

Installation Guidelines for Subsea Umbilicals

API RECOMMENDED PRACTICE 17I
FIRST EDITION, AUGUST 1996

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Installation Guidelines for Subsea Umbilicals

1 Scope

This document provides guidelines for the handling, storage, and installation of permanently installed umbilicals for subsea use in both static and dynamic applications. The systems may either be platform–subsea, platform–platform, or subsea–subsea. This recommended practice is based on umbilicals that comply with the requirements of API Specification 17E.

The umbilicals may have any number of individual cores that may carry electrical services (power or signal), fiber optic communications (single-mode or multi-mode), hydraulic or chemical functions, or any combination of these.

These guidelines set out the framework within which more detailed specifications and procedures must be produced to address the particular features of specific installations as defined within a client's scope of work. It is essential that such detailed specifications clearly define who is responsible for the satisfactory handling of the umbilical at each stage of the operations; this will depend on the nature of the contract(s) into which the relevant parties (normally the client, the umbilical manufacturer, and the installer) have entered. These guidelines indicate what needs to be taken into account and some possible approaches that may be taken. It should be noted however, that the inclusion of a particular approach within the document does not imply it is the only possible approach. Other approaches may be more suitable; this depends on the skills and equipment of the installation contractor. The installer and client shall agree in writing, during the initial arrangements, where, why, and how deviations from this document are permitted.

Throughout these guidelines, the words *should* and *shall* have the following specific meanings: *should* indicates a preferred course of action; *shall* indicates a mandatory course of action.

2 References

2.1 STANDARDS

Unless otherwise stated by the client, the following codes, standards, and guidance notes should be considered as part of this guideline.

The latest edition of each should apply. Harmonized Documents (HD), when available, should be used instead of British Standards (BS).

IEC¹

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

ISO²

- 1402 *Rubber and Plastics Hoses and Hose Assemblies-Hydrostatic Testing*

¹International Electrotechnical Commission, 3, rue de Varembe, Case postale 131, CH-1211 Genève 20, Switzerland.

²International Organization for Standardization, 1, rue de Varembe, Case postale 56, CH-1211 Genève 20, Switzerland.

4406 *Hydraulic Fluid Power-Fluids-Method for Coding Level of Contamination by Solid Particles*

2.2 OTHER REFERENCES

Including but not limited to:

- Classification Society Rules and Requirements
- Flag of Registry Regulations
- International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL)
- International Convention of Load Lines, 1966
- International Convention of Safety of Life at Sea (SOLAS), 1974 containing 1983 Amendments
- International Rules for the Prevention of Collision at Sea
- International Telecommunications Union Radio Regulations, 1976 (ITU Geneva)

3 Definitions and Abbreviations

3.1 DEFINITIONS

For the purpose of this standard, the following definitions apply:

3.1.1 armoring: One or more layers of helically applied wires surrounding the laid-up functional components of an umbilical that provide mechanical strength, protection, and ballast to the umbilical. The wires may be galvanized or plastic coated steel or other suitable material.

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

3.1.3 bellmouth: A flared opening on the bottom of the J-tube.

3.1.4 bend restrictor: A device for limiting the bend radius of the umbilical, usually by mechanical means, and typically comprised of a series of interlocking metal or molded rings. That is also known as a *bend limiter*.

3.1.5 bend shoe: A rigid former shaped as a sector of a circle. It ensures that the minimum bend radius of the umbilical is not infringed, particularly when overboarding umbilical during second end I or J-tube pull-ins. That is also known as an arch or *overboarding chute*.

3.1.6 bend stiffener: A device for limiting the bend radius of the umbilical by providing a local increase in bending stiffness. This is usually a molded device, sometimes reinforced depending on the required duty. This is sometimes known as a *bend strain reliever*.

3.1.7 birdcaging: A compressive instability of the armor wires, which causes them to increase their pitch circle diameter locally.

3.1.8 bullnose: See pull-in head (3.1.48).

3.1.9 cable: A generic term used to describe a bundle of insulated electrical conductors or optical fibers. Can also be used in place of the term *umbilical*.

3.1.10 cable engine: A device for tensioning and paying out cable.

3.1.11 capacitance: A measurement of the electrical cable's ability to store electrostatic charge. This is measured in Farads.

3.1.12 carousel: A storage container that can be rotated by a drive about a vertical axis. It incorporates an inner core structure and an outer peripheral structure, both of which support the umbilical. The umbilical is stored at nominally zero tension. Carousels that do not have a structure on their outer periphery to support the umbilical are often known as turntables.

3.1.13 caterpillar: Form of cable engine in which the umbilical is held between two belts.

3.1.14 Chinese finger: Type of gripper or stopper to hold the umbilical via its outside diameter; comprised of a number of spirally interwoven wires attached to an eye. Other types include *Siemens Stoppers*, *Chain Stoppers* and *BT(M) Stoppers*.

3.1.15 Chinese lantern: A configuration for a dynamic umbilical.

3.1.16 client: The company which has a contract with the installer for the installation of the umbilical.

3.1.17 communication cable: See signal cable.

3.1.18 conductor: The part of the cable along which electricity can travel. It is manufactured from conductive material, such as copper, in either stranded, multi-bunched, or solid form.

3.1.19 connector: A device used to join two electrical cables or two optical units.

3.1.20 coupling: A device used to join two hose lengths.

3.1.21 crossing: The means by which an umbilical crosses an exposed pipeline.

3.1.22 cross-talk: The measurement of noise induced in a signal cable due to an adjacent power cable. This is measured as a power ratio in two ways:

- a. Differential Mode—measured difference between signal pair.
- b. Common Mode—measured with one signal line grounded, that is, measured between one signal line and ground.

3.1.23 DC conductor resistance: Resistive value of the electrical conductor. Measured in ohms.

3.1.24 design working load: Maximum tensile load at which the umbilical functionality is unimpaired.

3.1.25 end fitting: An attachment secured directly to the end of a hose incorporating one-half of a metal-metal seal, used to enable connection of the hose to another piece of equipment. See also coupling (3.1.20).

3.1.26 factory acceptance test: The test series carried out on the complete umbilical system and normally witnessed by the client at the manufacturer's premises as soon as practicable after manufacture is complete. The results of these tests are submitted to the client for approval.

3.1.27 harmonized document: Documents intended for international use, particularly those that have been ratified by the appropriate international bodies.

3.1.28 hose: A flexible pipe that can perform functions similar to a rigid pipe and withstand repeated flexure at small radii without adverse effects.

3.1.29 hose assembly: A length of hose with end fittings installed at each end.

3.1.30 I-tube: A vertical pipe attached to the platform structure through which an umbilical can be routed.

3.1.31 inductance: A measurement of electromagnetic force induced within the electrical cable. This is measured in Webers per ampere and has a SI derived unit of Henry.

3.1.32 installer: The organization responsible for the installation of the umbilical.

3.1.33 insulation resistance: The resistance in ohms of a conductor's insulation when a constant DC potential is applied across the cable insulation.

3.1.34 J-tube: A vertical pipe from the seabed to the platform topsides through which an umbilical can be routed. It begins just above the mudline and includes a bend at the bottom end (for which it is named).

3.1.35 J-tube seal: A device for sealing the annular space between the umbilical and the wall of the J-tube.

3.1.36 joint: A means of joining together two lengths of umbilical. This is also known as a joint box, splice box, or repair joint.

3.1.37 kilometer point: The distance along the route as laid.

3.1.38 manufacturer: The manufacturer of the umbilical or its component parts.

3.1.39 manufacturer's written specification: Specification of umbilical and umbilical components supplied by the manufacturer to the client or installer.

3.1.40 maximum working pressure: The maximum pressure, in bar (gauge), at which the hose is rated for continuous operation. The operating pressure for a system may be lower or equal to, but not greater than, the maximum working pressure.

3.1.41 minimum bend radius: The minimum radius of curvature, measured from the outermost diameter on the inside of the bend to the center of the bend. The stated value may alter in differing phases of the installation operation, for example, storage, laying, trenching, and burial.

3.1.42 operating pressure: The highest internal pressure at which a hose shall be used in service.

3.1.43 optical time domain reflectometry: A fault finding test which uses pulse echo techniques to locate breaks or significant change in attenuation of optical fibers.

3.1.44 plough: Equipment, surface towed, for burying umbilicals.

3.1.45 polarization index: Ratio of electrical resistance measured at 10 minutes and 1 minute; used as a method for assessing the quality of insulation.

3.1.46 power cable: Cables designed to transmit AC power at electrical transmission voltages up to and including standard rated voltages $U_o/U(U_m) = 6/10(12)$ kV rms

3.1.47 powered sheave: A sheave wheel that has a means of being driven, used for transferring the umbilical.

3.1.48 pull-in head: A device used for terminating the end of an umbilical, so that it can be pulled up a J- or I-tube. In some designs the terminated armors may then be used to anchor the umbilical above the J- or I-tube. It is normally a streamlined cylindrical housing into which the umbilical armouring is terminated and within which the ends of the service lines are contained. It can be rapidly disassembled to access the services for post pull-in tests and monitoring. A form of pull-in head may also be used at the subsea end of the umbilical. That is also known as a *bullnose* or a *pulling head*.

3.1.49 reel: A device for storing umbilicals, also known as a drum. It is comprised of two flanges, separated by a barrel, with the barrel axis normally being horizontal.

3.1.50 sheath: Any covering of the laid-up components by a layer of metallic, or polymeric, impervious, or non-impervious material.

3.1.51 signal cable: Cable elements transmitting electrical control and communication signals up to and including standard rated voltages $U_o/U = 0.6/1$ kV rms. This is sometimes called *telecommunication* or *telecom cable*.

3.1.52 stab plate connector: A multiway connector having a number of protruding pins, each carrying a sepa-

rate service. It mates simultaneously with corresponding sockets in the other half of the connector when the two halves are pulled together, usually by clamping screws.

3.1.53 supplier: Company that supplies raw materials, fluids, or component parts.

3.1.54 time domain reflectometry: A fault finding test which uses pulse echo techniques to locate breaks or significant change in impedance of electrical conductors.

3.1.55 trencher: Self-propelled equipment for burying umbilicals. This can utilize disk cutters, chain cutters, plow shares, or jetting techniques.

3.1.56 turntable: Similar to a carousel (q.v.) but lacking an outer peripheral structure.

3.1.57 ultimate tensile strength: The tensile force at which the umbilical parts.

3.1.58 umbilical: Collection of hoses, electrical conductors, and/or optical fibers designed for subsea use.

3.1.59 weak link: A device used to ensure that the umbilical parts at a specified load.

3.1.60 webbing stop: A device used to grip or lift umbilicals, consisting of one or more bands of webbing.

3.1.61 U : The rated rms power-frequency voltage between two conductors for which cables and accessories are designed.

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

3.1.63 U_m : The maximum rms power-frequency voltage between two conductors 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.

3.2 ABBREVIATIONS

3.2.1 AC: alternating current.

3.2.2 BS: British Standard.

3.2.3 DC: direct current.

3.2.4 DP: dynamic positioning.

3.2.5 DPS: dynamic positioning system.

3.2.6 FAT: factory acceptance test.

3.2.7 IEC: International Electrotechnical Commission.

3.2.8 ISO: International Standards Organization.

3.2.9 kV: kilovolts.

3.2.10 LAT: lowest astronomical tide.

3.2.11 OTDR: optical time domain reflectometer.

3.2.12 pC: picocoulombs.

3.2.13 rms: root mean square.

3.2.14 ROV: remotely operated vehicle.

3.2.15 TDR: time domain reflectometer.

3.2.16 V: volts.

4 Quality Assurance

4.1 QUALITY ASSURANCE SYSTEM

The installer shall have a recognized quality assurance system.

The quality assurance system shall include, at a minimum, the following requirements:

- a. Definition of personnel responsibilities and project organization.
- b. Certification of all handling equipment.
- c. Inspection of installation operations.
- d. Pre- and post-lay testing.

4.2 QUALITY PLAN

The installer shall prepare a detailed quality plan which describes how to apply the quality system to ensure that the contracts requirements will be met. An audit plan shall be described together with the procedures to be used for identifying any non-conformances and their causes, documenting the findings, and implementing actions to prevent recurrence.

The quality plan shall ensure the adequate and documented control of all work performed under the contract.

The quality plan shall provide for the identification and acquisition of the personnel resources, skills, equipment, and inspection or testing techniques that will be needed to achieve the required quality.

The quality plan shall ensure that any measuring equipment is adequately calibrated to traceable standards.

The quality plan shall ensure the preparation and client approval of documented installation inspection plans and test plans. These plans describe where inspections or tests occur in the work program and include the related procedures and acceptance criteria against which these actions are to be carried out. The plans shall have a suitable format for the installer, client, and any certifying authority to indicate their surveillance requirements and their carrying out of that surveillance, for example, witness or monitor, against each task. The method of advising the client of the timing of such activities shall be indicated, along with the lead time.

The quality plan shall describe the procedures that shall be used to ensure that all work carried out by subcontractors employed by the installer is in accordance with all the installer's applicable requirements.

The quality plan shall ensure that all quality related records, test, calibration and inspection data which are required to be produced shall be systematically compiled, indexed, filed, and maintained to allow ready access for retrieval and review.

4.3 SAFETY PLAN

A safety plan shall be produced to ensure the planned operations necessary for the installation are carried out safely. Care shall be taken that the plan addresses the issues raised by any risk assessment and the resulting contingency procedures.

5 Umbilical Storage

5.1 INTRODUCTION

Upon satisfactory completion of all umbilical factory acceptance tests, the umbilical shall be stored under cover on either a carousel, or a reel, or coiled into a storage tank until load-out is undertaken. The umbilical shall not be stored in direct sunlight.

5.2 METHODS OF STORAGE

Storage at the manufacturer's facility, or elsewhere, can be undertaken in a number of different ways, depending on the umbilical design, weight and length. When choosing the storage method, consideration should be given to the following, as a minimum:

- a. Umbilical handling parameters:
 1. Weight and length.
 2. Minimum bend radius.
 3. Crush limitations.
 4. Reeling geometry.
 5. Size/weight of reels if stored product is to be moved.
- b. Terminations:
 1. Rigid length.
 2. Weight.
 3. Need for bend stiffeners/limiters.
- c. Necessity to monitor and test the umbilical, including handling and transportation for integration testing.
- d. Protection from accidental damage, for example, by dropped objects or moving vehicles.
- e. Necessity to protect the umbilical from temperature extremes.
- f. Site location, for load bearing and access considerations.

5.3 PROTECTION OF UMBILICAL SERVICES

5.3.1 Hydraulic Services

In the case of umbilicals containing hoses, each hose shall be filled with the fluid specified in Section 10, and the hose ends shall be capped off. The hoses shall be pressurized to 70 bar (gauge) unless otherwise specified in the manufac-

turer's written specification, and the manufacturer shall log the pressure in each hose string on a weekly basis until load-out. Any pressure variations logged which cannot be accounted for by temperature variation shall be further investigated and documented.

5.3.2 Electrical Services

Electrical cores, if present, shall be capped off and sealed to avoid water ingress.

5.3.3 Optical Fibres

Optical fiber tails, if present, shall be suitably protected to avoid any possibility of water ingress or mechanical damage.

5.4 SPARE LENGTH

A spare length may be delivered as a separate item or may be part of the total umbilical as an overlength. The precautions described in Section 5.3 shall be applied to the spare (or over) length. The remaining length shall be clearly and indelibly marked with the project title and the length on the reel.

5.5 REPAIR KITS

Any repair kits (repair joints) shall be stored under cover in suitable containers to prevent damage or deterioration of quality. The containers shall be clearly labelled. The labelling shall include the expiration date of any parts of the kit (for example resins or solvents) that have limited shelf lives.

5.6 HANDLING FOR INTEGRATION TESTS

It may be necessary to carry out integration testing of control umbilicals. In the case of short, relatively light umbilicals, this may be undertaken away from the manufacturer's premises at the control system supplier or elsewhere. Considerable care shall be taken to ensure that any umbilical which is transported and handled is done so without infringing any of the handling or storage parameters or causing damage to the outer covering of the umbilical.

The manufacturer shall prepare a suitable procedure for transportation and handling. This procedure shall state who is responsible for the handling of the umbilical at each stage. All transportation and handling shall be carried out in accordance with these approved procedures.

After an umbilical is transported or used in integration tests, the complete umbilical FAT shall be repeated as per Section 14 of API Specification 17E, including a visual inspection of the outside of the umbilical, and the documentation of results.

6 Preinstallation Work

6.1 UMBILICAL INFORMATION

The manufacturer shall provide to the installer, at the ear-

liest possible time, at a minimum, the following umbilical information:

- a. A cross-sectional drawing, with details of the outer covering material.
- b. The design working loads.
- c. The ultimate tensile strength.
- d. The axial stiffness.
- e. The bending stiffness.
- f. The weight in air (hoses empty).
- g. The weight in air (when filled with the fluid(s) specified in Section 10).
- h. The weight in water (when filled with the fluid(s) specified in Section 10).
- i. The length (and tolerance on/accuracy of length).
- j. Details of length markings applied and their direction.
- k. The overall diameter (minimum nominal and maximum).
- l. The minimum bend radius under installation conditions.
- m. The load-torque characteristics (torque-balance).
- n. The crushing load per unit length.
- o. The allowable combination of axial steady state and fatigue loads, and number of cycles, to which the umbilical may be subjected.
- p. Repair joint dimensions and fitting procedure.
- q. The pressure to be applied to the hoses during installation.
- r. The Maximum Working Pressure and hose sizes.
- s. Power/signal/optical characteristics.
- t. Details of storage prior to load-out.
- u. Confirmation of longitudinal line for twist monitoring.
- v. Friction characteristics of umbilical outer covering.

6.2 ROUTE INFORMATION

The client shall supply to the installer, at the earliest possible stage, environmental and preliminary survey information (including geophysical data and planned pipelines, umbilicals and subsea structures) regarding the proposed route. This will enable the installer to select suitable vessels and installation techniques and to take account of any crossings required.

6.3 TERMINATION INFORMATION

The client or manufacturer, as applicable, shall provide the installer with information on the proposed system of termination of the umbilical. This information shall include the following, at a minimum:

- a. The dimensions.
- b. The weight in air.
- c. The weight in water.
- d. Details of functional interfaces with subsea structure.
- e. The lifting arrangements designed into the termination, weaklinks, junction boxes and in-line splices.
- f. Hang-off location temporary and permanent arrangements on the platform.

6.4 PLATFORM INFORMATION

The client shall provide the installer with the relevant details of the platform(s). These include, at a minimum:

- a. Plan/elevation/envelope of jacket and topsides.
- b. I/J-tube dimensions, geometry and locations on the platform for padeyes, shackles and winches.
- c. I/J-tube bellmouth sealing details.
- d. Pipeline and riser positions.
- e. Other activities scheduled for the work site during the installation operations.
- f. Detail drawings relating to the top of J-tube and surrounding area, including roofing over J-tube.

The client shall allow the installer free and unrestricted access to the platform and the surrounding area, except as specifically stated. The client shall inform the installer of the permit to work system and the nature and location of any known obstructions.

Suitable sites on the platform shall be provided, as necessary, for the installer to mount appropriate vessel positioning system stations, installation aids, and pull-in winches. Details of services available on the platform (if any) shall also be provided.

6.5 SUBSEA STRUCTURE INFORMATION

The client shall provide the installer with details of the subsea structure and equipment so that the subsea pull-in of the umbilical termination can be planned.

6.6 INSTALLATION ANALYSIS

The installer shall, as part of the installation engineering phase, carry out a dynamic installation analysis on the umbilical. This analysis shall be used to establish the loading imposed on the umbilical due to its self weight, currents and laying vessel motion. Additionally, the analysis shall examine the limitations imposed on the umbilical due to trenching operations, rock dumping, crushing due to lay cat-erpillars and engines, and the load-out, overboarding and pull-in operations. Limiting installation conditions due to seabed stability considerations shall be considered. The installation analysis shall aid in the generation of the required installation.

The calculation methodology adopted, and the use of any software packages, should be documented.

The analysis shall be used to establish the following information:

- a. Allowable limits in the offset between the touch down point of the umbilical on the seabed and the vessel as a function of seastate and current.
- b. The variation of tension and curvature along the umbilical as a function of seastate 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 and minimum values of tension and minimum radii of curvature.

- d. Maximum allowable vessel motions to avoid overstressing the umbilical.
- e. Residual tension from plowing-in.
- f. The catenary at the bottom of the I/J-tube from vessel to bellmouth.
- g. Limitations on the pull-in at the subsea termination.
- h. Limitations on unsupported span shapes during load-out to preclude loop formation.
- i. Methods of handling overlengths near terminations.

The limits shall be established to be compatible with the umbilical design loads, minimum bend radius and allowable crushing load as supplied to the installer by the manufacturer. The manufacturer shall provide to the installer any previous installation analysis results, and the results shall be compared.

The client shall provide the installer with information about the degree of protection required. The installer shall demonstrate that by laying the umbilical on the surface of the seabed, and trenching, burial rockdumping, mattresses or otherwise, this requirement can be met.

The installer shall state the limiting sea states for each part of the installation procedure. This shall include the limiting sea state and length of time for which the vessel can be hove-to while the umbilical is being laid, without causing damage to the umbilical. The conditions which shall cause the umbilical to be abandoned shall be clearly stated. If necessary, the proposed method of installation shall be altered to avoid infringing the allowable umbilical limitations. Other weather-related considerations include conditions for the pull-in, handling, and deployment of terminations and launch or recovery of ROVs, trenchers, and plows.

The installer shall demonstrate that the proposed installation vessel with its handling equipment can meet the requirements of the installation, including repair if this is contained within the contingency procedures.

Similarly, the burial equipment and methodology shall be justified for the operation, and limits stated. Particular attention shall be paid to the forces applied to the umbilical by its interaction with the equipment.

The installer shall also calculate the maximum tensile load levels that will be required to be applied to the umbilical during the pull-in operation, and to demonstrate that they are acceptable for the umbilical design. The calculation shall consider, at a minimum, the following factors:

- a. Umbilical weight (in air and water) and bending stiffness.
- b. Catenary configuration due to the vessel stand-off distance, length of cable on the seabed (if any) and hence back-tension at the I/J-tube entrance.
- c. Cable contact with the I/J-tube over the whole I/J-tube length.