Installation Guidelines for Subsea Umbilicals

API RECOMMENDED PRACTICE 17I
FIRST EDITION, AUGUST 1996

EFFECTIVE DATE: OCTOBER 1, 1996

American Petroleum Institute

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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).

IEC[1]

228 *Conductors of Insulated Cables*

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

ISO[2]

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

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.*

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

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

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 separate 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 strop: 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 earliest 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 caterpillars 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, mattressing 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.

d. The physical geometry of the I/J-tube.
e. The force required to pull-in the I/J-tube seal and bend stiffener, if they have been preinstalled on the cable prior to a pull-in.
f. Maximum allowable deck load (pull-in and hang-off).

In all cases, suitable monitoring methods and equipment shall be available and procedures shall be developed to cover contingencies, should these arise.

6.7 PLATFORM SITE VISIT

The installer shall visit the platform(s) to examine the I/J-tube(s) and hang-off positions to decide where to position the pull-in winch, temporary rigging, and testing and monitoring spread. The requirements on equipment regarding safety zoning and other applicable requirements shall also be established. If ROV operations are scheduled from the platform, the feasibility of these shall also be assessed.

7 Load-out

7.1 INTRODUCTION

The load-out operation is the loading of the umbilical(s) onto the installation vessel from the manufacturer's facilities. Occasionally, for example if the umbilical has been used for integration tests with the control system, load-out may not occur from the manufacturer's facilities.

7.2 ALLOCATION OF RESPONSIBILITY

It is essential that responsibility for the satisfactory handling of the umbilical at every stage shall be clearly defined. The exact points in the operation at which responsibility is transferred from one party to another must be stated and agreed to before operations commence.

The following sections assume that after FAT, all operations are controlled by the installer.

7.3 TECHNICAL AUDIT OF MANUFACTURER'S FACILITIES

The installer shall visit the manufacturer's facilities and inspect the equipment which the manufacturer intends to use for their portion of the load-out operation, and to assess the acceptability of the facility for the operation.

The matters to be considered in the course of the visit include the following, at a minimum:

a. Lay vessel
   1. Constraints on the draft of the vessel and other dimensions.
   2. Mooring and maneuverability requirements.
   3. Craneage operations from the vessel.
b. Umbilical storage facilities
   1. Method of storage.
   2. Access to facility.
   3. Arrangement of terminations.
   4. Limitations on handling from storage due to umbilical parameters (weight, minimum bend radius, crush load limitations).
   5. Protection during storage.
c. Onshore umbilical handling systems:
   1. Type of system.
   2. Method of control and communications.
   3. Manning requirements (likelihood of 24 hour working).
   4. Rated pay-out speed.
   5. Interface with storage facility.
   6. Interface with vessel umbilical handling system.
   7. Requirement to provide additional equipment (portable cable engine, etc.).
   8. Limitations on handling due to umbilical parameters (weight, minimum bend radius, crush load limitations).
   9. Craneage and lifting facilities for handling terminations.

The availability of onsite manpower and support functions, together with any local labor agreements, shall be reviewed.

7.4 LOAD-OUT PROCEDURE

The installer shall write a load-out procedure describing the proposed operation and identifying all the onshore equipment to be used. (The manufacturer shall provide procedures for the onshore load-out equipment for inclusion in the installer's procedure.) The procedure shall identify which end of the umbilical needs to be loaded first, and the order of umbilical loading in cases being loaded. If any rigid joints and rigid terminations are incorporated in the umbilical, the procedure shall detail the method and equipment to be used in handling these.

7.5 PRE-LOAD-OUT MEETINGS

The installer and the manufacturer shall meet to establish the basis for the operation and to confirm the point of handover of responsibility for the umbilical. A number of matters need to be reviewed and emphasized, including:

a. Chain of command for the operation and point of handover of responsibility.
b. Responsibilities and staffing for the load-out.
c. Interfaces between the installer and the manufacturer.
d. Communications procedures.
e. Review of the load-out procedure and contingency.
f. Timetable for load-out, including timetable for necessary access permits.
g. Handling of terminations and any intermediate joints.
h. Required assistance from the manufacturer for pre- and post-load-out tests.
i. Provision of all necessary information to the vessel master for the calculation of vessel stability.
j. Safety procedures and the generation of a safety plan.

7.6 PRE-LOAD-OUT TESTS

These tests are required to be carried out only if the complete umbilical assembly has been transported from the manufacturer's works to another site, or has been stored for more than three months.

In either of these circumstances, it is essential that the point at which responsibility for the umbilical is transferred from one party to another (normally from manufacturer to installer) is stated and agreed upon before operations commence.

These tests shall be carried out prior to the load-out operation, but with sufficient time allotted that rectification could be carried out if necessary. If there is no pre-load-out test, the installer shall be invited to witness the FAT.

7.7 LOAD-OUT

Following berthing of the vessel, the person in charge of the load-out shall arrange for:

a. A briefing for all personnel involved in the operation to explain the procedures to be adopted, the communications procedures and the timetable for the load-out. Particular emphasis should be placed on the safety plan for the operation.
b. Examination of calibration and functional testing records of the onshore and vessel based equipment to be used and confirmation that these are all current.
c. A messenger rope to be passed from the shore to the ship.

Upon satisfactory completion of the preliminary activities, the load-out can commence. Normally, a messenger rope is used as a lead-in for the umbilical and the umbilical is passed from its storage onshore along the handling system to the vessel, where it is re-stored on the vessel storage system.

7.8 STOPPING AND STARTING THE LOAD-OUT

All operations shall be coordinated by the person responsible for the load-out and shall aim to prevent the possibility of damage to personnel, assets, or umbilical. If in the view of an operator involved in the operation there is a problem or the possibility of a potential problem arising, he shall have the authority to cause the load-out to be halted in a controlled manner. Once the operation has been stopped, only the person responsible for the load-out shall authorize re-commencement. This authorization shall only be given once the responsible person is satisfied that the problem has been resolved, or the potential problem averted.

7.9 HANDLING OF THE UMBILICAL

The handling of the umbilical during the load-out shall be carried out and monitored in a manner to ensure that the umbilical and its associated accessories are not subjected to any damage.

7.9.1 Twist

The umbilical shall be visually monitored at all times throughout the operation to observe the presence of twist. The presence of significant twist shall be investigated.

7.9.2 Minimum Bend Radius

The bend radius of the umbilical shall at all times be greater than the value of minimum bend radius as specified by the manufacturer.

7.9.3 Lifting the Umbilical

If it is necessary to sling the umbilical, bend shoes or webbing strops shall be used. At no time shall wire ropes be used for this purpose. When strops are used, care shall be taken to avoid infringing the minimum bend radius requirement or inducing buckling, by using multiple strops.

The use of Chinese fingers shall be permitted.

7.9.4 Transfer Across Spans

When the umbilical is transferred across any open space unsupported, the tension shall be such that the resulting catenary does not infringe the minimum bend radius. At each end of the span, the umbilical shall be supported by suitably radiused bend shoes, sheaves, chutes or bell mouths.

The catenaries shall be carefully monitored, and the load-out speeds altered accordingly, to ensure that the catenary tensions, in addition to the shapes, remain acceptable and in agreement with the values contained in the load-out procedure, and that there is no possibility of the umbilical kinking or forming a loop.

If the storage facility is not directly alongside the point at which the vessel is berthed, a gantry may be used for transporting the umbilical to the vessel. Alternatively, roller trays or caterpillars may be used.

7.9.5 Terminations

Terminations shall be handled using the lifting devices such as eye bolts or lifting lugs designed into them. Handling of large terminations shall require special consideration. When carrying out lifting operations on terminations, care shall be taken that there is no inadvertent removal of the protective coating on the item due to scratching, chafing, or similar effects. The operation shall be planned to ensure that the load-out handling of the termination does not introduce unacceptable levels of tension, twist, or bending into the umbilical at the termination.

The subsea termination shall be fastened on board the vessel in a position that allows access for testing of the umbilical and in the orientation required (with respect to the vertical) to ensure subsequent satisfactory pull-in and connection to the subsea structure.

7.9.6 Weak Link

Prior to commencement of the load-out, the weak link(s), if fitted, shall be checked to verify that its override system (if applicable) is in place and that there is no possibility of inadvertent actuation during load-out or subsequent laying.

7.10 LOAD-OUT MONITORING

7.10.1 Electrical

The DC conductor continuity shall be continuously monitored during the load-out operation. The system used shall be capable of recording brief breaks in continuity, for instance by use of a high frequency response chart recorder. Should there be any loss of continuity, the operation shall be halted and a DC Conductor Resistance Test on individual cables shall be carried out in accordance with the requirements in Section 10. In the event of a failure, a Time Domain Reflectometry Test may be carried out as specified in Section 10.

7.10.2 Hydraulic

Each hose shall be pressurized to 70 bar (gauge) unless otherwise specified in the manufacturer's written specification and this pressure shall be maintained to within ± 5 percent for the duration of the umbilical load-out. The pressure shall be continually monitored with a chart recorder. Ambient temperature shall be recorded. Any variations in measured pressure outside these limits shall cause cessation of the load-out for further investigation.

7.10.3 Optical Fibers

The attenuation shall be continuously monitored during the load-out operation using an OTDR. Should there be any change in attenuation or any apparent discontinuity in the fibers, the operation shall be halted and an investigation should be carried out.

7.10.4 Visual Tests

7.10.4.1 Umbilical Condition

The umbilical shall be examined during the load-out operation for signs of distortion, kinking, surface damage, raised diameters, bird-caging of armor wire, or other defects. The entire umbilical length shall be examined. Any defect shall be reported to the client.

7.10.4.2 Umbilical Length

The installer shall ensure that the length loaded out onto the vessel is as specified and that length markings as required for the subsequent lay operations are marked on the umbilical. The equipment to measure the length shall be calibrated to a standard and the measuring procedures documented according to the manufacturer's written specification.

7.11 POST-LOAD-OUT TESTS

The test details are given in Section 10.

7.12 LOAD-OUT ON REEL OR CAROUSEL

In cases when the umbilical is not transferred from onshore carousel/reel to vessel carousel/reel, (that is, the storage system is the installation system), load-out monitoring is not required. However, a full series of post-load-out tests shall be carried out. If the operation involves an earlier transfer from storage system to storage system, the monitoring of that operation shall be identical to the load-out monitoring.

8 Installation

8.1 INTRODUCTION

Installation procedures shall be written by the installer in accordance with the quality plan. There are a number of different types of lay which can be used, including:

a. Free lay onto the seabed.
b. Simultaneous lay and bury.
c. Lay and post bury.
d. Lay into a predug trench.

The burial can be carried out either with a plow or a trencher, or left to occur naturally. Additionally, there are a number of different routings which are possible:

a. Surface–surface (platform–platform).
b. Surface–subsea.
c. Subsea–subsea.

Consequently some of the details of the operations vary, but there are a number of common features in all types of operation which are described in the following sections. The major activities for each of the routings are shown in Table 1.

8.2 VESSELS AND EQUIPMENT

8.2.1 Introduction and Applicable Specifications

All marine vessels and equipment shall be capable of performing their required function, shall meet their specification as declared by the installer to the client, and shall be operated by specialist personnel according to an International Safety Management Code (ISM Code).

The umbilical installation vessel shall comply with all codes, standards, and regulations of the relevant statutory authorities. A duplex DP system shall be required, and prior to mobilization in the field, sea trials with the DP system may be required.

Table 1—Variations in Routing Activities

Platform–Platform	Platform–Subsea	Subsea–Platform	Subsea–Subsea
Preinstallation work	Preinstallation work	Preinstallation work	Preinstallation work
Preload out tests	Preload out tests	Preload out tests	Preload out tests
Load-out transpooling	Load-out transpooling	Load-out transpooling	Load-out transpooling
Post-load-out-tests	Post-load-out-tests	Post-load-out-tests	Post-load-out-tests
I/J-Tube pull-in	I/J-Tube pull-in	Lay-down of subsea termination/hookup of subsea termination	Lay-down/hook-up of subsea termination
Main lay (burial)	Main lay (burial)	Main lay (burial)	Main lay (burial)
Lay monitoring	Lay monitoring	Lay monitoring	Lay monitoring
I/J-Tube pull-in	Lay-down of subsea termination	I/J-tube pull-in	Lay-down of subsea termination
	Pull-in of subsea termination and hookup		Pull-in of subsea termination and hookup
Post-lay/burial survey	Post-lay/burial survey	Post-lay/burial survey	Post-lay/burial survey
Post-installation survey	Post-installation survey	Post-installation survey	Post-installation survey
Post-lay tests	Post-lay tests	Post-lay tests	Post-lay tests

All marine vessels shall be classed and registered. Certificates shall be available for inspection by the client.

Maritime operations shall be undertaken in accordance with the relevant international regulations. Use of divers and ROVs shall also be subject to the relevant codes of practice and regulations.

8.2.2 Requirements for Vessel and Equipment

The installation vessel and its installation equipment shall be in good condition and working order and be verified according to the quality and safety plans prior to the vessel mobilization.

Applicable equipment, for instance that for measuring load, shall be calibrated in accordance with the quality plan. Items of lifting equipment shall have suitable certification.

Vessel equipment requirements shall include but not be limited to suitable:

a. Communication facilities.
b. Positioning and navigation systems.
c. Lay chutes of a size that will avoid infringement of the minimum bend radius of the umbilical design.
d. Conveyor systems to move the umbilical without the presence of unsupported spans or the possibility of the umbilical coming into contact with surfaces other than those of the handling and storage systems.
e. Cable engines.
f. Powered/unpowered sheaves.
g. Trenching/burial equipment.
h. Remotely operated vehicle (ROV).
i. Diving spread.
j. Tension measuring equipment; means to continuously monitor and record the tension to which the umbilical is subjected. Alarms shall be included within the system.
k. Length measuring system.
l. Departure angle measuring equipment; means to continuously monitor the angle at which the umbilical leaves the vessel. Alarms shall be included within the system.
m. Umbilical functional testing equipment. For a typical list see Appendix C.
n. Installation aids.
o. Device to cut the umbilical in cases of emergency.

It shall be ensured that the umbilical, with its associated terminations, can be handled, moved across the deck of the vessel, and overboarded in a safe manner without the possibility of damage and holdups due to sharp edges, rough surfaces, and obstructions.

The installer shall carry backup equipment onboard the vessel whenever this is practicable and shall ensure that at all times suitable spares are available for the rapid repair of all essential items.

Selection of spares shall be undertaken by the installer following consultation with the equipment manufacturers.

The client shall be responsible for the provision of spares for client supplied equipment.

8.2.3 Choice of Cable Engine

Factors which shall be considered with regard to the choice of cable engine include the following:

a. Required lay speed.
b. Expected installation and recovery tensions.

c. Diameter of umbilical and any joints.
d. Availability of deck area.
e. Reliability of engine and level of system redundancy required.
f. Necessity for more than one engine.
g. Method and accuracy of measurement of tension.
h. Tolerance on control of tension.
i. Method and accuracy of measurement of gripping force.
j. Allowable gripping forces on umbilical.
k. Method and accuracy of measurement of umbilical length.
l. Wear on gripping components.

It should be noted that the friction characteristics of the outer covering of the umbilical are extremely important when considering the cable engine. If there are concerns that the combination of cable engine and wet umbilical outer covering (for example, polyethylene) may require high crushing loads to overcome the low coefficient of friction, then handling trials should be considered. Consideration should also be given to the frictional characteristics of the outer covering in relation to the armoring.

When the umbilical is stored in a carousel or in a cable tank it is inadvisable to rely upon a single linear cable engine for braking, unless the design is one that fails safe. An additional (redundant) method of restraining pay-out should be provided; for example, a second cable engine or a capstan.

8.2.4 Choice of Burial Equipment

The choice of equipment is governed by a number of considerations. These include the following:

a. Type of installation planned:
   1. Simultaneous lay and bury.
   2. Free-lay and post-bury.
   3. Lay into predug trench (with or without subsequent burial).
b. Seabed operations:
   1. Soil type (hard, mid-range, soft) and conditions.
   2. Presence of boulders and boulder size.
   3. Cutting requirements/plowing forces.
   4. Trench/burial depth.
   5. Need to pass obstructions such as pipeline crossings.
   6. Necessity to work close to structures.
c. Machine characteristics:
   1. Limitations on launch/recovery of system due to sea-state.
   2. Length of time to launch/recover.
   3. Limitations on system operation post-launch due to surface conditions.
   4. Rate of operation through soil type(s) to be encountered.
   5. Reliability and redundancy.
   6. Seabed weight and maneuverability.
   7. Necessity for diver intervention.
   8. Necessary deck spread and launch equipment.
   9. Potential risk of damage to umbilical.
   10. Umbilical monitoring equipment (cameras, sensors, load measuring).
   11. Machine sensors (sonar, pipe trackers).
   12. Ability to accommodate bundled (piggybacked) umbilicals.

The reaction forces within, or the geometry through, the machine shall not damage the umbilical or its outer covering.

8.3 PREINSTALLATION SURVEY

8.3.1 Introduction

Before commencing the umbilical installation the installer shall carry out a preinstallation survey along the proposed route and width of corridor, unless the client has arranged for others to undertake it.

The preinstallation survey shall be carried out using equivalent positioning and navigation equipment to that which will be used during the installation operations.

The survey shall identify any seabed obstructions and debris that may be hazardous to the umbilical or may impede its installation. The installer shall propose suitable methods of seabed preparation for those areas in which preparation is considered necessary and shall carry out that preparation.

8.3.2 Requirements of Survey

Consideration shall be given during the preinstallation survey to the following activities:

a. Surveillance of the planned route using a side scan sonar or an ROV in order to confirm the data from earlier activities and to survey the right-of-way for the umbilical installation vessel.
b. Confirmation of the position of any adjacent pipelines, cables, umbilicals, or other structures.
c. Establishment of the position and identity of any pieces of debris which lie along the proposed route and in a defined corridor on either side of it. Removal of debris where necessary and feasible should be undertaken subsequently.
d. Survey of possible route deviations which may be necessary to avoid debris, to comply with contingency plans, or to use up excess umbilical length prior to termination laydown.
e. Survey of the platform(s) environs, including the I/J-tubes, and the area of termination laydown.
f. Confirmation that any preinstalled messenger wires and fittings are in good condition and usable.
g. Confirmation that all subsea preparations for any pipeline crossings are satisfactory.
h. Deployment of temporary installation aids where necessary; for example, at turn points on the route, mud mattresses at subsea termination positions.

i. Deployment of transponders or beacons at critical positions, for example, pipeline crossings, on the route and at the target area for laydown of the umbilical subsea termination.
j. Bathymetric, sub-bottom profiler and side scan sonar surveys of the route.
k. Determination of the water depth along the route length, and subsequent correction to LAT by making allowance for the predicted tide during the survey.
l. Conduct of a magnetometer survey along the route. If there are any anomalies between this survey and the results of the sonar survey, they should be further investigated.

8.3.3 Reporting

The output from the survey shall be as follows:

a. A report on the proposed route, including full details of any hazards identified, seabed preparations required and debris to be cleared. This shall highlight any discrepancies between information supplied by the client to the installer and the survey findings.
b. A set of survey video tapes, which include the camera position on the display.
c. A route chart, indicating water depth, possible route deviations and the positions of any hazards or debris.

8.4 INSTALLATION OPERATIONS

8.4.1 Personnel Responsibilities

The individuals responsible for the execution of each activity, the verification against specified requirements and the authority with regard to acceptance of satisfactory completion of activities shall be specified in the quality plan as stated in Section 4.

The interaction between the various personnel directly involved in the installation depends on the specific activity being carried out. Consequently, the details of such interactions shall be specified in the installer's procedures for the project.

8.4.2 I/J-Tube Pull-in Operations

8.4.2.1 Introduction

In the course of installing umbilicals, it is usually necessary to carry out at least one I or J-tube pull-in operation. In the case of platform-platform links between two platforms, two such operations are necessary.

8.4.2.2 Preparatory Work

Prior to the pull-in, a number of preparations shall be carried out in order to ensure that the operation can be completed successfully. These preparations are the following:

a. Review of calculations (see Section 6.4), to establish limit loads during the pull-in operation.
b. Gauging (pigging) of the tube to check that it is clear of obstructions and fouling.
c. Placement of messenger put into tube (if one is not already in place). This can be done by blowing one down the tube.
d. Establishment of pull-in equipment and personnel on platform. This includes installing the winch, and its associated rigging, including the load monitoring and umbilical functional testing equipment, and preparing the hang-off arrangement.
e. Check of communications facilities.

Umbilical terminations are described in Appendix A.

8.4.2.2.1 Weather Window for Pull-in

The availability of a suitable weather window shall be established prior to initiating operations. The required window shall take account of the predicted duration of the pull-in and lay operation, vessel and equipment capability, and the results of installation analyses regarding sea state versus umbilical loading.

Due regard shall be given to the length of time for which the vessel can remain hove-to without causing damage to the deployed umbilical.

8.4.2.2.2 Initiation of Pull-in Operations

The vessel shall contact the existing facilities as soon as possible on route to the installation site.

Following successful completion of the platform preparatory activities described in Section 8.4.2.2, the pull-in operation may proceed, and the vessel may approach the platform.

On entering the zone around the platform, vessel operations shall become subject to all the regulatory requirements that pertain to operations on the platform.

8.4.2.2.3 Visual Survey

Following the arrival of the lay vessel in the vicinity of the platform, a visual check of the seabed and I/J-tube entrance shall be carried out by either ROV or diver. The purpose of this is to check both the physical condition of the I/J-tube, the seabed conditions, and the profile on the route into the I/J-tube to confirm the findings of the preinstallation survey.

If the I/J-tube is fitted with a blind flange at the bottom, it is necessary to remove this flange. A transponder may be attached to the I/J-tube bellmouth at this time if one is required for subsequent operations.

The identity, position, and condition of the messenger wire shall be established at this stage. If the messenger wire is attached to a clump weight the exact position of the clump weight shall be determined. This operation is particularly important if there is more than one I or J-tube in close proximity, and therefore more than one clump-weighted

messenger wire. It is also essential to ensure that there is no possibility of two or more messenger wires becoming entangled in subsequent operations.

8.4.2.3 Recovery of the Messenger Wire

On the platform the winch pull-in wire shall be fastened to the messenger wire at the top of the I/J-tube. The bottom end of the messenger wire shall then be attached to the wire of the winch positioned on the deck of the lay vessel. The deck winch is then used to recover the messenger wire onto the deck of the vessel as the platform winch pays out. It may be necessary to use a significant tension when the messenger wire is attached to a diaphragm in the I/J-tube bellmouth.

Once the end of the messenger wire is on the deck, the clump weight (if present) is removed and the recovery procedure continued until the end of the pull-in wire is on the deck. The end of the umbilical can then be attached to the wire.

8.4.2.4 Umbilical Pull-in

The pull-in head may be overboarded from the vessel and the umbilical paid out from the vessel. The vessel position shall be adjusted to produce the required catenary so that the umbilical enters the I/J-tube at the correct angle and that the umbilical is not dragged excessively along the seabed.

Monitoring of the pull-in operation shall be undertaken using:

a. The tension monitoring equipment on the platform.
b. The tension monitoring equipment on the vessel.
c. The ROV video camera, which will visually monitor the umbilical in the vicinity of the I or J-tube entry, to establish the catenary shape, extent of seabed contact (if any), umbilical bend radius and umbilical twist. The umbilical shall have frequent length markings in this region to assist observation.
d. The amount of umbilical paid out.

Pull-in tension shall be carefully monitored and compared with the previously calculated values. Any increase in tension above that previously agreed shall cause the operation to be suspended and the cause of the increase to be investigated.

At the point at which the pull-in head is about to enter the J-tube bellmouth, particular emphasis shall be placed on the information provided by the ROV video camera, to remove any possibility of snagging the pull-in head. Similar care shall also be taken as the I/J-tube seal and bend stiffener (if they are preinstalled on the umbilical) approach the I/J-tube entrance and their required position in the I/J-tube. Small vessel movements may be required at this point to ensure that entry is unimpeded.

8.4.2.5 Securing the Umbilical on the Platform

On arrival at the relevant deck level, the umbilical shall be securely fastened. The permanent hang-off arrangement, either a mechanical termination of the armor wires or potting off of the wires, can be fitted as soon as the pull-in is completed, if the termination has not been attached to the umbilical prior to the pull-in. Alternatively, when the permanent method would take a long period of time, the fastening can be made temporarily using split clamps, Chinese fingers, and so forth so that the testing and lay can proceed without delay. Later the permanent hang-off can be constructed.

8.4.2.6 I/J-Tube Bottom Seal/Bend Stiffener

On most installations the bottom of the J-tube is sealed, although this is installation specific.

The seal may already be in place at the end of the pull-in operation if preinstalled onto the umbilical prior to the pull-in. In some cases the seal is operational at the end of the pull-in without any further intervention. On other occasions it may be necessary for diver or ROV to make the seal operative.

Where there is no preinstalled seal, it is necessary to fit it after the pull-in and hang-off have been completed.

8.4.2.7 I/J-Tube Chemical Protection

It is normal practice to introduce chemical inhibitors, biocides, and oxygen scavengers into the I/J-tube to provide protection to the I/J-tube material. All chemicals used and their ultimate combination within the tube shall be confirmed at an early stage as compatible with the umbilical materials with which they come into contact.

8.4.2.8 I/J-Tube Top Seal

Where the umbilical hang-off does not seal the top of the I/J-tube, it may be necessary to fit a suitable top seal. The top seal and hang-off arrangements shall have provision for the introduction of chemical treatments, if required.

8.4.2.9 Removal of Temporary Rigging

Following commencement of the lay-away from the platform, the pull-in winch and temporary rigging can be dismantled and removed, although it is recommended that this not be carried out until a successful post-installation test has been undertaken. Any localized damage to protective coatings on the platform should be made good.

8.4.2.10 Second End Pull-in

This operation is required in the case of platform–platform umbilicals, and also in the case where the lay of a platform–subsea umbilical commences at the subsea end.

The I/J-tube pull-in at the second end, although similar in

many ways, can be more complicated than a pull-in operation at the start of the lay due to the presence of the umbilical which has already been laid and the catenary to the vessel. Irrespective of the details of the operation, the procedures used shall include the requirements of close tension control and visual monitoring of the catenary, the seabed umbilical subject to displacement, and the entrance to the I/J-tube.

8.4.3 Movement of Vessel Away from the Platform

In the case of a first end pull-in, the lay vessel shall proceed to lay umbilical along the planned route to clear the immediate vicinity of the platform as soon as the pull-in is complete. In the case of simultaneous lay and bury operations, this will also necessitate launching the burial vehicle prior to the lay-away, unless this has been done prior to the pull-in. While this is under way, platform connection of umbilical test and monitoring equipment shall be carried out, when the monitoring is being undertaken from the platform. Commencement of the main lay of the umbilical along the route beyond the immediate vicinity of the platform shall not proceed without confirmation that the umbilical testing has been satisfactorily completed, the monitoring equipment is connected and operational and pressurization (if applicable) has been achieved unless otherwise dictated by the procedures.

For a second end pull-in the vessel shall move away at the completion of the pull-in.

8.4.4 Lay-down of Subsea Termination (First End)

(If the initial part of the operation is installation of a subsea termination, this is carried out in place of the I/J-tube pull-in operations described in the previous sections.)

Any necessary work required to prepare the seabed shall be carried out. The termination is overboarded and lowered to its designated position on the seabed. The termination shall be fitted with a transponder and light-sticks to aid position monitoring. Depending on the design of the system, the designated position may be the final position, or a subsequent pull-in to a manifold may be required. As the termination is lowered, the umbilical position and tension shall be carefully monitored and controlled to avoid the generation of slack within the umbilical length. Once the termination is on the seabed and suitably secured, the umbilical routing away from the termination shall be as designed.

As an alternative for a first end subsea termination, the lay-away method may be used. In this case the lay vessel shall pass the first end umbilical termination underneath the drilling rig and into the moonpool. In the moonpool there is a guidebase or Christmas tree to which the umbilical will be connected. After relevant testing (see Section 10), the guidebase or Christmas tree with umbilical connected is lowered to the wellhead and secured. After conclusion of this operation, the lay vessel will commence the main laydown of the umbilical along the route. At the vessel selection stage, it shall already have been verified that the vessel can maintain position during the above mentioned activities under the design environmental conditions allowed for that operation.

Considerable care needs to be taken if the termination is of a design which may give rise to the presence of significant hydrodynamic forces due to currents, vessel heave, or the wake from thrusters. These forces may induce large rates of twist into the umbilical by virtue of termination rotation.

8.4.5 Lay Route

The umbilical lay route shall be shown on umbilical route alignment charts. These charts shall show the way-points, the coordinates of changes in direction of the route and the corridor within which the umbilical shall be laid. The charts shall also detail the extent and location of any additional protection required, such as tubular protectors or mattressing, the presence of other umbilicals and risers, pipelines and pipeline crossings, and dimensioned target areas for lay-down of the umbilical subsea terminations.

8.4.6 Handling Requirements for the Main Lay

The major mechanical requirements during the main lay are to avoid the following:

a. Introducing too much slack in the vicinity of the touchdown position, by virtue of low tension/large departure angle, to preclude the possibility of loop (“hockle”) formation.
b. Infringing the minimum bend radius at the touchdown point, to stop over-bend of the umbilical.
c. Introducing large rates of twist into the umbilical, to reduce the probability of loop formation and birdcaging.
d. Applying excess tension, which may overstress the umbilical.
e. Flexing the umbilical, close to the overboarding point, where catenary loads are at their maximum, and at the touchdown point for extended periods to exclude the likelihood of fatigue failures of the umbilical structure.

8.4.7 Vessel Positioning to Achieve Required Touchdown

The umbilical touchdown point shall be continually visually monitored by the ROV to verify that the umbilical is being laid within the required corridor as defined on the route alignment charts. This shall be achieved by means of reference to the ROV’s on-board acoustic transponder. The ROV high-resolution sonar (if fitted) can also be used to confirm by reference to other seabed features that the umbilical remains within the defined corridor. If the ROV suffers technical problems of a nature which means that it cannot carry out the monitoring function then the lay shall be stopped.

It is particularly important to control length when the vessel is altering course. In the situation when the route is

curved, the vessel is moved from one alter course point to the next by entering the coordinates of each location using the umbilical lay reference, allowing for umbilical touchdown layback. The ROV shall monitor the touchdown position to ensure the umbilical continues to be laid in the correct corridor. Subsea beacons laid during the preinstallation survey can assist with positioning at critical points along the route.

If the vessel is headed in the direction of lay with the umbilical being laid over a stern chute, any deviation of the umbilical lead from directly astern of the vessel route due to the presence of cross currents or tides can easily be estimated. If it is considered necessary, a small vessel offset can be applied at any subsequent turn point to take account of any tidal current. If a crab-lay is undertaken, the offset between the vessel and the touchdown point, as indicated by the ROV transponder, should be used to make an estimate of the effects of currents and tides so that the route can be altered to take account of this.

In very deep water the touchdown point may have to be monitored with sidescan sonar or an ROV deployed from a separate survey vessel.

8.4.8 Control and Monitoring of Length Laid

It is necessary to monitor umbilical length paid out against distance travelled along the planned route in order to do the following:

a. Detect whether excessive umbilical length is being laid.
b. Allow the lay of a fixed umbilical length over the planned route while ensuring correct positioning of the subsea terminations in the predetermined laydown target area.

A computation of the umbilical length paid out shall be made continuously. Suitable entries at each marked distance point on the umbilical shall be used. The umbilical shall be marked in accordance with API Specification 17E, with 10-meter marking intervals at each end and 100-meter markings over the central length.

As each umbilical marking passes a specified datum mark on the vessel, a navigation fix shall be taken and the following information recorded and/or calculated:

a. Time and date.
b. Reference number of navigation fix.
c. Coordinates of overboarding point.
d. Coordinates of touchdown point.
e. Distance along route as laid (KP).
f. Umbilical marked length at datum.
g. Umbilical length measurement equipment reading.
h. Overlength since last calculation.
i. Cumulative overlength.
j. Distance to end of lay
k. Umbilical remaining inboard of datum mark.
l. Catenary tension at overboarding point.
m. Mean umbilical pay-out rate.
n. Comments.

Some of this can be precalculated to facilitate rapid simple checks that the lay is proceeding to plan.

Details regarding length control at completion of lay are given in Section 8.4.1.1.

8.4.9 Integrity Monitoring During Lay

Lay monitoring may be undertaken from the platform if the first operation is an I or J-tube pull-in. When the first operation is a lay of a subsea termination, lay monitoring must to be carried out from the installation vessel.

8.4.9.1 Electrical

The conductor continuity shall be continuously monitored during the lay operation. In the event that there is any loss of continuity, the operation shall be halted and a DC conductor resistance test on the individual cables shall be carried out in accordance with the requirements laid down in Section 10. In the event of a failure, a time domain reflectometry test may be carried out as specified in Section 10.

6.4.9.2 Hydraulic

Each hose shall be pressurized to 70 bar (gauge) unless otherwise specified in the manufacturer's written specification, and this pressure shall be maintained for the duration of the umbilical lay. The pressure in each hose shall be continually monitored with a chart recorder. Should there be any unexplainable loss of pressure, or if the behavior of one hose string relative to the rest is markedly different, the operation shall be halted, and the cause of the pressure loss investigated.

8.4.9.3 Fiber Optic

Each optical fiber shall be continuously monitored using an OTDR. Should there be a significant change in attenuation, or a loss of continuity, the operation shall be halted, and the cause of the fiber problem investigated.

8.4.9.4 Visual Tests

The umbilical shall be examined during the operation for signs of distortion, kinking, surface damage, bird-caging of armor wire, or other defects defined in the installers quality plan. The examination shall be for 100 percent of the umbilical length. Any defect shall be reported to the client.

8.4.10 Burial Operations

Burial of an umbilical may be required for protection against dropped objects or fishing activities, or for stability requirements.

The burial operation depends on the type of equipment used, and whether the operation is a simultaneous lay and burial, or a post-lay burial.

Plowing or trenching shall be performed as a single pass operation. If the required burial depth is not achieved, then the required protection shall be provided by other means. Application of the additional protection shall be carried out so as not to put the umbilical at any risk.

Other methods of protection are listed in Appendix B.

Deployment/recovery of plows and trenchers shall not take place within a radius of 50 meters of any subsea facility.

8.4.10.1 Monitoring During the Burial Operation

The burial operation shall be continuously monitored both by the on-vehicle instrumentation and from the surface, using both ROV and surface survey, navigational, and sonar systems.

At a minimum, the following parameters shall be monitored:

a. The tow force (plow).
b. Loads induced on the umbilical.
c. Configuration of the umbilical in front and through the vehicle.
d. Burial depths.
e. Vehicle and vessel positions.
f. Area ahead of the vehicle for obstructions.

If at any time the instrumentation or visual inspections indicate that damage to the umbilical may have occurred, the installer shall interrupt the trenching or plowing operation and perform a diver and/or ROV video survey of the damaged area.

8.4.10.2 Interaction With Umbilical

The minimum bend radius of the umbilical during the burial operation shall not be less than the minimum bend radius of the umbilical as per the manufacturer's written specification.

8.4.11 Approach to Subsea Termination Position (Second End)

As the subsea termination laydown position is approached, it is necessary to ensure arrival at the correct point, by carefully monitoring the lay distance remaining and gaining or losing route length over umbilical length as required. A transponder shall be deployed on the termination during laydown to give accurate positioning at seabed touchdown.

Any contingency plans for route deviations shall have been agreed upon prior to mobilization as part of the initial development of procedures.

Having continually compared the umbilical length laid with the position on the route, approximately 1–2 kilometers from the laydown target area the length of umbilical remaining to be laid in comparison with the planned route distance still to go shall be assessed. If necessary a revised route shall then be produced to accommodate the umbilical length remaining. This procedure shall be repeated and the route revised at appropriate distances (typically 100–200 meters initially reducing to 25 meters when within 200 meters of the laydown position). By adoption of this technique any residual umbilical length can be used up gradually, thereby avoiding the need to deal with large amounts of excess umbilical length in the area where the termination is to be put down. When the umbilical is to be buried, it is desirable to bury as much as possible to minimize the length requiring alternative protection.

Alternatively, in the case of congested areas, the approach adopted might be to limit putting excessive length on the seabed. In that case the umbilical is laid towards the final way-point at a short, measured distance from the final target. It can then be determined what the actual overlength of the umbilical is. Subsequently, in the field, the overlength can be reduced, the umbilical terminated and testing carried out (see Section 10).

8.4.12 Lay-down of Subsea Termination

The dimensions and location of the target area for the termination laydown shall be marked on the route alignment chart and physically on the seabed with a transponder. In soft soil conditions a mattress may have been laid as part of the preinstallation work.

The final laydown of the umbilical shall be carried out so that the umbilical lies on the seabed with the extra length arranged in an S, a C, or other form so that the pull-in does not cause the umbilical to infringe its minimum bend radius.

A predeployment test of the umbilical and subsea termination may be carried out, although if the previous testing and monitoring activities are satisfactory, the slightly increased risk to the umbilical may make this activity unnecessary.

Preparations should now be made to overboard the termination. Light-sticks and a transponder shall be attached to the end of the winch wire or crane hook and/or the termination to facilitate a properly controlled deployment of the end termination onto its target area.

The termination shall be lowered into the water, with the vessel maneuvering as required to maintain the desired umbilical laydown route. As the termination arrives within 5 meters of the seabed the operation should halt to confirm that a satisfactory laydown shall be achieved. If necessary, lift the termination and reposition the vessel so as to achieve the desired laydown position and heading.

8.4.13 Pull-in of Subsea Termination

The subsea termination should now be pulled into its final position in the subsea structure.

In the case of a stab plate connector, the act of pulling the termination into its final position shall cause the functional

connections to be made. Alternatively the functional connections may be made by jumper hoses and/or cables, which is effected after pull-in. In the case of a stab plate connector, the angular orientation of the termination with respect to the subsea structure is critical.

A detailed procedure shall be prepared for the final stages of pull-in depending on the particular design.

Factors to be considered include:

a. Details of mechanical fastening.
b. Installation of cathodic protection straps.

Once the termination is in the specified final position, the necessary mechanical fastenings shall be installed.

In the case of the stab plate connectors, this completes the connections and the pull-in. When jumpers are to be used, these shall now be installed paying due attention to any temporary jumper connections that may be required as part of the flushing or test procedures.

8.4.14 Pipeline Crossings

When a crossing is necessary, the proposed crossing design and applicable procedures shall be properly documented and permission obtained from the pipeline owner. The proposed crossing design should include positive separation between pipe and umbilical.

As the lay vessel approaches the crossing area, the location of the crossing shall be checked. Visual observation of the area by ROV and use of sonar shall also be undertaken, and the touchdown point carefully monitored over the crossing. A transponder shall be installed at the crossing to ensure that an accurate location fix can be made, thereby achieving the correct placement of the umbilical at the crossing point.

For burial operations, it is necessary to transition the plow/trencher back to the surface of the seabed short of the crossing point and return the vehicle back to the vessel deck and secure it there for the crossing. No attempt shall be made to fly the plow/trencher over the pipeline, and it shall be fastened on deck during the crossing. Plowing/trenching can then be restarted on the other side of the crossing.

Further protection is necessary to ensure that the umbilical is not vulnerable to damage at the crossing.

8.4.15 Arming of Weak Link

The arming of the weak links, if fitted, shall be carried out on completion of the following:

a. Burial of the umbilical by plow or trencher (if required).
b. Second end pull-in and hook-up of termination.
c. Attachment of any weak link restraints to the structure.

Yet this arming shall be carried out before the installation test, which in this context may be a post-pull-in test or a final system functional test.

8.4.16 Completion of Protection

After completion of burial of the umbilical by plow or trencher, there will still be lengths of umbilical which remain exposed due to limitations on the positions in which the plow or trencher can be deployed. These limitations on deployment, and subsequent exposed umbilical lengths, may be located at the following:

a. The approach to the I/J-tube(s) at the platform(s).
b. The approach to the subsea termination.
c. Any pipeline crossings.
d. Any parts of the route that are of too small a radius for the trencher or plow to negotiate and are consequently laid without burial.
e. Repair joints where a spare length or repair has been effected following damage during installation.
f. Regions where the trencher has been recovered for change-out of cutting teeth and the like.

During the initial installation planning, a decision shall be made whether or not to protect the exposed umbilical in the above-listed areas (8.4.16, items a–f). Protection may be accomplished by sandbagging, laying mattresses over the umbilical, or alternatively by rockdumping over the umbilical. A further method that is used in the vicinity of the I/J-tube is applying molded tubular protectors to the umbilical prior to its being overboarded.

8.4.17 Post-lay Survey

In the case of a simultaneous lay and bury operation the post-lay and post-burial surveys are combined.

The post-lay survey shall be carried out (usually by the installer) to confirm the as-laid position of the umbilical, and to confirm the absence of damage to the umbilical.

The survey shall be carried out either as a separate operation using visual observation from an ROV when a lay and post-burial operation is undertaken, or from the plough/trencher when a simultaneous lay and bury operation is performed.

The video recording shall include a display overlay showing the camera position coordinates and heading.

The resulting video records shall be supplied to the client.

8.4.18 Post-burial Survey

A survey of the entire route of the umbilical immediately following burial shall be undertaken (most normally by the installer). The survey shall show that the burial operation has been carried out in accordance with the specified requirements.

The survey shall be carried out by ROV and should include the following:

a. A video survey of the entire length of the umbilical route.
b. Identification of the positions of any unburied or unsupported lengths of the umbilical.

If shown to be necessary, the installer shall carry out suitable remedial work, so that the installation meets the agreed burial requirements. In these circumstances, the relevant areas shall be re-videoed.

The documentation shall include the following items:

a. A written report of the survey findings.
b. A full set of videotapes of the survey.
c. Charts showing the as-buried position and depth of burial of the umbilical.

8.4.19 Post-pull-in Test

These tests shall be performed once the subsea termination has been pulled into its final position. In the case of a stab plate connector, the act of pulling the termination into its final position shall cause the functional connections to be made. In this event, the post-pull-in test becomes the post-hook-up test.

The test details are given in Section 10.

8.4.20 Post-hook-up Test

These tests shall be performed once the subsea functional connections have been made. The installer shall ensure by liaison with the control system vendor that these tests shall cause no damage to the control system.

The test details are given in Section 10.

8.4.21 Retrieval of Installation Aids

The installer shall be responsible for retrieving all temporary subsea installation aids after successful completion of installation of the umbilical.

8.4.22 Contingencies

There are a number of potential problems which may arise during the course of an installation operation for which contingency planning is required. The installer shall carry out a risk assessment study to cover foreseeable occurrences, including common mode failures, and produce suitable procedures.

Examples of some of the matters that need to be addressed, and possible approaches, are contained in Appendix D.

8.5 POST-INSTALLATION SURVEY

The installer shall carry out a survey along the entire subsea route of the umbilical including the I/J-tube bellmouth(s) and subsea termination. The survey shall be carried out using a side scan sonar and/or a video camera mounted on an ROV, and equipped with a remote monitor so that the client may view the survey as it takes place.

The survey shall verify that the umbilical and associated accessories such as seals, weak link, bend restrictor, and protection have been installed in accordance with the specification requirements, and that all temporary installation aids have been removed.

The post-installation survey shall also include all umbilical terminations and anchor points which shall be inspected for leakage and damage.

The results of the survey, together with the continuous, unedited original recording of the whole inspection shall be part of the as-built documentation. The recording shall include a display/overlay showing the equipment position coordinates and heading, so that the as-laid position of all items is recorded.

If the survey shows that the client specification has not been met (for instance, inadequate protection), the installer shall undertake appropriate remedial work.

The various surveys (post-lay/post-burial) may be combined into a single post-installation survey.

9 Repairs to Umbilicals

9.1 INTRODUCTION

If damage occurs to the umbilical in the course of installation, or sometime after installation, it may be necessary to effect a repair. The approach adopted depends on the stage at which the problem occurs and the length of umbilical which has suffered the damage. It is also possible that the repair might be required following an emergency abandonment (cutting) of the umbilical. Each repair shall be installation specific. The installer, in conjunction with the manufacturer, shall prepare procedures for the repair of the umbilical prior to the commencement of the installation.

9.2 DAMAGE OCCURRING DURING INSTALLATION

Damage which occurs during installation may manifest itself either from the monitoring of the services within the umbilical or from visual observation. At the time the damage is suspected, the installation operation shall be suspended for further detailed investigation and assessment of the problem. If required, further testing shall be undertaken to assess the nature and extent of the problem, and the exact location of the fault if it is not obvious.

Parameters such as vessel and touchdown position, date and time, and environmental conditions when the lay operation is suspended shall be noted for reference in any subsequent investigation.

Once it has been established that there is damage to the umbilical that would impair its function, the installer shall prepare a fully detailed written damage report, along with a suggested course of action for repair or recovery.

Umbilical recovery shall then be carried out. The operation will continue until the damaged portion of umbilical is on the deck of the vessel.

10 Testing

10.1 SUPERVISION

The installer shall appoint a QA/QC representative who shall be responsible for supervising and documenting each test. A certificate shall be produced for each test, recording all appropriate test data. Test failures shall be clearly indicated on the certificate.

The installer shall ensure that adequate safety equipment and procedures in accordance with the safety plan are available during the testing.

10.2 TEST PROCEDURES

All tests referenced in this section are in accordance with API Specification 17E. For further details on umbilical tests refer to API Specification 17E unless otherwise agreed between client and installer.

The following tests shall be carried out as required in Sections 10.3, 10.4, 10.5, and 10.6 for pre-load-out, post-load out, post-installation and post-hookup.

10.2.1 Electrical

10.2.1.1 General

Unless otherwise specified these tests shall be carried out on each completed electrical power and signal unit contained within the electrical cable bundle of the completed umbilical.

10.2.1.2 DC Conductor Resistance Test

The corrected DC conductor resistance shall be within ± 2 percent of the values obtained during the umbilical factory acceptance tests.

10.2.1.3 Insulation Resistance

Each conductor shall be tested for insulation resistance. Insulation resistance shall be measured and calculated in accordance with IEC 502. The value of insulation resistance shall not be less than the value as defined in the manufacturer's written specification.

10.2.1.4 High Voltage Test

Each insulated conductor shall be high voltage DC tested. The DC withstand voltage for communication conductors shall be three times U_o.

Each insulated conductor shall withstand a minimum DC withstand voltage between conductor and all other conductors and armouring 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.

10.2.1.5 Time Domain Reflectometry

A time domain reflectometry (TDR) trace shall be obtained for each conductor, and where possible, from both ends.

The width of the pulse shall allow the whole cable to be scanned.

Graphs produced shall have detailed all the major points such as start and end of the cable and joints (if present).

The TDR traces obtained shall be compared with those obtained during the FAT and any changes accounted for to the client's satisfaction.

10.2.2 Hydraulic

10.2.2.1 General

Unless otherwise specified these tests shall be carried out on each completed hose assembly including any intermediate couplings and end fittings that form part of the umbilical bundle.

From the FAT, carried out in accordance with API Specification 17E, and environmental conditions during installation, it shall be decided whether the hose pressure test (Section 10.2.2.3), the pressure decay test (Section 10.2.2.4) or both shall be carried out offshore to demonstrate umbilical integrity. The decision arrived at shall be justified at the time of producing test procedures.

10.2.2.2 Test Fluid

The installer shall be responsible for frost protection of the fluids. When there is judged to be any risk of freezing, a change in either fluid or concentration may be necessary. The installer shall take all reasonable precautions to ensure that contamination of the test fluid is prevented and all test fluid shall be new and unused. Manufactured hose lengths shall be capped off with screwed caps at all times when testing is not in progress. Tests shall be carried out at ambient temperature.

10.2.2.2.1 Hydraulic Control Hoses

The test fluid shall be the specified system control fluid new, unused and filtered to 5 microns absolute. The test fluid shall be guaranteed clean to ISO 4406 class 15/12.

10.2.2.2.2 Chemical Injection Hoses

The test fluid shall be a solution of potable water plus 25 percent monoethylene glycol, filtered to 5 microns absolute. As necessary, suitable biocides shall be added.

10.2.2.3 Hose Pressure Test

A proof test as specified in ISO 1402 shall be carried out on each final hose assembly, including all fittings and couplings that are in the umbilical bundle.

The test pressure shall be 1.5 times (or according to installer's written specification which shall be based on the manufacturer's data) the maximum working pressure, and must remain constant to within ± 5 percent for a period of 60 minutes after stabilization of pressure has been achieved. The maximum rate at which the pressure is raised or lowered shall be 10 bar/minute. If the pressure is not held within the specified tolerance then the reason for the excessive decay shall be investigated. The test pressure and fluid temperature shall be measured at both ends of the hose, where possible.

Note: The test pressure for the post-hook-up hydraulic tests shall be 1.0 times the operating pressure for control lines, and 1.1 times for chemical lines.

10.2.2.4 Pressure Decay Test

Each hose assembly shall be connected to a hydraulic supply at one end-fitting, taking care to obtain a leak-free seal. A pressure transducer connected to a chart recorder with an event marker shall be installed at the end-fitting not connected to the hydraulic supply. The chart recorder shall be used to record the pressure for the entire test.

The hose shall be filled with the specified test fluid, bled of all entrapped air and the remaining end-fitting closed off.

The chart recorder shall be started and the entire hose pressurized to the test pressure specified in Section 10.2.2.3 (with a rate of pressure rise that is no greater than 10 bar/minute) and isolated from the pressure supply. After a period of 15 minutes repressurize the hose to the test pressure and isolate from the supply. Allow a further period of 15 minutes before repressurizing to the test pressure a third and final time. The test shall be complete 15 minutes after the final repressurization. The start of each repressurization shall be marked on the pressure trace using the event marker.

Note: The test pressure for the post-hook-up hydraulic tests shall be 1.0 times the operating pressure for control lines, and 1.1 times for chemical lines.

The pressure at each successive event marker on the trace shall be higher than the pressure at the previous markers, and the pressure trace after the last pressurization must show clear signs of leveling out. (Typical industry practice is that the initial pressure decay should be no more than one third of the test pressure.)

10.2.2.5 Flushing and Cleanliness Test

Once the umbilical has been fully installed, that is, laid-down, pulled-in, buried (if required), prior to or post-hook-up, depending on the system design, each hose shall be flushed according to the procedure laid out below.

Upon satisfactory completion of all other acceptance tests the installer shall flush each hydraulic control hose assembly individually with the specified test fluid.

All equipment for carrying out and monitoring this test shall have cleanliness levels equal to, or better than, ISO 4406 15/12.

Each hose shall be flushed with a minimum of two times the theoretical hose volume. In the case of a direct hydraulic control system the flushing requirement may be relaxed.

The flow rate should be sufficient to ensure turbulent flow throughout the hose. If this proves impossible to achieve on very long hoses without exceeding the maximum working pressure at the hose inlet, then the highest flow rate possible subject to this constraint should be used. A Reynolds Number of 10000 shall be used when calculating the ideal flow rate.

If gas-assisted flushing procedures are adopted to achieve turbulent flow in long hoses, then the installer shall first demonstrate to the client through experiment that the permeation of the gas through the hose liner over the time period of testing is insignificant, and not liable to cause blistering or other damage to the hoses.

10.2.3 Optical Fibers

10.2.3.1 General

Unless otherwise specified these tests shall be carried out on each optical fiber (or the fibers suitably concatenated) that form part of the umbilical bundle.

10.2.3.2 OTDR

Traces using an optical time domain reflectometer shall be taken at wavelengths as laid down in the manufacturer's written specification. The traces shall be the same as those from the factory acceptance test.

10.3 PRE-LOAD-OUT TESTS

These tests are only required to be carried out if the complete umbilical assembly has been transported from the manufacturer's works to another site, or has been stored for more than 3 months.

In either of these circumstances it is essential that the point at which responsibility for the umbilical is transferred from one party to another (normally from manufacturer to installer) is stated and agreed before operations commence.

These tests shall be carried out immediately prior to the load-out operation.

Electrical: Section 10.2.1	DC Conductor Resistance Test
Hydraulic: Section 10.2.2	Hose Pressure Test Pressure Decay Test
Optical Fibers: Section 10.2.3	OTDR

10.4 POST-LOAD-OUT TESTS

These tests shall be carried out immediately after the load-out operation.

Electrical: Section 10.2.1	DC Conductor Resistance Test Insulation Resistance High Voltage DC Test Time Domain Reflectometry
Hydraulic: Section 10.2.2	Hose Pressure Test Pressure Decay Test
Optical Fibers: Section 10.2.3	OTDR

10.5 POST-INSTALLATION TESTS

These tests shall be carried out immediately after the installation operation.

Electrical: Section 10.2.1	DC Conductor Resistance Test Insulation Resistance Time Domain Reflectometry
Hydraulic: Section 10.2.2	Hose Pressure Test Pressure Decay Test Flushing and Cleanliness Test
Optical Fibers: Section 10.2.3	OTDR

10.6 POST-HOOK-UP TESTS

These tests shall be carried out immediately after the hook-up operation.

Electrical: Section 10.2.1	DC Conductor Resistance Test Insulation Resistance Time Domain Reflectometry
Hydraulic: Section 10.2.2	Hose Pressure Test Pressure Decay Test
Optical Fibers: Section 10.2.3	OTDR

10.7 SUBSEA-TO-SUBSEA INSTALLATION

For testing of subsea-to-subsea installations a suitable temporary termination shall be manufactured to allow looping of all electrical and hydraulic services for testing purposes. If such a unit is supplied it should be operable by a diver or the ROV.

11 Umbilicals in Towed Production Systems

11.1 INTRODUCTION

Control umbilicals may be installed within bundles alongside production and service pipelines as part of a towed production system. The carrier pipe shall offer sufficient protection to the contents of the bundle.

11.2 UMBILICAL CONSTRUCTION

Any umbilical installed in the carrier pipe may be of a single construction or an individual construction of electrical cable and individual hoses or steel tubing. Splices in the umbilical, within the carrier pipe, shall not be acceptable. The armoring requirement of the umbilical shall be reviewed at the design stage with respect to the reduced installation stresses and inherent carrier pipe protection.

11.3 BUNDLE DESIGN

The following shall be considered during bundle design:

a. The bundle mass/displacement calculations shall take into account the umbilical mass.
b. If the umbilical is contained within the bundle, it shall have adequate support by means of internal spacers, or if piggybacked to the outside, the external fixings shall take into account wave-induced and current-induced drag loads during launch and tow. The crush loads induced by the clamps shall be considered. Alternatively, the umbilical may be installed inside a small sleeve pipe inside the carrier pipe.
c. The umbilical may exit the bundle through the bulkhead or through the carrier pipe wall depending on the type of penetration required, and its location for the termination detail.
d. The bundle expansion due to thermal loads shall be taken into account when fixing the umbilical lengths and adequate overlength provision made to prevent any adverse effect on the umbilical and end termination connectors.
e. Consideration shall be given to the potential consequences of carrier pipe nitrogen pressure permeating through the umbilical sheath into the interstitial spaces.
f. Bundle annulus temperatures shall be established such that operational conditions for the umbilical can be confirmed as being within design limits.
g. Compatibility of umbilical construction materials with annulus filling (inhibitor, biocide, gel, cement) shall be considered.
h. The umbilical shall be capable of accommodating the axial tension applied during the bundle fabrication stage, especially the pull-in operation, without damage to the internal construction.
i. Corrosion protection if steel tubes and end connectors are employed within an inhibited water environment.

11.4 HANDLING OF THE UMBILICAL

The handling of the umbilical prior to attachment to, or insertion in, the bundle shall conform to the applicable portions of Section 7.9.

11.5 LOAD-OUT MONITORING

On load-out of the umbilical onto transportation reels the umbilical shall be monitored according to Section 7.10.

11.6 VEHICLES AND EQUIPMENT (REEL DEPLOYMENT)

The transportation vehicle shall be suitable to accommodate the umbilical loads and be capable of travelling at slow

speed for unreeling operations. The umbilical powered reel shall be of sufficient power and speed control to suit the unreeling speed and required control.

The construction site shall have a suitable surface, gradient and wheel bearing capacity for the road transportation vehicle. The umbilical shall have a support track between the reel and lay into the bundle.

11.7 PERSONNEL RESPONSIBILITIES

For further details refer to Section 8.4.1.

11.8 UMBILICAL INSTALLATION

11.8.1 Introduction

There are two methods of installing an umbilical into a bundle:

a. By attaching the umbilical to a flowline during flowline assembly prior to fabrication of the carrier pipe around the flowlines.
b. By laying the umbilical into the bundle prior to sheathing the carrier pipe over the bundle.

11.8.2 Flowline Attachment

The umbilical shall be deployed from a reel of sufficient diameter such that the minimum bend radius is not exceeded. Where steel tubing is being installed by unspooling from a reel, a system shall be used to straighten the tubing prior to attachment to the flowline. Care shall be taken that no kinking can occur, and that the umbilical is protected from weld splatter.

11.8.3 Lay-in Method

If physical constraints exist, umbilical weight including the reel shall be such that it can be transported along the construction track for the unspooling of the umbilical. The umbilical construction may be supplied in its individual components to reduce the transportation weights and ease installation. (See Section 11.9).

11.9 JUMPER/RISER CONNECTIONS

The bundle towhead may contain an umbilical termination unit for connection to umbilical jumpers or umbilical risers. Alternatively, preconnected umbilical jumper or umbilical riser length may be transported piggybacked to the outside of the towhead and/or bundle.

11.10 TESTING

11.10.1 Onshore Testing

Onshore testing shall be performed after completion of the bundle. Testing should be in accordance with Section 10. Functional tests may be performed in the case of a towed production system.

11.10.2 Offshore Testing

Offshore testing shall be performed in accordance with Section 8.

12 Dynamic Umbilicals

12.1 INTRODUCTION

From a number of different dynamic umbilical configurations, a selection can be made which for given conditions, reduces fatigue damage during service life to acceptable levels. Fatigue damage in the umbilical can occur as a result of fluctuating tension, bending, and torque. Possible locations are at the interface between riser top and vessel, at the place where the riser touches the seabed, or in locations with a sudden change in stiffness.

Umbilical configurations are generally one of two types:

a. The free hanging catenary. A simple configuration with only an umbilical end termination at the vessel and no other supports than the seabed at the touchdown point.
b. The compliant (S or wave) shape with intermediate supports. The supports may be small buoyancy modules clamped on the umbilical, arches with buoyancy cans, tethers with clump weights, a tower with the top in midwater, or combinations thereof.

In addition, the local geometry can be enhanced, in order to limit fatigue damage, by:

a. Bend limiters at the ends. These devices mechanically restrict the umbilical from bending beyond its minimum allowable bend radius.
b. Bend stiffeners. These devices are incorporated in a termination, or are otherwise made part of the outer structure of the umbilical, and gradually increase the local bending stiffness.

The umbilical shall have the minimum number of connectors; as a result it is likely that the riser and stationary section on the seabed is a continuous length. However, some configurations require a seabed termination at the junction between the dynamic and static sections, which may conveniently allow for differences in construction between these two sections.

Some general guidance on selection of a configuration is given in Table 2.

12.2 INSTALLATION

12.2.1 Introduction

Although the installation of a static and a dynamic umbilical have much in common, there are a number of differences which have to be considered. These shall be dealt with during the preinstallation activities (Section 6).

12.2.2 Constraints on Installation

The installation of a dynamic umbilical is affected by:

a. The configuration of the installed umbilical.

b. The type of supports to be fitted to the umbilical or placed on the seabed.
b. Constraints imposed by other umbilicals, risers or anchor chains in close proximity.

12.2.3 Installation Analysis

Results from analysis carried out during the engineering phase shall be used by the installer to prepare detailed procedures and to quantify dimensions of the support structures and coordinates of the riser geometry, in addition to the applicable portions of the other installation analyses (Section 6.6).

The installer shall obtain information for examination of I/J tubes and hang-off positions on the production vessel in order to decide where to position the pull-in winch, temporary rigging, and testing and monitoring equipment. It may also be required to use cranes from the production vessel or an additional DSV to assist in installing supports, arches, and clump weights. Reach and capacity of these cranes shall be confirmed. The requirements on equipment regarding safety zones shall be established. If ROV or diver operations are scheduled from the vessels, the feasibility and safety of these shall also be assessed.

12.2.4 Installation Operations

In general the simplest configuration, with additional equipment, suitable for the safe operation under the expected environmental conditions, is preferred for the installation. Sufficient space shall be allowed for access and for any handling equipment which may have to be employed during prevailing installation sea-states. Allowance shall be made for increased installation loads caused by the inertia or suspended cable and/or buoyancy devices. Consideration shall be given to the crush resistance of the umbilical when it is suspended over a sheave or a support. The bending radius of the umbilical shall be closely monitored and controlled during the installation activities to prevent overstraining or kinking.

The free hanging configuration is very simple to install and does not create any specific constraints to equipment and procedures. The umbilical is simply transferred from the lay vessel and tied in to the production vessel. The configuration is then achieved by paying out the umbilical and moving the vessel in the direction of the track to be followed, the touchdown point being constantly monitored by an ROV.

In cases where buoyancy modules are attached to part of the umbilical to create a lazy wave configuration, the same procedure is used in principle as described above.

For configurations where support is given to the umbilical by a midwater buoy system with clamps, arches, tethers, and clump weights, the installation will be carried out with the lay vessel paying out the umbilical, assisted by a DSV (or possibly the production vessel) with cranes to install these supports. Effective communication and intimate knowledge of

Table 2—Dynamic Umbilical Configurations

Configuration	Advantages	Disadvantages
Free hanging catenary	Simple configuration. Very simple installation. No connection at seabed required.	Liable to rapid wear at seabed touch down point (unsuitable for shallow water or large top motions). High static load at top end connection.
Lazy S	No connection at seabed required. Midwater support is relatively stable. Support may be shared with other risers.	Motion and potential for wear at seabed can be significantly reduced if buoy tension is sufficient. Need to control bending not only at end terminations but also at midwater buoy. Not attractive where large midwater velocities are anticipated.
Steep S	Wear at seabed eliminated. Support may be shared with other risers.	May need a connection at seabed. Possible yaw instability of midwater buoy. Limited by buoy motions, particularly for shallow water applications or where large midwater velocities are expected. Seabed unit must resist upward forces.
Lazy Wave	No connection at seabed required. Simple installation.	Motions and potential for wear at seabed touchdown. Motions greater than for Lazy S although may be less than for free hanging riser. Not well suited for closely spaced, multi-line applications.
Steep Wave	Simple installation for deep water.	May need a connection at seabed.
Chinese Lantern	Simple configuration. Access from vessel floating above. Wear at seabed eliminated.	Limited capacity to absorb vertical movement. Positive and negative cycles of tension. Swivel or similar seabed connection for vertical termination may be required.
Tower with underwater catenary	Eliminates wear at seabed. No motions of midwater support.	Cost of tower and installation. Riser bending control must be provided at tower attachment.

the procedures by all parties involved is required.

These installations can be carried out either starting with a tie-in at the production vessel and laying away; or laying towards the production vessel and finishing with the surface tie-in. In the latter case, careful measurements are necessary to ensure that the remaining umbilical length fits the required geometry between the position of the touchdown point and the production vessel.

Testing shall be carried out in accordance with Section 10.

12.2.5 Umbilical Retrieval

The operation to retrieve an umbilical shall be similar to the reverse of the installation operation. The umbilical design with support system shall facilitate a straightforward retrieval operation. It will be necessary to carry out a pre-survey to assess the condition of, and the distances between, the installed risers and supports to assist in planning a safe retrieval operation without risk to the remaining umbilical and riser systems.

APPENDIX A—UMBILICAL TERMINATIONS

A.1 SUBSEA TERMINATION

The subsea end of a hose or electrical cable within any umbilical assembly will be terminated in half of an underwater mateable connector assembly. Electrical connectors will either be conductive or inductive, and hydraulic connectors will generally be selfsealing monocouplings. The subsea umbilical termination may be via a stab plate or junction box carrying all hydraulic, optical, and electrical connectors or with independent connections (jumpers) for each hose, optical cable, and electrical cable. The termination may be of a compact cylindrical design, perhaps less than 1.5 meters long and 0.8 meters in diameter and weigh a fraction of a ton. Alternatively, the termination could be cubical, having side lengths of several meters and a weight of several tons. Terminations are often referred to by acronyms such as UTA (umbilical termination assembly), SDU (subsea distribution unit), and SUT (subsea umbilical termination). Connection may be made to a subsea junction box, subsea manifold, or directly to a subsea control pod.

Depending on the arrangements (if any) that have been incorporated into the hydraulic circuits of the subsea structure to facilitate flushing of the umbilical, it may be necessary to make temporary hydraulic connections using jumpers to allow flushing to be carried out.

It is prudent, prior to the installation, to rehearse the tasks involved in connecting the subsea termination(s) with the personnel involved (divers or ROV operators).

A.2 TOPSIDES TERMINATION

The surface end of any umbilical will have the armor layer(s) terminated and connected to a flange or mounting at the top of the J-tube or I-tube known as the platform hang-off unit. The hang-off can be mounted either on top of the I/J-tube or on a bracket on the platform superstructure above the I/J-tube. Hoses, optical cables, and electrical cables will have appropriate terminations as specified in the manufacturer's written specification for connection to the topsides control equipment.

For the pull-in operation a bullnose shall be provided by the manufacturer to pull the umbilical topsides connection through the platform I/J-tube. All hydraulic, optical, and electrical connections shall be contained within the bullnose assembly and shall be sealed as appropriate to prevent ingress of water and other contaminants.

APPENDIX B—SUBSEA PROTECTION SYSTEMS

B.1 MATTRESSING

A protection mattress is an assembly of concrete segments that are flexibly linked together in an interlocking pattern with a network of polypropylene (or similar) ropes to form a continuous flexible barrier that may be used both for protection and to counteract seabed scour.

A mattress is typically 150 millimeters thick and about 5 to 10 meters long by 2.5 meters wide.

At the platform end of an umbilical, mattressing would normally be started nearest the I/J-tube bellmouth, typically from about 5 meters from the bellmouth depending on the umbilical configuration and distance to the touchdown point on the seabed. The configuration shall be confirmed by an ROV visual examination. Mattressing shall continue along the umbilical until the position at which the umbilical specified burial depth is achieved.

Similarly, at the subsea termination end, mattressing shall commence close to the subsea structure and continue until the point of full burial depth is reached.

At points of curvature in the umbilical route where mattressing is required, the mattresses shall be overlapped as necessary to avoid leaving exposed sections of umbilical within gaps.

At pipeline crossings, the first mattress laid shall be positioned centrally over the crossing to fully cover the apex of the umbilical path as it traverses up the slope formed by the filler material (such as rockdump, grout bags, or concrete pipe protection units) on one side of the pipe, over the pipe and down the slope on the other side. The mattressing shall continue on either side, until the point of specified burial depth is reached.

When all the required mattresses have been laid, the ROV shall carry out a video survey of the completed protection, recording the mattress positions.

B.2 ROCKDUMPING

Rockdumping can be used as an alternative to mattressing, and can be carried out in less calm sea conditions than are required for mattressing. The process uses a large specialized vessel and it may not be convenient to deploy such a vessel until the lay vessel is clear of the area.

The rock, of approximate diameter 75 to 200 millimeters, is dropped through a gall pipe of typically 1.2 meters in diameter which is lowered from the vessel. The lower end of the chute carries a frame equipped with thrusters, or a cable and winch system, to assist with positioning by adjusting the position of the frame and chute relative to the vessel. The frame also carries sonar to assist with location of the target. The depth of cover is controlled by the appropriate combination of vessel speed and rate of rock discharge.

An ROV is used for a pre-rockdump survey and a post-rockdump survey to ensure that the desired depth of cover is achieved.

B.3 INSTALLATION OF TUBULAR PROTECTION

Additional protection may be required on umbilicals in areas where it is not possible to protect them in other ways. Molded material applied to the umbilical in a tubular form during installation is one method of supplying such additional protection. The protectors are split and are attached to the umbilical with metal straps. The order of application of the segments around the umbilical is important, and the protection manufacturer's specification shall be followed.

APPENDIX C—TEST EQUIPMENT

C.1 HYDRAULIC EQUIPMENT

The installer shall as a minimum be equipped with the following items when handling hydraulic umbilicals:

a. Hydraulic power unit(s).
b. Flow measuring transducers.
c. Pressure transducers.
d. Temperature transducers (thermocouples or probes).
e. Suitably sized jumper hoses.
f. Selection of hydraulic fittings to match the jumper hose sizes in e. above.
g. Particle counting apparatus.
h. Spare filter elements for each filter.
i. Spare valves and actuators for items critical to the successful installation of the umbilical assembly.
j. Fluid reservoir tank(s).
k. Strip chart recorders.
l. Swaging equipment for hosing couplings.
m. Dead weight tester.
n. Fluid transfer pump.

Sizes and lengths of components may vary for each installation, and prior to the load-out operation the installer shall determine the equipment requirements to meet the needs of the client's specification for the installation. This includes consideration of the tests to be carried out and cleanliness levels specified.

C.1 ELECTRICAL EQUIPMENT

The installer shall as a minimum be equipped with the following items:

a. Time domain reflectometry apparatus.
b. DC continuity tester.
c. Instrumentation power supplies.
d. Dual beam storage scope.
e. Voltage measuring equipment for power and signal cables.
f. Current measuring equipment for power and signal cables.
g. Megger.

C.3 OPTICAL FIBER EQUIPMENT

A suitable optical time domain reflectometer (OTDR) shall be provided to monitor the continuity and attenuation of the optical fibers. The instrument shall be capable of measuring the optical performance at wavelengths as defined by the manufacturer's written specification.

APPENDIX D—CONTINGENCIES

D.1 I/J-TUBE OPERATIONS

D.1.1 Umbilical Jam in the I/J-Tube

This is likely to be revealed by an unexpected increase in the measured pull-in tension. In this situation, it is usual to pull back the umbilical a short distance before continuing with the pull-in. If this is unsuccessful, it is normal to recover the umbilical from the I/J-tube and re-gauge the I/J-tube prior to a further attempt at the pull-in.

D.1.2 Lay Vessel Failure to Hold Position

If the vessel moves off position, the umbilical shall be laid over the side in a manner to compensate for the vessel movement, until such time as the vessel can maintain its position. The pull-in on the platform shall be halted and the platform winch prepared to pay-out if necessary. Following the reestablishment of the position holding capability, the umbilical deployed to compensate for the vessel movement shall be recovered, and the vessel returned to its position to continue the pull-in operation.

D.1.3 ROV Failure

Depending on the stage of the operation when this occurs, the pull-in can be suspended and the ROV recovered to the surface for repair or replacement. Alternatively, the umbilical may be removed from the I/J-tube during the repair period.

D.1.4 Pull-in Winch Failure

The vessel shall cease to pay out the umbilical and the exact nature of the winch problem established. Depending on the results, and the point at which the problem occurred in the operation, a number of options are available:

a. Abort the pull-in and recover the umbilical from the I/J-tube until the winch is made serviceable.
b. Suspend the lay operation, with the umbilical maintained in its position, until repairs to the winch or powerpack are made.
c. Continue the pull-in using a mechanical system such as chain hoist. Monitoring of the pull-in tension shall be maintained.

D.1.5 Deterioration in Weather Conditions

If the weather is worse than was anticipated when the operation was commenced, and forecast to deteriorate outside the allowable range while the pull-in is under way, the lay vessel shall stop the pull-in and lay away the umbilical from the platform to a safe distance. Once a suitable distance has been achieved, the vessel shall heave to and await an improvement in the conditions. If the weather hold is lengthy, at periodic intervals the vessel shall be moved a short distance and a length of umbilical be paid out so that the portion of umbilical prone to most fatigue damage (at the point of overboarding from the vessel) is regularly changed. Following improvement in the weather to a condition suitable for recommencement of operations, the vessel can retrace its course, recovering the umbilical, until it is back in its original position and the pull-in can restart. Alternatively, if the pull-in is at an early stage, the pull-in can be aborted and the umbilical recovered onboard the vessel. All such lay-away and recovery operations shall be performed with the normal level of monitoring and control.

D.1.6 Abandonment of Umbilical

In the event of a need to abandon the umbilical from the lay vessel, the procedures adopted shall ensure that the cutting operation can be undertaken safely and in a controlled manner. Any necessary cutting equipment shall be thoroughly checked prior to the pull-in.

If time permits, the cut end being overboarded should be sealed to ease the subsequent repair.

D.2 LAY CONTINGENCIES

D.2.1 Vessel DP Failure

If both the primary and secondary DP system references fail, the vessel should be held in position using manual (joystick) control.

If the vessel suffers a total DP system failure and moves off position, the umbilical shall be overboarded in a manner to compensate for the vessel movement, until such time as the vessel can maintain its position. Similarly, the umbilical and tow wires of subsea vehicles shall be paid out. Monitoring of the catenary and the touchdown point shall be maintained. Following the reestablishment of the position holding capability, the lengths of umbilicals/wires deployed to compensate for the vessel movement can be recovered and the vessel returned to its position to continue the lay operation.

The contingency procedure for this eventuality shall include the detail of the load at which the umbilical should be cut to prevent excessive damage to its services.

D.2.2 Flexing of Stationary Umbilical

If the lay/burial operations are temporarily halted, a length of umbilical shall remain suspended in the catenary from the vessel until operations restart.

The suspended length is subjected to flexing, particularly at the point at which it exits the vessel lay chute and at the

point of touchdown on the seabed, due to vessel motion. The umbilical shall not be subjected to such flexing for more than a limited period (typically a few hours) before the umbilical should be paid out so that the point of maximum flex is moved a few meters along the umbilical. The period of time shall take cognizance of the results of any mechanical fatigue work carried out during the design stage. A vessel position move shall be made as the umbilical is paid out to maintain the correct catenary.

D.2.3 Obstruction to Progress of Subsea Vehicle

If in the course of trenching or plowing debris is discovered on the route, the choices that can be made are:

a. Halt the operation until the debris has been cleared, by either diver or ROV.
b. Alter the route so as to go around the obstruction.
c. Cease to trench/bury, ensuring that there is a suitable transition, and use a different form of protection in this area.

If the subsea vehicle's cutting or plowing implement has become entangled with an item such as a buried hawser, the operation shall be halted until the implement has been released. Care shall be taken to avoid any risk of damage to the umbilical. This disentanglement may be achieved by divers or an ROV using suitable cutting equipment, but in severe cases it may be necessary to reverse a trencher, or recover it to the surface. Following disentanglement, the implement shall be carefully visually inspected prior to recommencement of the operation.

D.2.4 Recovery of Subsea Vehicle

The condition may arise due to mechanical or electrical breakdown of the subsea vehicle during burial (whether simultaneous with the lay or post-lay) that the vehicle cannot be released from the umbilical using the normal systems. Depending on the design of the subsea vehicle it may be necessary to deploy divers to release the umbilical from a disabled vehicle. Alternatively, provision may be made for this to be carried out solely using an ROV.

D.2.5 Lack of Visibility During Trenching and Plowing

If the subsea visibility during trenching and plowing is such as to preclude the possibility of visual monitoring of the umbilical where it enters the vehicle bellmouth, then the operation shall be temporarily suspended. However, with the approval of the client the operation may continue if the vehicle is equipped with an umbilical position measuring system which confirms the angle of entry of the umbilical into the vehicle bellmouth in both horizontal and vertical planes. This matter shall be dealt with at the installation planning stage.

D.2.6 Failure of Burial Vehicle Cameras

Loss of operation of the trencher/plow cameras shall not require the installation to be suspended, provided that adequate visual monitoring can be continued using the ROV mounted systems, or that there is a suitable on-vehicle umbilical position monitoring system.

D.2.7 Onset of Bad Weather

The limiting weather conditions for the operation of all items of equipment used in the installation operation shall have been specified prior to the commencement of the operation as part of the installation analysis. The limiting conditions may vary depending on the particular stage of any operation, for instance, a subsea vehicle may be able to operate in worse weather conditions than those required for its safe deployment or recovery.

If the installer considers that weather conditions may deteriorate beyond those acceptable, he should continue to review the weather trend at short intervals as necessary (typically hourly) so as to anticipate the need for any contingency action.

If it is decided that contingency procedures shall be implemented, these can include:

a. Temporary suspension of the lay operation while the vessel is hove-to, while the subsea vehicle remains deployed.
b. Recovery of the plow/trencher. In the case of a simultaneous lay and bury, the vessel will remain in position, however, in a post-bury operation the vessel can run for shelter if necessary.
c. Recovery of the plow/trencher followed by continuation of a free-lay, preferably on the design route, but if necessary on an alternative safe route.

In circumstances where the weather deterioration is such that the umbilical and subsea vehicle have to be abandoned, contingencies such as those in Section D.3 can to be initiated.

D.3 ABANDONMENT AND RECOVERY OF UMBILICAL

D.3.1 Abandonment of Umbilical and Vehicle

In the case of simultaneous lay and bury operations where the subsea vehicle is still on the seabed during umbilical abandonment, the vehicle umbilical shall be paid out from the vessel and buoyed off.

This can be done by running the control umbilical off the winch in parallel with the umbilical, and buoying off the control umbilical at its end. The position of the subsea vehicle and the end of the vehicle umbilical should be recorded, to aid subsequent retrieval.

The umbilical shall be layed on the design route or a safe alternative route from the abandonment location. (Safe alternative routes should have been established during procedure development and preinstallation survey works.)

The vessel shall be maneuvered so that the possibility of entanglement of the umbilical and vehicle control umbilical is minimized.

During this emergency lay away all normal umbilical monitoring procedures shall be continued, and the lay down route recorded.

If time permits and the umbilical is not already terminated, the pull-in head (bullnose) should be fitted. Alternatively the ends of the umbilical services should be blanked off to prevent water ingress. A transponder and buoyancy device should be attached to the end of the umbilical, to ease recovery at a later time.

The rest of the operation shall be carried out in a manner analogous to that of overboarding and laying-down of a subsea termination.

It shall be confirmed that the seabed at the point at which it is intended to lay down the termination is suitable for that purpose.

D.3.2 Recovery of the Umbilical Following Emergency Abandonment

A possible approach is as follows:

The end of the umbilical (blanked off end, pull-in head, or subsea termination) shall be located by interrogation of a transponder fitted during the emergency abandonment, and a suitable line attached. The vessel shall be moved so that the desired horizontal offset between the seabed touchdown point and the vessel lay chute is established. The umbilical recovery can then proceed by moving the vessel towards the end of the umbilical in discrete steps, simultaneously raising the end of the umbilical. The umbilical touch down point shall be visually monitored with an ROV to enable the correct offset to be maintained to keep the umbilical under the required tension. The end of the umbilical shall be brought onto the vessel and the umbilical laid into the vessel lay chute, while the load is transferred from the lifting line to the vessel cable engine. The remainder of the umbilical shall then be recovered up to the point of abandonment. The umbilical can be stored on the carousel/reel as it is recovered.

After recovery, the umbilical should be inspected, and cut back as necessary. Suitable tests should be defined as part of the contingency procedures.

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