



PETROBRAS

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SUBSEA CONTROL UMBILICALS

E&P-ENGP/IPP/ES

Electrical Cable Element: Four Twisted Pairs of 6.0 mm² @ 0.6/1.0 (1.2) kV

INDEX OF REVISIONS

REV	DESCRIPTION AND/OR AFFECTED SHEETS
0	Original

	ORIGINAL	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
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1 - PURPOSE

This specification defines the minimum requirements for design, manufacture, qualification and acceptance of the submarine electrical cable component and accessories required for subsea control umbilicals that requires four **(4) TWISTED PAIRS of 6.0 mm² conductors. Cable Voltage Class shall be 0.6/1.0 (1.2) kV**, according with IEC 60502-1 Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 3 kV ($U_m = 3.6$ kV) standard. Typical cable use will be comms-on-power utilities for subsea multiplex control system.

NOTE: This specification is part of a document package for product development or bid purposes, that shall be referred in full for all relevant umbilical design data and its intended application.

2 - GENERAL

2.1-According to the respective umbilical RM, the electrical cable in this document shall be composed of four (4) individually screened (shielded) twisted pairs of 6,0 mm² conductors, either bundled and sheathed together or individually, according with the electrical characteristics of item 3 of this document. The cable configuration for each type of umbilical is open to the supplier best design, provided the following rules are observed:

- Cable configurations by which the four pairs are bundled and sheathed together shall be armored and placed whenever possible in the center of umbilical.
- Cable configuration by which each electrical pair is an individual cable by itself shall have each of said pair as an individually armored cable.
- Each set of two PAIRS shall be terminated by a cable/hose crossover interface according to the specifications mentioned elsewhere in this document (see item 2.20).
- ATTENTION: QUADS will not be allowed to fulfill this specification.

2.2- Unless otherwise herein specified, the standards that applies for the electrical cable element design, manufacture and testing are the current versions of:

- API Spec 17E & ISO 13628-5: Design and operation of subsea production systems, Part 5: Subsea Umbilicals.
- IEC 60502-1 Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 3 kV ($U_m = 3.6$ kV).
- IEC 60228: Conductors of insulated cables.

Alternative standards, if proposed, shall be submitted to PETROBRAS for approval before the umbilical detail design;

2.3-The electrical cable shall be provided with adequate mechanical strength to protect it over the range of loads during manufacture, handling, installation, operation and retrieval expected during the specified service life;

2.4-The electrical cable functional characteristics shall be assured during umbilical manufacturing, storage, transportation, handling, installation, testing, operation and retrieval, for the specified umbilical service life;

2.5-Materials to be used in the electrical cable and its accessories shall withstand the aging and degradation due to ambient conditions during the specified service life. It

includes, among others, agents such as sea water and marine growth, as well as UV radiation when the cable extremities are subjected to long term (i.e. six months) sun radiation during umbilical storage at a non protected area or during operation (i.e. cable sections connected to the platform facilities);

2.6-The electrical cable design shall allow the lowest possible friction between the cable elements. Supplier shall state how the cable design and manufacture will address the movement between its components. Lubricants, if used, shall be compatible with other materials of the cable;

2.7-The electrical cable shall have at least two mechanical barriers against water to get into contact with the electrical conductors. Supplier shall state in its proposal how the cable design will accomplish this feature;

2.8-Each electrical conductor shall be made of high conductivity plain or tinned annealed copper wire with a minimum of 7 strands, complying with IEC 60228 standard;

2.9-All conductors shall be insulated with single or double pass ethylene propylene rubber (EPR), cross-linked polyethylene (XLPE) or other equivalent thermoplastic material suitable for subsea use. Supplier shall state the minimum and average insulation thickness in the bid proposal cable data sheet and confirm it prior the electrical cable manufacture;

2.10-WATER BLOCK SYSTEM: The conductors shall be longitudinally sealed to prevent water penetration (between the wires) along the electrical power cable in case of umbilical (cable) severance. The sealing material must be thermally and chemically compatible with all other materials in the umbilical. The Supplier shall state in the umbilical proposal the designed technical characteristics related to the water penetration prevention, explaining how this requirement will be addressed;

2.11-Each twisted conductor pair shall be covered with a thermoplastic material suitable for subsea use;

2.12-The electrical cable shall be designed and manufactured in such a way that fusion between polymeric layers and between insulation and copper cores is avoided. Supplier shall state in its proposal how the cable design and manufacture will accomplish this feature;

2.13-The electrical cable shall have sheaths with thickness and physical properties suitably selected to not compress the electrical cores due to shrinkage after extrusion. Also, extruded layers, which are designed to assure water tightness at the interface between electrical cable and its connector, in order to assure such property, shall have their circularity controlled during manufacturing process. Supplier shall state in its proposal how the cable design and manufacture will accomplish the above features;

2.14-The shielding requirements for each pair shall be according with ISO 13628-5 or API Spec 17E standards. Drain wire total cross-sectional area shall not be less than 0.30 mm²;

2.15-The insulated conductors shall be coded as per ISO 13628-5 or API Spec 17E standards. Sequential numbers shall be used for conductor identification. Color coding may be used as an alternative. Conductor markings shall be stable under all

environmental conditions for storage, handling and operation during the specified service life and shall not impair conductor insulation.

2.16-Fillers, if used, shall be of polymeric material that shall not degrade other materials in the cable, specially the conductor insulation. Refer also to ISO 13628-5 or API Spec 17E standards;

2.17-Steel wires for armoring, if used for each pair individually or in the cable bundle, shall not degrade with corrosion. Supplier shall be asked at any moment prior to the final delivery of the umbilical to make accelerated corrosion tests to demonstrate that mechanical strength of the armor wires will be compatible with the umbilical minimum 20 year working life. Supplier shall present PETROBRAS a report on the necessity (or not) of anti-corrosive treatment of cable armoring, if used, prior cable manufacture;

2.18-The electrical cable outer sheath shall be of a thermoplastic material that shall not degrade the quality of other materials which it may be in contact in the lay-up. The cable outer sheet shall not be considered as a mechanical barrier against sea water intrusion. The outer sheet shall be designed so that the electrical insulated conductors are capable to operate in a fully flooded environment;

2.19-The electrical cable minimum bending radius shall be compatible with the dimensions of accessories such as pull-in heads for which the cable may be stored during deployment or abandonment in the sea bed. The reference minimum bending radius for the cable without armors shall be preferably no larger than 500 mm;

2.20-The specified service life of the electrical cable, accessories, connectors and the crossover referred below is 25 years of operation or the value specified in the electrical cable umbilical specification, whichever is the greatest. Manufacturer shall document all characteristics of the material used to construct such components confirming that all kinds of possible degradation will not occur (including aging and corrosion);

2.21-According with the configuration specified in 2.1 above, all subsea cables shall be terminated subsea in a set of cable/oil-filled hose crossovers already assembled and tested in the electrical. Each cable/oil-filled hose crossover will have an electrical penetrator to receive the subsea equipment (Manifold & other) electrical system cable conductors and a JIC standard hose interface to allow the hose be oil-filled and pressure tested after the subsea equipment electrical cable conductors are soldered into the penetrator;

3 - ELECTRICAL CHARACTERISTICS

Cable Voltage Class	0.6 / 1.0 (1.2) kV
Nominal Operating Frequency (Power)	50/60 Hz (see Note 1 below)
Nominal Operating Frequency (Signal)	15.5 kHz (see Note 1 below)
Maximum DC Conductor Resistance:	3,1 Ω/km
Minimum Insulation Resistance:	1 GΩ @ 500 VDC @ 20°C @ 1 min.
Operating Temperature	-10 to + 40°C
Maximum Inductance @ 1 kHz	0.8 mH/km
Maximum Mutual Capacitance @ 1 kHz	84 nF/km
Maximum Attenuation @ 1 kHz	0.48 dB/km
Maximum Attenuation @ 2 kHz	0.58 dB/km
Maximum Attenuation @ 5 kHz	0.72 dB/km
Maximum Attenuation @ 10 kHz	0.93 dB/km
Maximum Attenuation @ 15 kHz	1.09 dB/km
Maximum Attenuation @ 20 kHz	1.25 dB/km
Maximum Attenuation @ 30 kHz	1.52 dB/km
Max. Near End Differential Mode Cross Talk @ 1 kHz	- 63 dB
Max. Near End Differential Mode Cross Talk @ 2 kHz	- 59 dB
Max. Near End Differential Mode Cross Talk @ 5 kHz	- 53 dB
Max. Near End Differential Mode Cross Talk @ 10 kHz	- 48 dB
Max. Near End Differential Mode Cross Talk @ 15 kHz	- 46 dB
Max. Near End Differential Mode Cross Talk @ 20 kHz	- 44 dB
Max. Near End Differential Mode Cross Talk @ 30 kHz	- 41 dB
Maximum AC Loop Resistance @ 20C	6.16 Ω/km
Characteristic Impedance @ 1 kHz	127.0 Ohm
Characteristic Impedance @ 2 kHz	102.6 Ohm
Characteristic Impedance @ 5 kHz	89.6 Ohm
Characteristic Impedance @ 10 kHz	82.7 Ohm
Characteristic Impedance @ 15 kHz	80.8 Ohm
Characteristic Impedance @ 20 kHz	79.3 Ohm
Characteristic Impedance @ 30 kHz	78.2 Ohm

Note 1: Typical system with comms-on-power Subsea Control System.

4 - CABLE TERMINATIONS AND ACCESSORIES

4.1-It shall be included the electrical cable scope of supply the following items already assembled in the umbilical cable or to be assembled by Supplier technicians on board the laying vessel prior the pull-in operations:

a) Subsea Splices: Male-female pairs of controlled-environment (subsea) type electrical connectors with suitable mating halves for hand made assembly of the umbilical splices onshore or onboard the laying vessel. The use of dry-mateable connectors without oil-filled controlled-environment chambers to protect the front electrical contacts will not be allowed. According with the cable configuration, each splice may have two or four electrical connectors. A single connector for all four pairs will NOT be allowed.

b) Subsea Termination: Electrical cable/oil-filled hose crossover for interface with the subsea equipment.

c) Topside Termination: Supplier shall refer to the respective umbilical RM or contact PETROBRAS to clarify the specific requirements.

4.2-The electrical connector and the cable/oil-filled hose crossover shall guarantee the functional characteristics of the electrical cable and be adequate for the umbilical handling, installation and operational conditions;

4.3-Suitable protection caps to prevent water ingress in the electrical cable shall be supplied in order to cope with the following situations: (i) the electrical cable is not terminated during the pull-in operation or (ii) the umbilical needs to be abandoned on the sea bed;

4.4-All electrical connectors and the crossover(s) required for splices and terminations subsea shall comply with the following characteristics:

4.4.1-Operating Conditions:

- a) Maximum operating water depth: see RM;
- b) Maximum operating temperature: 60°C;
- c) Minimum operating temperature: 2°C;
- d) Shock and vibration conditions compatible with the umbilical handling and installation;

4.4.2-Electrical Characteristics:

- a) Number of electrical contacts: min. 4 (four);
- b) Contact capacity: > 10 Amperes/contact;
- c) Voltage rating phase to ground: 1000 VAC rms (1414 VAC peak);
- d) Voltage rating phase to phase: 2000 VAC rms (2828 VAC peak);
- e) Insulation resistance (without connections): > 5 GΩ @ 20°C;

4.4.3-Electrical Cable Interface: The conductor packing in electrical cable connector and the cable/oil-filled hose crossover entrance and the anchorage and packing system of the cable at the connector shall be compatible with the 6.0 mm² electrical cable conductor cross section (with crimps and extended cable glands, if necessary), dimensions and materials;

4.4.4-Electrical Connector Specification:

- a) Suitable for long term subsea application according with the service life specified by the umbilical RM;
- b) Parts such male pins that may have eventual short term contact with seawater during abandonment shall be made of high corrosion resistant alloys.

- c) To allow at least 30 dry connections and disconnections without damage in the coupling and packing systems;
- d) It shall have at least two independent barriers to avoid water penetration between the electrical contacts or interfaces and the external environment;
- e) A pressure compensated chamber shall be incorporated between the cable water blocking and the electrical connector harness to prevent water ingress;
- f) The design of the electrical connector cable termination shall allow field assembly and testing on board of the laying vessel;
- g) The electrical connector shall have an aligning, coupling and clamping system compatible with the required clearances for packing and operation during the umbilical specified service life;
- h) The electrical connector shall incorporate a cable termination that shall be able to anchor firmly the cable outer jacket or its armor;

4.4.5-Cable/Oil-Filled Hose Crossover Specification:

- a) The cable/oil-filled hose crossover shall be able to field assembly into the umbilical electrical cable;
- b) The crossover shall be designed in two sections (cable termination and oil-filled hose section) bolted together and insulated by a penetrator;
- c) The crossover shall have at least two independent mechanical barriers against sea water ingress at the rear of the penetrator insert which shall allow it to be tested separately during qualification and final assembly;
- d) The umbilical electrical cable termination at the crossover shall incorporate a fully pressure balanced system that shall also be compatible to be field assembly and testing;
- e) The crossover umbilical electrical cable termination shall be able to anchor firmly the cable outer jacket or its armor;
- f) The crossover cap (hose end) shall have a **3/4" (Three Quarters of an Inch) - 16 UNF, JIC 37° male fitting** interface and shall incorporate a filling plug to allow the hose testing and filling up with silicon oil.
- g) The penetrator insert that interfaces with the hose side shall have solder cups of at least 2.5mm². The necessary boot sleeves shall also be included in the scope of supply;
- h) It shall be included in the scope of supply the necessary accessories to hold the crossover in place on the subsea equipment where it will be permanently attached;

- i) Parts such electrical contacts that may have eventual short term exposition to seawater during abandonment shall be made of high corrosion resistant alloys.

4.4.6-Shield Electrical Connection (Splices):

- a) If the umbilical length is such that requires one or more subsea splices, the individual pair shields shall be electrically tied together and connected through a single pin in the electrical connectors used for each splice.

5 - QUALIFICATION TESTS – General Requirements:

5.1-The electrical cable and its accessories shall be subjected to the qualification tests hereafter specified;

5.2-As a general directive, the electrical characteristics of the electrical cable, connectors, cable/oil-filled hose crossover and components (i.e. those to be verified by testing) shall be checked and documented before, during and after the mechanical resistance and hydrostatic pressure tests, whenever it is applicable;

5.3-If Supplier decides to change the configuration of a cable previously qualified by PETROBRAS, new qualification tests are required for the new design (the old results of tests are not valid anymore). Change in the cable configuration means any modification in its characteristics (or in its accessories) such as: cross section, dimensions, lay angles, manufacturing process, materials, sealing systems, etc...

5.4-If Supplier has already tested the proposed electrical cable, connectors, cable/oil-filled hose crossover, accessories under similar conditions to those in this technical specification or previously supplied to PETROBRAS the same products under this technical specification, it may present the gathered data and final results for PETROBRAS approval in order not to repeat them. However, PETROBRAS, at its own discretion, may reject results of any tests which procedures have not been previously approved by PETROBRAS or coming from tests that have not been witnessed by a PETROBRAS representative;

5.5- Supplier shall present PETROBRAS for comments and approval the fully qualification test program specifications at least 60 days in advance prior to the scheduled start of the tests. Each test procedure shall include its acceptance criteria. No test shall be done without PETROBRAS representatives in attendance, or without a written waiver by PETROBRAS;

5.6- Supplier must repeat any qualification test herein specified, at PETROBRAS discretion, in order to confirm (i) the results of qualification tests previously carried out for any cable configuration, materials, accessories, connectors, etc..., (ii) the control of manufacturing process of such items.

6 - QUALIFICATION TESTS – Electrical Cable:

6.1-As a general directive, the qualification tests for the electrical cable shall comply with the Standards listed in item 2.2, according with the following minimum requirements below:

- a) Visual and Dimensional Checks: at least 5 (five) meters of cable/conductor shall be striped for examination and verified for signs of imperfections and damages. Each conductor shall be free of internal or external damages or failures such as breakage, deformations, buckling and Z-kinks. If any damage is found by the visual examination described above, it shall be repeated again in consecutive lengths of the cable at least three more times without any damage or failure for the cable to be considered as passed in this test.
- b) Conductor Resistance Test: a Direct Current (DC) resistance test shall be performed on each insulated conductor of two complete cable samples (i.e. maintaining the cable configuration) at least 1 (one) meter long each, following the further criteria of API Spec. 17E. This test shall be performed before and after the sample pressurization according with the Hydrostatic Pressure Test (see below).
- c) Resistivity of the Screening Layers: see API Spec. 17E.
- d) Insulation Resistance: a DC insulation resistance test shall be performed according to the API Spec 17E, except that it shall be carried out in on each insulated conductor of two complete cable samples (i.e. maintaining the cable configuration) at least 1 (one) meter long each. This test shall be performed before the sample pressurization - according with the Hydrostatic Pressure Test (see below) - and repeated under pressure after at least 24 hours is elapsed and again after the sample depressurization.
- e) High Voltage DC Test: a high voltage DC test shall be performed according to the API Spec 17E, except that it shall be carried out in on each insulated conductor of two complete cable samples (i.e. maintaining the cable configuration) at least 1 (one) meter long each. This test shall be performed before the sample pressurization - according with the Hydrostatic Pressure Test (see below) - and repeated after the sample depressurization. Each stranded pair shall withstand a test voltage of at least 20 kV applied for at least 5 (five) minutes to the dielectric composed by the conductors and the cable shield and also between conductors.
- f) High Voltage AC Test: see API Spec. 17E.
- g) Complete Voltage Breakdown: see API Spec. 17E.
- h) Inductance Characteristics: see API Spec. 17E. Test frequencies shall be: 50/60 Hz, 1 kHz, 10 kHz and 15.5 kHz.
- i) Capacitance Characteristics: see API Spec. 17E.
- j) Attenuation Characteristics: see API Spec. 17E.
- k) Characteristic Impedance: see API Spec. 17E.

6.2-Hydrostatic Pressure Test: a two meter long sample of the specified cable shall be subjected to a pressure equivalent to 1,5 times the umbilical specified maximum water depth for at least 24 hours. The test bench shall include a hyperbaric chamber with instrumentation to record the internal pressures and temperatures.

6.3-Bending Under Tension Cyclic Test: the purpose of this test is to verify if the electrical cable can withstand the expected strain imposed by tension and compression loads after manufacture and installation. A minimum of five samples of the electrical cable shall be subjected to at least 5000 (five thousand) cycles of bending under tension. The samples shall be flexed from negative to positive bending radius per cycle. The bending radius shall be equivalent to 30 times the radius of the cable and the applied tension shall be

equivalent to one third of respective (armored or unarmored) cable breaking load. Electric continuity shall be monitored during the test to provide instant indication of any conductor failure. The samples dimension (i.e. diameter and length) shall be recorded before and after the test. Electrical tests that shall be carried on each sample before and after the bending under tension test are: Insulation Resistance, Conductor Resistance and High Voltage DC (the late only after the bending test). After the final electrical tests, each sample shall be striped for examination and verified for signs of imperfections and damages. Each conductor shall be free of internal or external damages or failures such as breakage, deformations, bucklings and Z-kinks.

6.4-Supplier shall demonstrate the effectiveness of the conductor water block system by performance verification test in which three samples with one end open shall be immersed in a hyperbaric chamber filled with fluorescent liquid and kept pressurized for at least 72 hours with a pressure equivalent to 1.1x the umbilical rated water depth. The sample length and the maximum % of the length which the water can penetrate will be specified by the Supplier prior the test and is to be verified by careful stripping and visual inspection of each sample to see how far the liquid has penetrated in the cable.

7 - QUALIFICATION TESTS – Electrical Connectors, Crossovers and Cable Termination:

7.1-The qualification tests, specified below, shall be carried for each type/model of a matched (male/female) pair of electrical connectors and crossovers included in the scope of supply of the umbilical electrical cable. Supervision by the umbilical supplier is required whenever this qualification test are carried out by sub-suppliers or third parties:

- a) Insulation Resistance: According to MIL-STD-202, method 302, condition B (500V), minimum insulation resistance: 5 G ohms;
- b) Dielectric Withstanding Voltage: According to MIL-STD-202 method 301, with a test voltage of 3 kV or lower up to the electrical connector maximum;
- c) Durability: 30 (thirty) cycles of dry connection and disconnection;
- d) Thermal Shock: 5 (five) cycles between limits of +1 and +70° C, according to MIL-STD-1344A method 1003.1;
- e) Humidity: According MIL-STD-1344A, method 1.002.2 for 240 hours;
- f) Hydrostatic Tests: in hyperbaric chamber at 1,5 times the pressure equivalent to the umbilical specified maximum water depth, after assembling in electrical cable sample;

7.2-The connector or crossover cable termination shall be terminated with an umbilical electrical cable test sample and a suitable test cable/hose assembly to simulate the complete interface. Then it shall be tested in a hyperbaric chamber at 1,5 times the pressure equivalent to the umbilical specified maximum water depth. Qualification tests shall include the verification of the integrity of secondary barriers against water penetration after simulating the primary (main) barrier failure;

8 - QUALIFICATION TESTS – Abandonment Cap:

8.1-Hydrostatic Tests: in hyperbaric chamber filled with fluorescent liquid at 1,5 times the pressure equivalent to the umbilical specified maximum water depth, after assembling in electrical cable sample;

8.2-After the Hydrostatic Test, it shall be performed Continuity Test and the Conductor Resistance Test for each conductor of the cable sample (as per item 5.1 above), then the cap shall be removed and the cable stripped for visual inspection of signs of the fluorescent liquid ingress into the electrical cable;

9 - FACTORY ACCEPTANCE TESTS – General Requirements:

9.1-The acceptance tests shall be performed after the electrical cable is manufactured;

9.2- Supplier shall submit to PETROBRAS in the Quality Plan a full acceptance test program, including procedures and acceptance criteria, at least 60 days in advance prior to the scheduled start of the tests. No test shall be done without PETROBRAS representatives in attendance, or without a written waiver by PETROBRAS;

10 - FACTORY ACCEPTANCE TESTS – Electrical Cable:

10.1-As a general directive, the FAT for the electrical cable shall comply with the “Factory Acceptance Tests” of API Spec.17E, according with the following minimum requirements below:

- a) Visual and Dimensional Inspection: see API Spec. 17E.
- b) Spark Test: see API Spec. 17E.
- c) DC Conductor Resistance Test: see API Spec. 17E.
- d) Insulation Resistance Test: a DC insulation resistance test shall be performed according to the API Spec 17E, except that it shall be carried out in each insulated conductor of the complete cable (i.e. maintaining the cable configuration).
- e) High Voltage DC Test: a high voltage DC test shall be performed according to the API Spec 17E, except that it shall be carried out in each insulated conductor of the complete cable (i.e. maintaining the cable configuration). Each stranded pair shall withstand a test voltage of at least 20 kV applied for at least 5 (five) minutes to the dielectric composed by the conductors and the cable shield and also between conductors.
Note: As each insulated pair incorporates a metal screen layer (shield), the insulation resistance and high voltage DC tests above are not required to be performed with the cable immersed in water. The voltage shall be applied between each insulated conductor and all the other conductors and collective metallic layers.
- f) Inductance Characteristics: see API Spec. 17E. Test frequencies shall be: 50/60 Hz, 1 kHz, 10 kHz and 15.5 kHz.
- g) Capacitance Characteristics: see API Spec. 17E.
- h) Attenuation Characteristics: see API Spec. 17E.
- i) Characteristic Impedance: see API Spec. 17E.
- j) Cross-Talk for the total length (frequencies in the table of Item 3 of this I-ET).
- k) Time Domain Reflectometry (TDR): see API Spec. 17E. TDR shall be recorded for each cable length manufactured and for the complete umbilical prior installation. The results shall be included in the umbilical manufacturing data book.

10.2-Hydrostatic Pressure Test: Petrobras at its own discretion may require the carrying out of this test in order to verify if the manufactured cable is keeping its original

characteristics which have been previously verified as per the original design and manufacturing methods. A sample of the specified cable shall be subjected to a pressure equivalent to 1,5 times the umbilical specified maximum water depth for at least 24 hours. The test bench shall include a hyperbaric chamber with instrumentation to record the internal pressures and temperatures.

10.3-Bending Under Tension Cyclic Test: Petrobras at its own discretion may require the carrying out of this test in order to verify if the manufactured cable is keeping its original characteristics which have been previously verified as per the original design and manufacturing methods. This test shall verify if the electrical cable can withstand the expected strain imposed by tension and compression loads after manufacture and installation. A minimum of five samples of the electrical cable shall be subjected to at least 5000 (five thousand) cycles of bending under tension. The samples shall be flexed from negative to positive bending radius per cycle. The bending radius shall be equivalent to 30 times the radius of the cable and the applied tension shall be equivalent to one third of respective (armored or unarmored) cable breaking load. Electric continuity shall be monitored during the test to provide instant indication of any conductor failure. The samples dimension (i.e. diameter and length) shall be recorded before and after the test. Electrical tests that shall be carried on each sample before and after the bending under tension test are: Insulation Resistance, Conductor Resistance and High Voltage DC (this one only after the bending test). After the final electrical tests, each sample shall be stripped for examination and verified for signs of imperfections and damages. Each conductor shall be free of internal or external damages or failures such as breakage, deformations, bucklings and Z-kinks.

10.4-Supplier shall demonstrate the effectiveness of the conductor water block system by performance verification test in which three samples with one end open shall be immersed in a hyperbaric chamber filled with fluorescent liquid and kept pressurized for at least 72 hours with a pressure equivalent to 1.1x the umbilical rated water depth. The sample length and the maximum % of the length which the water can penetrate will be specified by the Supplier prior the test and is to be verified by careful stripping and visual inspection of each sample to see how far the liquid has penetrated in the cable.

11 – FACTORY ACCEPTANCE TESTS – Electrical Connectors, Crossovers and Cable Termination:

11.1-The acceptance tests, specified below, shall be carried for each type/model of a matched (male/female) pair of electrical connectors and crossovers included in the scope of supply of the umbilical electrical cable. Supervision by the umbilical supplier is required whenever this acceptance test are carried out by sub-suppliers or third parties:

- a) Insulation Resistance: According to MIL-STD-202, method 302, condition B (500V), minimum insulation resistance: 5 G ohms;
- b) Dielectric Withstanding Voltage: According to MIL-STD-202 method 301, with a test voltage of 3 kV or lower up to the electrical connector maximum;
- c) Durability: At least 10 (ten) cycles of dry connection and disconnection;
- d) Hydrostatic Tests: in hyperbaric chamber at 1,5 times the pressure equivalent to the umbilical specified maximum water depth;

11.2-Even in the case the electrical cable and its connectors/crossovers interfaces has already been previously qualified for PETROBRAS, the umbilical supplier shall include a test to verify the integrity of the interface between the electrical cable after manufacture and one sample each of the connectors and crossovers included in each umbilical purchased by PETROBRAS. This test shall include the actual manufactured cable sample assembled in the connector or crossover cable termination to simulate the complete interface. Then it shall be tested in a hyperbaric chamber at 1,5 times the pressure equivalent to the umbilical specified maximum water depth. Acceptance tests shall include the verification of the integrity of secondary barriers against water penetration after simulating the primary (main) barrier has failed.

Note: Tests 11.1 (d) and 11.2 may be combined for one sample of each connector or crossover supplied. In any case, all internal connector/crossover boot seals that are in contact with the cable sample shall be replaced after testing.

12 – FACTORY ACCEPTANCE TESTS – Abandonment Cap:

12.1-Hydrostatic Tests: Petrobras at its own discretion may require the carrying out of this test in order to verify if the manufactured cable is keeping its original characteristics which have been previously verified as per the original design and manufacturing methods. In hyperbaric chamber filled with fluorescent liquid at 1,5 times the pressure equivalent to the umbilical specified maximum water depth, after assembling in electrical cable sample;

12.2-After the Hydrostatic Test, it shall be performed Continuity Test and the Conductor Resistance Test for each conductor of the cable sample (as per item 5.1 above), then the cap shall be removed and the cable stripped for visual inspection of signs of the fluorescent liquid ingress into the electrical cable;

13 – FACTORY ACCEPTANCE TESTS – Completed Umbilical

13.1-On completion of umbilical manufacturing and prior to fitting of end terminations, the umbilical electrical cores shall be tested according to Section 11.3 of API Spec17E.

14 - MANUFACTURING REQUIREMENTS

14.1-In addition to the requirements found in the applicable ISO 9001, API, IEC and BS Standards and those adopted by the cable supplier, the cable supplier shall assure the traceability of materials used in cable construction as well as of all manufacturing records;

14.2-For manufacturing, the diameter variation range of cable extruded layers shall be defined in such a way that the watertightness in the interface cable/connector and cable/crossover is assured, as applicable. The external diameter and thickness of extruded layers shall be continuously monitored and recorded lengthwise during manufacturing or a Spark Test be performed according to API Spec. 17E requirements.

14.3-The cable supplier shall provide on request the data book of the electrical cable, connectors and penetrators. This documentation shall include materials certificates, manufacturing and testing records as wells as other documents as required by the umbilical Quality Plan.

