0 -> -20	10	0.3
Total		3×10^6			5.7 months

Note: NB, Loads, angles, number of cycles and periods are illustrative only. In practice they should be derived from analysis.

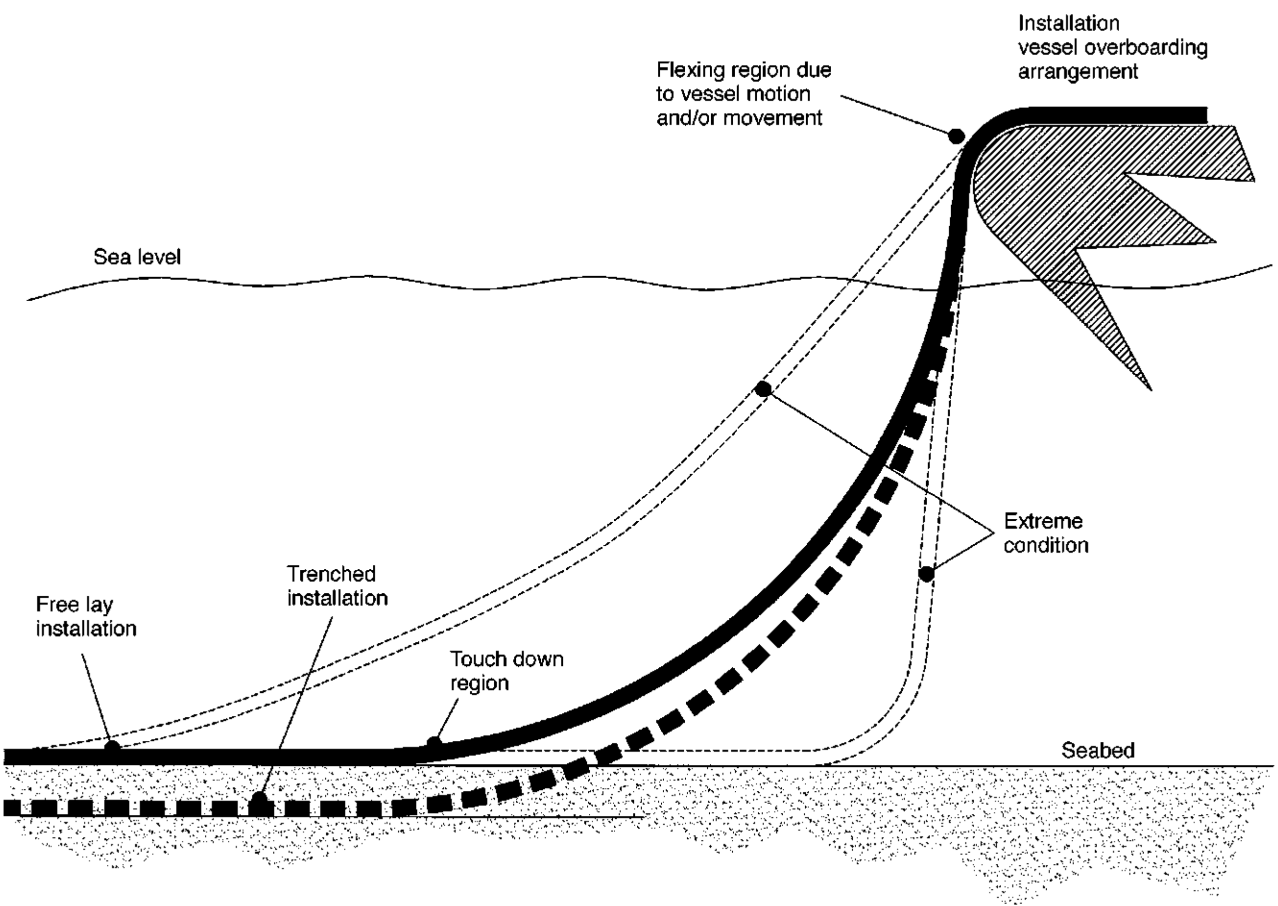


Figure I-1—Typical Umbilical Installation Deployment Arrangement

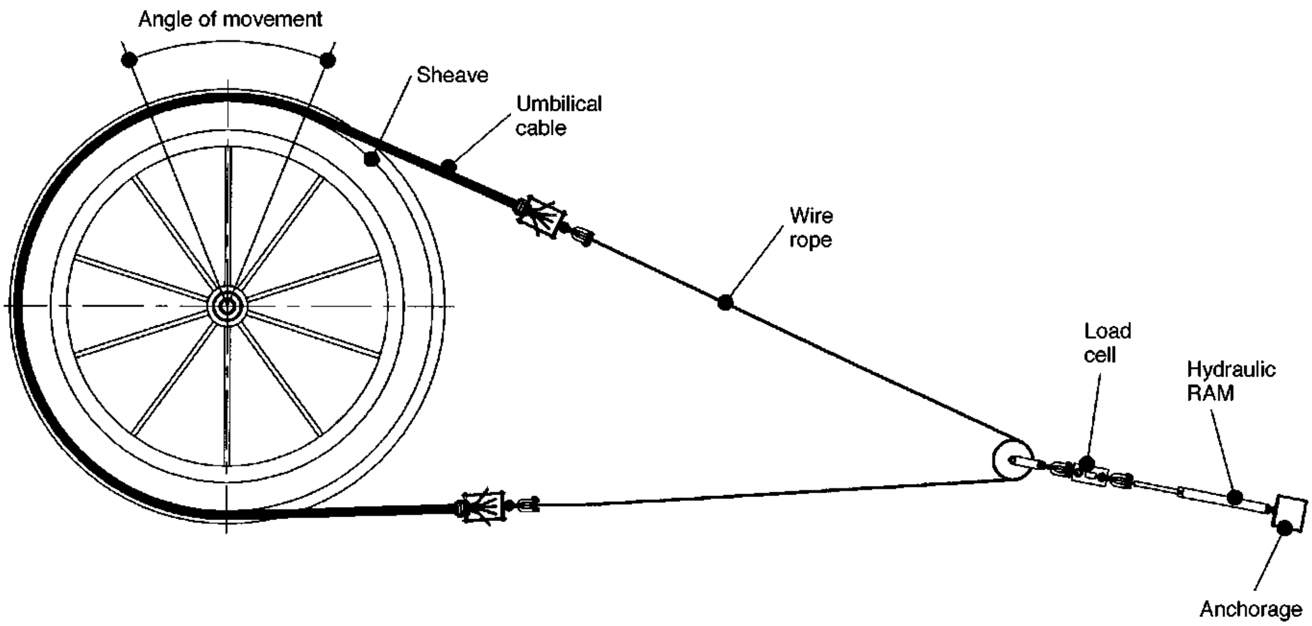


Figure I-2—Typical Arrangement for Fatigue Testing an Umbilical Around an Oscillating Sheave

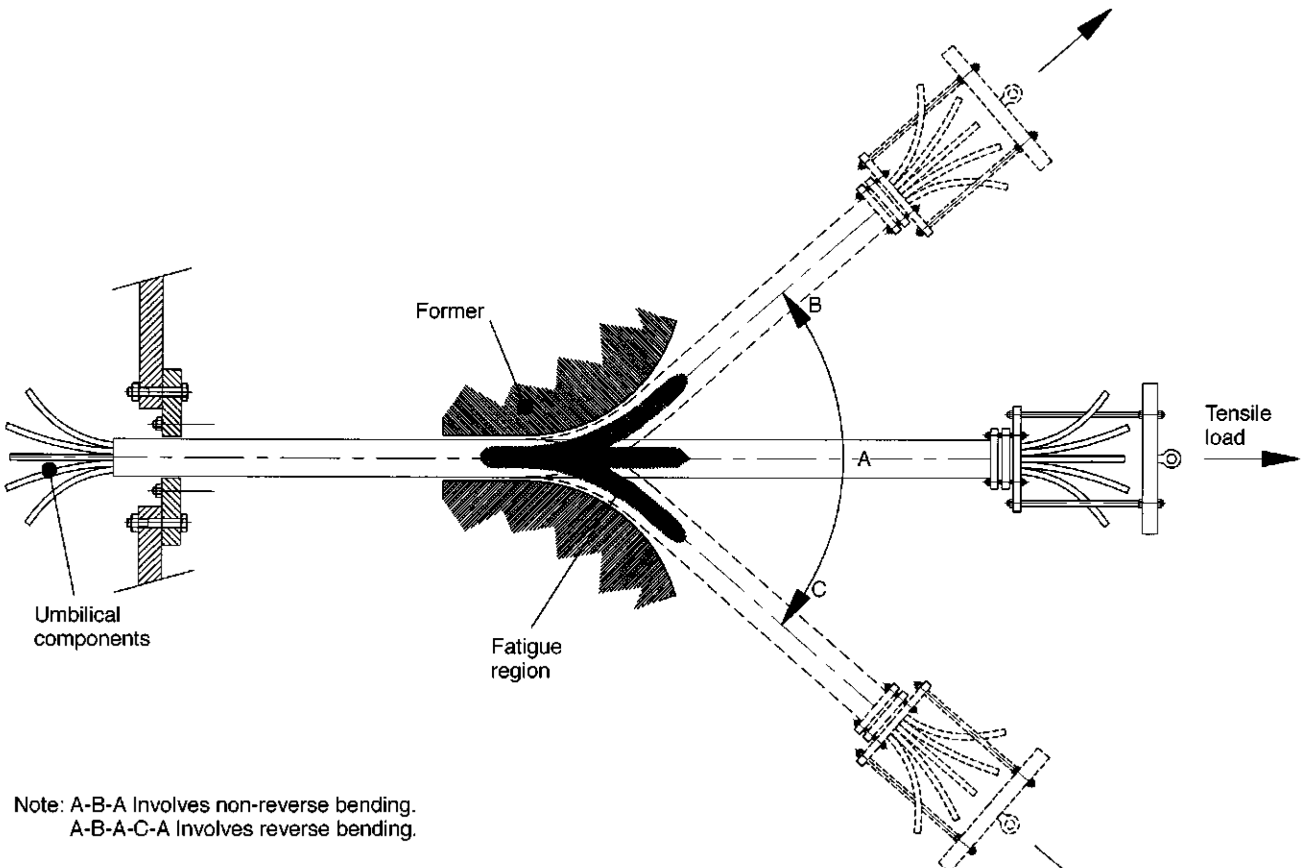


Figure I-3—Typical Arrangement for Fatigue Testing an Umbilical Against a Former

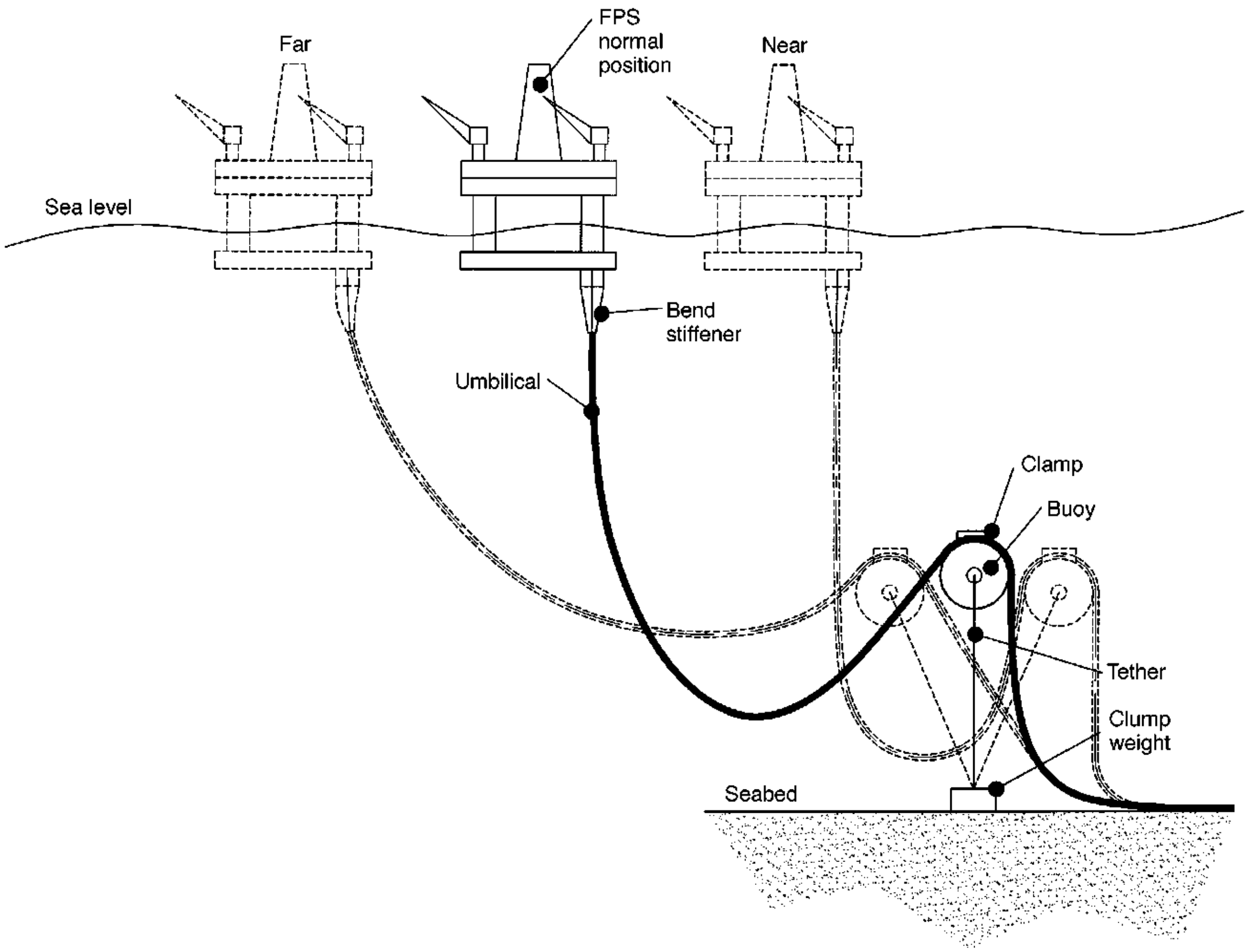


Figure I-4—Typical Installed/Excursion Configuration for an Installed Dynamic Umbilical — Shallow Water

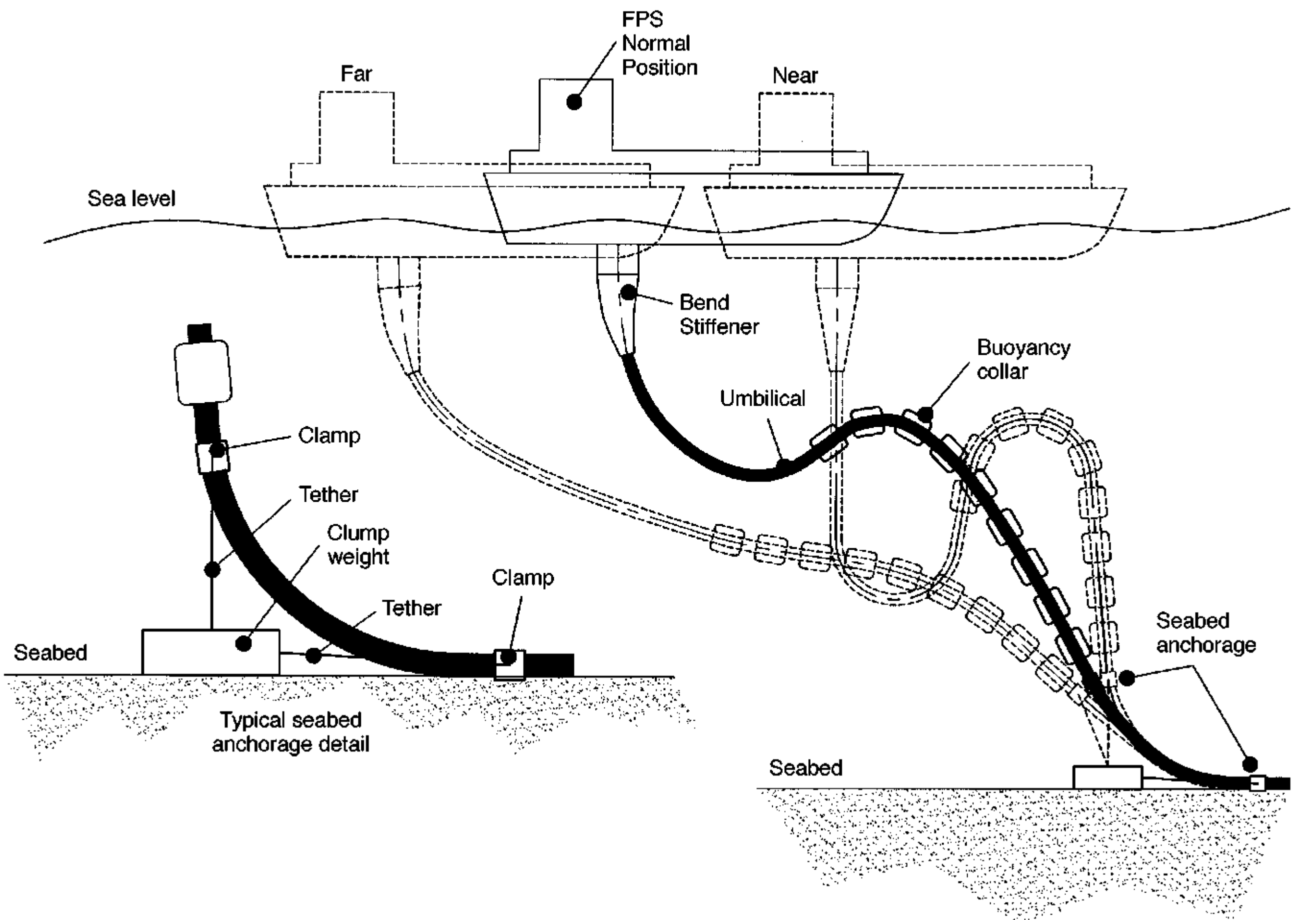


Figure I-5—Typical Installed/Excursion Configuration for an Installed Dynamic Umbilical — Deep Water

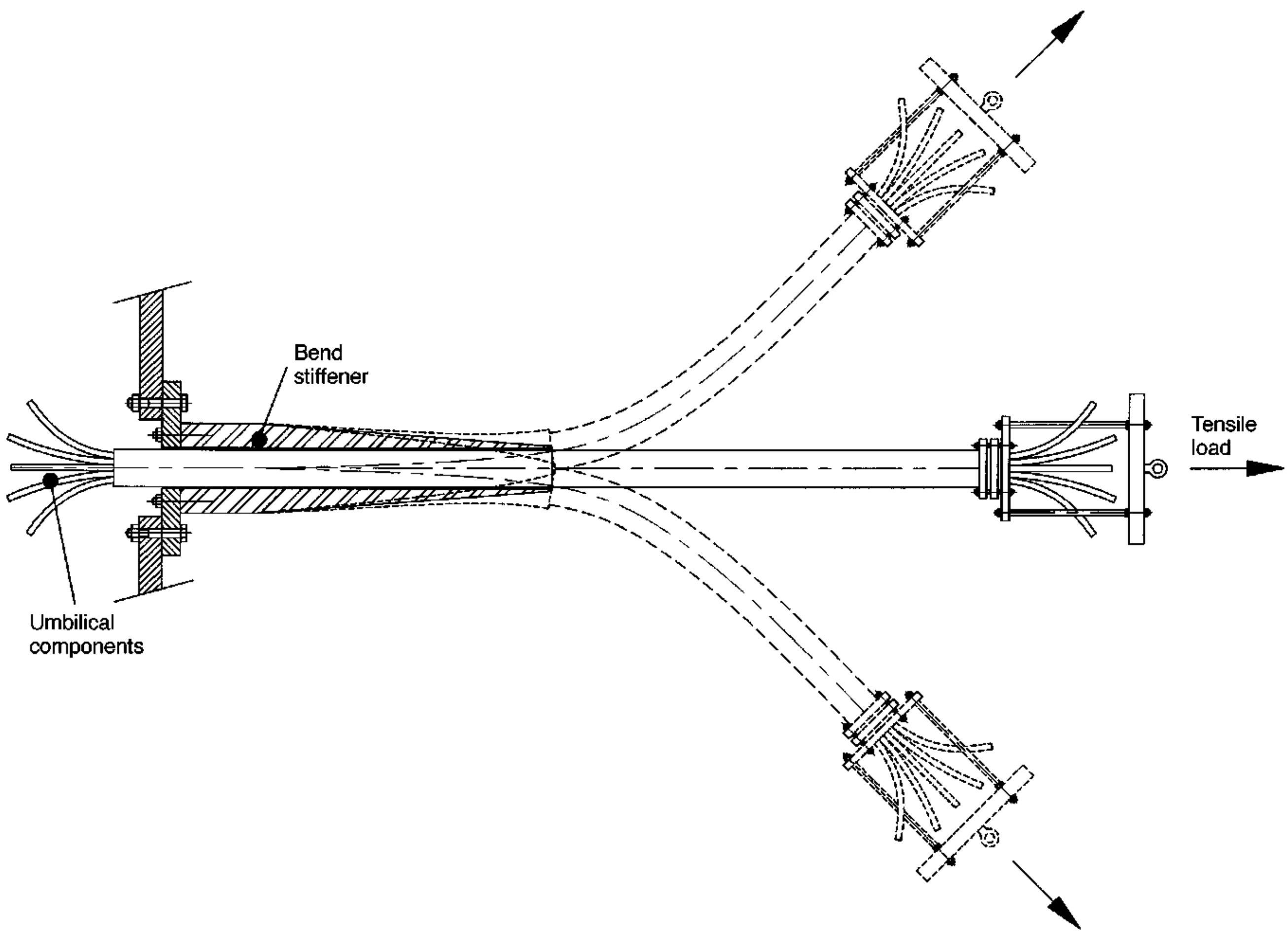


Figure I-6—Typical Test Arrangement for Subjecting an Umbilical to Bending Under Tension at a Built-in End Fitting

APPENDIX J—TEST METHOD FOR DETERMINING THE DYNAMIC RESPONSE OF THERMOPLASTIC HOSES WHEN USED AS HYDRAULIC CONTROL LINES IN UMBILICAL STABLE

J.1 Introduction

This test method specifies the procedure for determining the dynamic response characteristics of a thermoplastic hose. The test is designed to simulate emergency shut-down of subsea equipment and provides information for the simulation of hydraulic performance. The test shall be performed on the specified hose(s) in the completed umbilical when stored on a reel or carousel.

J.2 Test Set-Up

This test procedure requires the following equipment:

a. Hydraulic power supply.
b. Two pressure transducers.
c. Strip Chart recorder.
d. One valve (charge).
e. One rapid action valve (vent).
f. Reservoir tank.

The test arrangement is shown schematically in Fig J.1.

J.3 Test Procedure

The following procedure shall be repeated twice for each nominated hydraulic control hose in the umbilical.

The nominated hoses within the umbilical shall be connected in turn to the hydraulic supply and filled with the specified control fluid. The vent valve and jumper hose connecting the vent valve to the vent fluid reservoir tank shall be sized to offer minimal resistance to the discharge flow.

Alter bleeding air from the hose, close the full-flow vent valve at the remote end of the umbilical. Pressurize the hose to the maximum working pressure, with the rate of pressure rise and decay no greater than 10 bar (150 psi) per minute, and allow the pressure to stabilize for 5 minutes ± 10 seconds. Re-pressurize the hose to the maximum working pressure and again allow the pressure to stabilize. Repeat this procedure until the pressures at ends A and B of the hose remain within 2% of each other, and within 5% of the maximum working pressure, for a period of 5 minutes ± 10 seconds.

At the end of the final stabilization period and with the charge valve closed at the supply end of the umbilical and the recorder running, rapidly open the vent valve.

The recorder should remain running until the pressure at A is within 1% of the pressure at B or the pressure at A no longer continues to fall.

The air temperature and test fluid temperature shall be recorded.

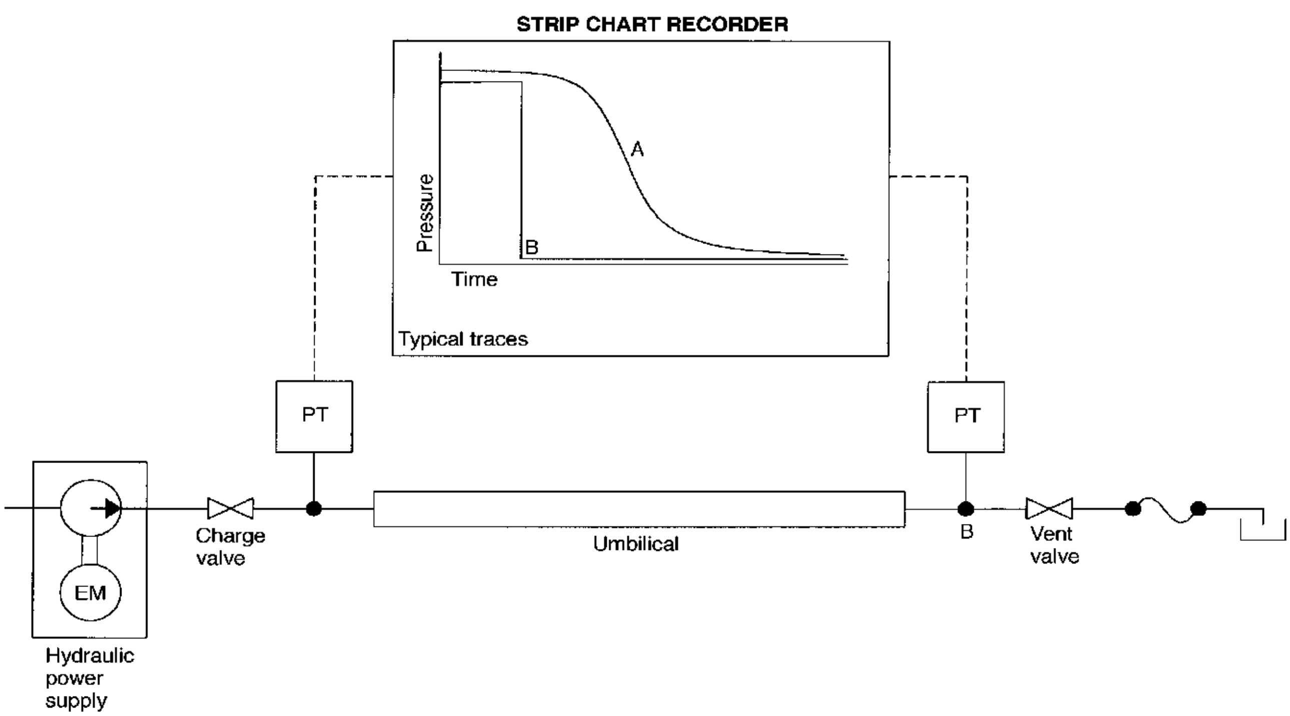


Figure J-1—Schematic Arrangement of Test Set Up for Determining Dynamic Response

PE-01300—2/98—5C ( )

Additional copies available from API Publications and Distribution: (202) 682-8375

Information about API Publications, Programs and Services is available on the World Wide Web at: http://www.api.org

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

Order No. G17E02