

NORSOK STANDARD

SUBSEA PRODUCTION CONTROL UMBILICAL

U-006
Rev. 2, June 1998

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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Standards Institution).

The purpose of NORSOK standards is to contribute to meet the NORSOK goals, e.g. by replacing individual oil company specifications and other industry guidelines and documents for use in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, the NORSOK standard will be withdrawn.

Annex A is informative.

INTRODUCTION

This NORSOK standard has been renumbered U-006 and replaces U-CR-006, rev. 1, January 1995.

ISO 13628-5 “Design and operation of subsea control umbilicals” is currently under development (presently at Committee Draft stage) and it is assumed that the ISO standard will replace this NORSOK standard.

1 SCOPE

This standard defines the minimum requirements for subsea production control and service umbilicals. The standard covers static and dynamic umbilicals and include the requirements for metal tubes as well as thermoplastic hoses for transfer of fluids.

This standard defines the functional and technical requirements for design and manufacture of subsea control umbilicals and applies to umbilicals containing electrical conductors, optical fibres, tubes and hoses.

2 NORMATIVE REFERENCES

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced below.

2.1 General references

NORSOK J-003	Marine Operations
NORSOK M-001	Material Selection
NORSOK M-601	Welding and inspection of Piping
NORSOK U-007	Subsea Intervention

2.2 Cable/Umbilical

BS 443	Galvanised coating on wire.
BS 1441	Galvanised steel wire for armouring submarine cables.
BS 5099	Spark testing of electrical cables.
BS 6234	Polyethylene insulation and sheath of electric cables.
BS 6622	Cables with cross-linked polyethylene (XLPE) or ethylene propylene rubber (EPR) insulation for voltages 3800/6600 and up to 19000/33000.
BS 6899	Insulation material tests.
IEC 704	Optical Fibre Cables Part 1: Generic specification.
IEC 228	Conductors of insulated Cables.
IEC 502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV to 30 kV.
IEC 811	Common test method for insulating and sheathing materials or electric cables.
IEC 885	Electrical test methods for electrical cables.
ISO 4406	Hydraulic Fluid Power - Fluids-Method of coding level of contamination by solid particles.
NAS 1638	Hydraulic fluid contamination.

2.3 Metal Tube and Fittings

ASME B31.3	Process Piping
ASME IX	Welding and brazing qualification
ASME V	Non-Destructive Examination
ASTM A450	General Requirements for Carbon, Ferritic Alloy and Austenitic Alloy Steel Tubes
ASTM G48	Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by the Use of Ferric Chloride Solution
BS 8010	Part 3. Pipeline Subsea: Design, Construction and Installation
DNV	DNV Pipelines rules
EN 287	Approval of welders
EN 288	Rules for Specification and Approval of Welding Procedures
EN 102 04	Documents on Material Tests

2.4 Thermoplastic Hoses

BS 5173	Methods of test for rubber and plastics hose assemblies, Section 102.1 Hydrostatic tests, Section 102.4 Volumetric Expansion Test.
BS 5540	Evaluating particulate contamination of hydraulic fluids.
ISO 527	Plastics, determination of tensile properties
ISO 1402	Rubber and plastics hoses and hose assemblies - Hydrostatic testing
ISO 3949	Plastics hoses and hose assemblies - Thermoplastics, textile-reinforced, hydraulic type
ISO 4080	Rubber and plastics hoses - Determination of gas permanence
ISO 4406	Hydraulic Fluid Power - Fluids - Method for coding level of contamination by solid particles
ISO 4671	Rubber and plastics hose and hose assemblies - Methods of measurement of dimensions
ISO 7751	Rubber and plastics hose assemblies - Ratios of proof and burst pressure to design working pressure
ISO 8308	Rubber and plastics hoses and tubing - Determination of transmission of liquids through hose and tubing walls

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

NORSOK	Norsk Søkkel Konkurransesposisjon, the Competitive standing of the Norwegian Offshore Sector, the Norwegian initiative to reduce cost on offshore projects.
Functional specification	As defined in ISO 13879 and 13880: Document that specifies the requirements expressed by features, characteristics, process conditions, boundaries and exclusions defining the performance of the product, process or service.
Technical specification	As defined in ISO 13879 and 13880: Document that prescribes technical requirements to be fulfilled by the product, process or service in order to comply with the functional specification.
Shall	Verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties.
Should	Verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.
May	Verbal form used to indicate a course of action permissible within the limits of the standard.
Can	Verbal form used for statements of possibility and capability, whether material, physical or casual.

3.2 Abbreviations

IEC	International Electrotechnical Commission.
ISO	International Organisation for Standardisation.
NPD	Norwegian Petroleum Directorate.
NTS	Norwegian Technology Standards Institution.
OLF	The Norwegian Oil Industry Association.
TBL	Federation of Norwegian Engineering Industries.
FAT	Factory Acceptance Test
ROV	Remotely Operated Vehicle
ROT	Remotely Operated Tool
WP	Working Pressure
DP	Design Pressure
TP	Test Pressure
QT	Qualification Testing
CR	Conductor Resistance
IR	Insulation Resistance
HV	High Voltage

4 TECHNICAL REQUIREMENTS

4.1 Functional Requirements

The control umbilical system shall be designed to transfer high and low pressure fluid supply, chemical injection fluids, annulus fluids, electrical power/signal and optical signals. If the umbilical contains a service line, it shall be designed to transfer chemical fluids, and will temporarily be exposed to well fluid at maximum wellhead temperature. The transfer process shall take place without fluid leakage or electrical noise/interruption.

All aspects of design, fabrication and testing (electrical and mechanical) shall be in accordance with this and other relevant international standards listed in clause 2.

4.1.1 Design Life

The umbilicals and all permanent parts of the complete umbilical assembly shall have a minimum design life as given in the project design basis.

4.1.2 Installation

The umbilical system shall be designed to meet the following requirements:

- It shall be installable using typical installation vessels and equipment such as reels, baskets, carousels, turntables, tensioners, etc.
- It shall endure all installation loads, including load-out, handling on installation vessel, lay tension, initiation, laying, testing, abandonment, pull-in and connection, trenching, rockdumping, possible disconnection and recovery. It shall also endure a backstroke, if required, during connection/disconnection.
- It shall be possible to repair the umbilical during installation. A sealing system to preserve the umbilical shall be included for use in case of cutting and abandonment during lay.
- The umbilical shall have sufficient specific gravity to lie stable on the seabed and to enable installation in predefined route including laying curves. The submerged specific weight shall also be sufficient to enable trenching.
- It shall be possible to perform hydraulic and electrical monitoring during installation.
- Fluid filled lines should be pressurised to approximately 5-10 bar above the hydrostatic seabed pressure prior to installation. Temperature variations shall be accounted for.

4.1.3 Terminations

4.1.3.1 Topside terminations

The termination unit at the topside end of the umbilical shall be designed for hang off and shall also include a bull-nose suitable for pulling the umbilical up through the platform guide-tube onto a termination support. For free flooded umbilicals it is sufficient to seal off the individual ends of the conductors and tubes, and use an open bull-nose.

Tubes shall be individually sealed to prevent hydraulic oil loss and water ingress during the pulling operations. Electrical conductors shall be sealed to prevent water ingress along the insulation.

If the umbilical is intended for temporary lay down, pressure relief during retrieval shall be considered.

The J-tube seals shall withstand 100 year maximum wave and maintain its differential pressure capability during service life. Free span corrections between J-tube bell mouth and seabed shall also be designed according to project specific design basis.

4.1.3.2 Subsea terminations

The umbilical manufacturer shall be closely involved with the chosen control system manufacturer in the design of the subsea termination.

The umbilical manufacturer's normal scope of work in this area of interface include the following:

- Tensile strength termination
- Termination bend limiter/stiffener
- Hydraulic terminations
- Electrical terminations
- Optical terminations

The electrical cables shall be terminated such that the electrical conductors are protected against sea water by minimum two individual testable barriers.

It shall be demonstrated that the termination system is capable to handle the extreme temperature/pressure combinations, to which the umbilical is exposed to.

The axial load requirements shall not allow structural damage to the termination or template landing structure. Weak link(s) if used, shall prevent axial or tensile damage to the termination and landing structure.

4.1.4 Field Repair Jointing

This type of joint is a complete umbilical joint assembly made necessary due to length constraints, or in order to repair umbilical damage. The jointing of the lengths of the umbilical shall take the form of a streamline field splice of minimum diameter.

The umbilical manufacturer shall provide methods for jointing tubes, electrical conductors, optical fibres, armouring and cable sheath. The field splice design shall be as small in length and diameter as possible, and rated to take the maximum tensile load of the bundle. The field splice shall be so constructed as to relieve all tensile loading from the electrical conductors and optical fibres. The field splice shall be designed for minimum offshore assembly time and shall be suited for assembly in harsh environmental conditions and limited space.

Qualified procedures/stiffener in accordance with the requirements of this standard shall be worked out before any repair can take place.

Bend restrictors to either side of the splice shall be provided, preventing excessive bending movements at the field splice entry.

4.2 Design Requirements

4.2.1 Hydraulic and Chemical Lines

4.2.1.1 General

The following effects shall as a minimum be taken into account in the design of the lines:

- Ambient effects:
 - Cooling; effects on pressure
 - Fluid expansion effects
 - Low ambient temperature
- Dynamic effects:
 - Impact
 - Fatigue
 - Long term effects on elasticity
- Weight effects:
 - Live loads
 - Dead loads
- Thermal expansion/contraction effects:
 - Thermal loads due to restraints
 - Loads due to temperature gradients
 - Loads due to differences in expansion
- Effects of support and termination head movements.
- Cyclic effects. Pressure, thermal and other cyclic loads.
- Galvanic reactions.

The results from evaluation of the above shall also be reflected in the umbilical design with regard to the tube lay angle, armouring and outer sheathing.

All lines shall be in metal alloy tubing or thermoplastic hoses designed for the required working pressure. The umbilical shall contain the specified number of hydraulic lines, which shall be compatible with the specified fluids, at the specified pressure and temperature ranges.

Effects as bacterial growth, corrosion etc. shall be considered for long term storage.

4.2.1.2 Metal

The metal alloy tubes can be seamless or welded.

The standards ref. to in subclause 2.3 apply and the following design standards shall be basis for the design: DNV Pipeline rules, BS 8010 or ASME B31.3 including the requirements of chapter IX. Metal alloy tubing shall comply with NORSOK M-601 Welding and Inspection of Piping.

The complete tube string shall be hydrostatically tested to 1,5 x WP.

Repair of weld defects shall be performed in accordance with an approved and qualified procedure. Repair welding of base material is not accepted.

Cleanliness level (excluding servicelines) shall be to ISO 4406 class 15/12 or NAS 1638 class 6 or as specified in the project design basis.

4.2.1.3 Plastic

The standards ref. to in subclause 2.4 apply.

The thermoplastic hoses shall be supplied by a prequalified supplier. The raw material (pellets) shall be new unused material which is kept to a high level of cleanliness. The extruded hose shall be compatible with the specified hydraulic, injection and annulus fluids. The hose braiding material shall be made from a high strength fibre. The braiding shall be applied in a way which minimise torsional forces generated during the line pressurisation and to minimise volumetric expansion and elongation.

There shall be no jointing of the thermoplastic hoses, except when required for a field joint or a complete umbilical factory joint.

The hoses shall be hydrostatically tested to 1,5 WP.

4.2.2 Electrical Cable

The standards ref. to in subclause 2.2 apply.

Sufficient cushioning shall be provided to prevent damaging of the copper conductors, insulation and sheathing during umbilical manufacturing processes, installation and the operational life of the umbilical.

The conductors should be plain annealed, copper wire and stranded with a minimum of 7 strands and a minimum cross sectional area of 2,5 mm². The electrical cable shall be filled with material such as petroleum jelly or similar that minimises void spaces and allows for element movement.

All conductors shall be insulated with an appropriate thermoplastic material suitable for subsea operation. Contractor shall state the average and minimum insulation thickness, which should be single or double pass ethylene copolymer, polyethylene or equivalent. Insulation resistance shall be quoted. All conductors shall be identifiable with different coloured insulation. The colouring shall be such as not to degrade the quality and permeation characteristics of the insulation material.

The umbilical shall include insulated electrical conductors as cable units. The cable should consist of unshielded conductors twisted together in form of pair or quads, or a coaxial design. Conductors shall be in accordance with recognised international standards.

At least the following shall be performed during manufacturing, in addition to measurement of all electrical parameters and characteristics:

- Continuous spark test on all insulation and sheathing production runs, when extruded over a conductive layer.
- High Voltage test when immersed in water, for all production lengths of insulated conductors. The insulated conductors should be immersed in water for 48 hours prior to testing.
- Dimensional. Insulation and sheathing thickness and diameter.

4.2.3 Optical Fiber Cable

The standard IEC 704 apply.

The fibre(s) shall be contained within a package which shall prevent water or hydrogen coming into contact with each fibre. The package and its contents shall be designed to block water ingress.

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

The optical fibre cables shall be terminated in a waterblocked and pressure compensated arrangement.

Where production lengths dictate, optical fibre cable lengths may be jointed.

If jointing of the fibres is required use of high strength fusion splicing techniques is recommended.

4.2.4 Armouring and sheathing

The Contractor shall propose an armouring design, if relevant, with due consideration to the tube mechanical properties.

Steel wires shall comply with the general requirements of BS 1441, BS 443 or equivalent standards.

Outer covering shall be resistant to ultra violet light.

The design to be suitable to resist impact and abrasion, and shall be torque balanced over the range of loads (during installation and operation).

4.2.5 Mechanical Loading

Contractor shall propose a design with due consideration to the mechanical strains imposed on the umbilical during manufacture, storage, handling including laying, retrieval, pull-in, connection, and operational life. The calculated mechanical strains in all phases shall be presented and form the basis for the umbilical design. The following shall as a minimum be addressed in the design:

- maximum allowed handling tension and minimum breaking strength.
- torsional balance.
- minimum bending radius, bending stiffness related to the tension level and other mechanical/material performance characteristics.
- effect of radial loads - collapse pressure / crushing force
- effect of installation tools like tensioners
- minimum allowed impact load from blunt objects shall be 5 kJ, unless otherwise specified
- effect of external forces as anchor chains/wires, trawl gears, etc.
- method for termination of tensile strength for the proposed design (armour block) with calculations.
- functional requirements for bend restrictors or bend stiffeners must be established
- recommended back tension during laying and pulling into J-tubes

Analysis of the tube performance in the umbilical shall be performed as follows:

- Analysis of the tube flexibility stresses. Bending and torsional stresses shall be computed, and combined to determine the displacement stress range. For steel lines, possible plastic deformation must be evaluated.
- Fatigue analysis according to commonly used models.

4.2.6 Material Requirements

NORSOK M-001 "Material Selection" applies. All materials supplied shall comply with recognised standards.

For metal alloy tubing, materials shall be delivered with material certificates according to EN 10 204. Certification for other materials shall as a minimum meet the requirements in the referenced standards.

The chemical resistance of all materials applied shall be documented.

All metal alloys used in the total umbilical system shall be corrosion resistant in the specified temperature range, or equipped with a suitable corrosion protection system. This shall also include the platform topside termination assemblies.

4.2.7 Marking and Traceability

4.2.7.1 Umbilical

The completed umbilicals shall be marked with length identifications every 10 m within 400 m from each end, and every 100 m in between. There shall also be a continuous coloured, well observable line along the umbilical. Where two or more umbilicals are routed together, each umbilical shall be easy to identify by ROV.

4.2.7.2 Tubes, hoses and cables

Marking shall be performed with not more than 1,0 meter spacing along the line. Identification marking may be performed at any stage up to but not preceding the hydraulic testing.

The marking shall not contain any harmful elements which may cause corrosive attack in the temperature range.

All tubes, hoses and cables shall be numbered and be legibly marked with manufacturer's name or brand, standard dimension and grade identification. The marking shall also indicate working pressure and whether tubing is seamless or welded.

4.2.7.3 Fibres

If the cable contains more than one fibre then fibre identification shall be by means of fibre-colouring marking.

4.2.7.4 Traceability

All materials shall be properly identified. A material control system shall be used to ensure that only approved material is used in the assembly and that every part can be identified to the relevant documentation.

Special emphasis shall be put on a registration programme for tube jointing and welding acceptance tests. The umbilical manufacturer shall propose a filing system to ensure full traceability of tube sublengths and joints.

4.2.8 Tube Fittings

Contractor shall propose fittings design and material suitable for the correspondingly proposed tube design and material. The fittings shall have at least the same pressure rating and corrosion properties as the tubing. Methods must be adopted to avoid autonomous unscrewing of fittings.

Any tube fittings shall be manufactured from high performance, corrosion resistant alloy galvanically compatible with and suitable for assembly to the proposed tubing and pull-in head (also in the field) using tools supplied by manufacturer.

4.3 Fabrication Requirements

4.3.1 Factory Acceptance Test (FAT)

FAT shall be carried out on all umbilical lengths complete with terminations at the respective storage location.

Test fluid shall be as specified in data sheet. Cleanliness level to ISO 4406 class:

- Visual - The completed umbilical shall be visually inspected.
- Proof Pressure $1,25 \times \text{WP}$ for:
 - metal alloy tubes: no pressure decay over one hour after stabilisation, any temperature variations caused by ambient conditions shall be accounted for.
 - thermoplastic hoses: 3% pressure decay over one hour after stabilisation.
- Flow rate - A flow rate test shall be carried out to prove the integrity of the tubes following proof pressure tests.
- Flushing and cleanliness verification to ISO 4406, or NAS 1638 class: see project design basis.

All lines shall be circulated with an acceptable hydraulic fluid at a Reynolds number greater than 4000. If this is impossible to achieve, an alternative cleaning method must be proposed. The cleaning process shall continue, minimum 3 total volume change-outs, until three consecutive cleanliness readings indicate cleanliness level equal to or better than ISO 4406, or NAS 1638 class: see project design basis.

No readings shall be carried out before the total line volume is flushed, i.e. one full circulation. The three readings shall represent different parts of the line length volume.

Electrical cables - The following tests shall be carried out on each power/signal cable:

- CR, IR and HV DC tests

- Attenuation
- Mutual Capacitance
- Signal Propagation Delay Time
- Crosstalk attenuation (signal/signal)
- TDR.

Where applicable, the specified frequency shall be used, see project design basis.

Fibres - Each fibre within the cable shall be subject to an OTDR test at the specified wave lengths, from each end.

If any spooling/transfer, or long term storage of the umbilical takes place between FAT and load out, then the umbilical manufacturer shall confirm the quality of the umbilical prior to load out to the Company supplied vessel.

The following dimensional checks shall be performed in manufacture: Every 100 meters of sheath O.D. during manufacture - tolerances to be as per specified requirements and periodic checks of armour lay.

Optical test requirements to be specified in the project requirements

4.3.2 Documentation Requirements

As a minimum the following documentation should be available:

- Umbilical Design Specification.
- Analysis related to installation and operation.
- Material Selection Report.
- Corrosion Protection Report (if relevant).
- Failure mode, Effects and Criticality Analysis (FMECA).
- Welding Procedures/Specification.
- NDT-Specification, Tube Welding.
- Fluid Compatibility Analysis (if relevant).
- Qualification Test Report.
- Acceptance Test Report.
- Acceptance Test Procedure.
- Drawings, Umbilical, Terminations, Topside Hang-off.
- Installation procedure
- Handling procedure
- Line identification
- End termination
- Umbilical marking
- Information regarding flow characteristics that enables hydraulic calculations to be performed.
- A detailed stress analysis shall be provided, taking due account to the operational requirements, the laid-up configuration and the restraints within the umbilical.
- Procedures for assembly of the following:
 - Jointing in Factory controlled conditions

- Jointing dockside
- Offshore repair jointing
- Spliced cable Installation Procedure

All material certificates and all other test results and documentation pertinent to the materials shall be collected in a material data book.

ANNEX A QUALIFICATION TESTING (INFORMATIVE)

A.1 QUALIFICATION TESTING

A.1.1 General

In the case where metal alloy lines forms part of the umbilical's loadbearing structure, detailed analysis shall be carried out, covering all aspects of loads and load combinations for the lines during manufacturing, testing, loadout/transportation, installation and operation. Analysis shall be supported by qualification testing unless the design is field proven. For lines where plastic deformation and accumulation of strain in the material will take place, it shall be documented with analysis and material tests that the stress and strain in the material is within acceptable limits.

For line sizes or applications where traditional hose design is unsuitable, for example as service lines, flexible pipes may be used. Flexible pipes to be used in the umbilical shall be of field proven design from a prequalified supplier, the flexible pipe shall be qualified through a special qualification programme and approved by Company prior to use in the umbilical.

Detailed analysis shall be performed for the umbilical. For the umbilicals with service lines (containing one or more larger diameter lines), the load distribution and interaction between the elements shall be emphasised.

A.1.2 Qualification and Acceptance Testing of Tubes/Hoses

A.1.2.1 Metal alloy tubes

Metal alloy tubes shall as a minimum be tested as specified in the reference standard. The following tests in accordance with ASTM A450 is mandatory:

- Tensile test
- Flattening test
- Reverse flattening test (welded tubes)
- Hardness test
- Hydrostatic test
- Radiographic testing of welds
- Visual and dimensional checks
- Corrosion tests

A.1.2.2 Thermoplastic hoses

The following tests shall be carried out on unaged sample hose lengths to the requirements of ISO 3949:

- Change in length test
- Burst test

- Cold flexibility test
- Oil resistance test
- Impulse test
- Leakage test
- Volumetric expansion
- Coupling retention
- Compatibility test.

A.1.3 Qualification and Acceptance Testing of Electrical Cable

A.1.3.1 Qualification Testing

The following tests are required to be carried out on sample lengths taken from the production lengths.

- Dimensional checks.
- Stripping test - using proprietary tools, a sample of each cable should be stripped to check ease of removal of sheath and insulation.
- Water absorption - to be carried out in accordance with the requirements of BS 6899 Test method F, or equivalent standard.
- Material tests - insulation and sheath materials to be checked in accordance with the requirements of Clause 8 of BS 6899 or equivalent standard. Documentary evidence is required to prove that the cable materials are compatible with the specified hydraulic fluid and any other fluid which may come in contact.
- Tensile strength and elongation at break before and after ageing in oven shall be checked for each core size and each sheathed cable.
- High voltage breakdown - the voltage at which the insulation breaks down shall be checked.
- Dielectric Test - Dielectric test shall be performed between conductor/conductor and conductor/shield within the pair.
- The Dielectric test potential shall be determined by the following equation $DV = ((Rx2) \times 2 + 1000)$ where DV is the dielectric test voltage and R the conductor application voltage rating in VAC. The dielectric test voltage shall be in VDC. The dielectric test voltage shall be applied for a minimum of 10 seconds and a maximum of 60 seconds. Any evidence of flashover or insulation breakdown during or subsequent to this test constitutes a failure.
- Insulation resistance testing conductor/conductor in each twisted pair assembly. The test voltage shall be a minimum of 500 VDC with a minimum resistance of 500 Mohm x km.

A.1.4 Umbilical Qualification Test

The following qualification tests shall be carried out on an unaged sample of umbilical to prove compliance with the specified requirements. The length of samples to be agreed prior to the tests.

1. Torque balance - A sample length of umbilical shall be tested for torque and rotation characteristics up to maximum installation tension in one (1) tonne or min. 5 % increments. Values of torque and rotational angle shall be recorded at each step. The tests should be performed greater

than ten (10) times and the instruments/ recorder should not be zeroed between tests, in order to establish the residual torque and rotational set. The sample shall not be exercised prior to this test. All lines shall be pressurised to WP.

After the test, the sample shall be cut into four sections. The exposed ends examined for any damage to the bundle and the sample dissected to record layer information, lay angle, damage, etc. A photographic record of the exposed ends and dissection shall be made.

2. Tensile test - The sample shall be tensile tested to maximum installation tension ten (10) times. The elongation shall be recorded as a function of the applied load. The instruments/- recorders are not to be zeroed after each cycle in order to register the amount of residual tensile set.

After the tenth cycle, the sample is tensile tested to break or to a tensional load twice the maximum installation load to verify design figures. All cycle data shall be recorded and reported.

3. Bending and tensile test - This test shall be performed in accordance with CIGRE recommendation no. 68. An umbilical sample shall be subject to bending around a sheaf with diameter equal to the umbilical minimum bending diameter when tensioned to max. installation load. The sample shall be wound and unwound on the sheaf for 3 times consecutively without changing the direction of bending.

4.a) Bend Cycling Test I - A sample of minimum 50 meters shall be bend at least 180° around a cylindrical barrel with radius corresponding to minimum bend-radius and tensioned to maximum given design load. Thereafter the barrel shall be moved in two directions, a total of 400 times. Following the bending operation, the sample shall be immersed in water for 24 hours and a high voltage test, AC for 5 minutes carried out on each cable between each conductor and the remaining conductors connected to the water. A proof pressure test of 1,5 x WP shall be carried out on the fluid lines. The DC resistance and the capacitance of each conductor resp. pair shall be monitored and no increase in its value shall be noted when measured under the same temperature conditions.

The sample shall be stripped down for examination.

4.b) Bend cycling test II - An umbilical sample shall be subject to figure of eight reverse bend testing a total of 400 times. Typical tension according to umbilical design.

Following the bending operation, the electrical cable shall be high voltage tested, AC for 5 minutes between each conductor and the remaining conductors and shield connected to earth.

A proof pressure test at WP shall be carried out on the tubes.
The sample shall be stripped down for examination.

5. An umbilical sample shall be subject for pressure cycling to 1,2 x WP. The sample shall withstand a minimum of 7000 cycles to prove suitable for "severe cyclic application".

6. Burst test - A sample of sufficient length shall have one tube pressurised quickly until it bursts. The sample shall be stripped down for examination.

A.1.5 Ancillary Equipment Qualification Test

A.1.5.1 Umbilical joints QT

As a minimum requirement, the proposed umbilical joint shall be qualified for service in the following manner: A joint shall be connected onto a suitable length of umbilical, enabling it to be tensile and pressure tested:

- Tensile test up to the maximum installation load.
- Line pressure tested to 1,5 x WP for a period of not less than five minutes, not less than fifty times. Pressure chart to be enclosed in report.
- The joint shall also be placed into a pressure chamber and submitted to a water pressure simulating working depth for a period of not less than 48 hours.
- The insulation resistance (IR) shall be not less than 500 Mohms x km at any time of the testing. IR shall be measured at 12 hours intervals and the IR/pressure test shall be continued if a variation of more than 20 % occurs during the two last 12 hours periods, until the IR has stabilised. If this does not happen and the IR values keeps deteriorating, the test shall be considered failed when this value falls below 500 Mohms x km.
- All joints and fittings shall be compatible with specified hydraulic and service fluid and withstand contact with sea water at working depth pressure head.

A.1.5.2 Terminations QT

The following items will all require simulated operational testing before being accepted.

- Platform termination.
- Subsea termination.
- Weak link(s) (if used).

Procedures for testing of equipment shall be written by the umbilical manufacturer.