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	CLIENTE:		E&P					FOLHA: 1 de 16		
	PROGRAMA:									
	UNIDADE:									
SUB	TÍTULO:		<b>ELECTRICAL POWER CABLE ELEMENT &amp; TESTING</b>							
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<b>INDEX OF REVISIONS</b>										
<b>REV.</b>	<b>DESCRIPTION AND/OR AFFECTED SHEETS</b>									
0	Original Emission									
A	All pages: IEC 502 update to 60502-1 & 60502-2 (mainly for “Voltage Classes” and “Testing”)									
B	All pages: General revision to include comments from CENPES/TS									
C	Items 2.2; 2.12; 2.14; 2.15; 2.19; 2.20; 2.25.5; 2.8; 3.1; 3.2; 4.2.1.4.									
D	All pages (General revision & update) & topside interface according to the umbilical RM;									
E	All pages (General revision & update): Item 4 Electrical Power Cable Terminations and Accessories according to I-ET-3000.00-1500-71F-PAZ-001: Medium Voltage Subsea Electrical Connection Systems (PETROBRAS Technical Specification) & Technical Proposal, Qualification and FAT Tests revised (items 5 to 13).									
F	Item 1 – Purpose; Itens 5.13, 5.14 and 5.15 included; highlighted in grey.									
	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H	
DATA	12/09/2003	03/10/2003	10/03/2004	28/06/2006	11/12/2009	04/02/2013	08/10/2024			
PROJETO										
EXECUÇÃO	K059	K059	K059		CXS2	ES54, ES50, ES41	DVLY			
VERIFICAÇÃO				K059	K059	CXS2	CXS2			
APROVAÇÃO						K059	BERL			
AS INFORMAÇÕES DESTE DOCUMENTO SÃO PROPRIEDADE DA PETROBRAS, SENDO PROIBIDA A UTILIZAÇÃO FORA DA SUA FINALIDADE.										
FORMULÁRIO PERTENCENTE A PETROBRAS N-0381 REV. L.										




TÍTULO: **ELECTRICAL POWER CABLE ELEMENT & TESTING**

SUB/ES/EESUB/EPB

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## 1 PURPOSE

This specification defines the minimum requirements for design, manufacture, qualification and acceptance of ELECTRICAL THREE-CORE POWER CABLE ELEMENT (from 0,6/1 (1,2) kV up to 18/30 (36) kV) and its accessories for use as part of static/dynamic umbilical for subsea application. The required water depth and service life are specified in the umbilical Request of Material (RM) document.

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.

This Technical Specification applies only to already qualified structures US-11 and US-20. New integrated umbilical with power cables shall reference I-ET-3000.00-1500-700-PEK-004.

## 2 GENERAL

2.1 Unless otherwise herein specified, the standards that applies for the electrical threecore power cable design, manufacture and testing are:

- IEC 60502-1 (2004-04): Power cables with extruded insulation and their accessories for rated voltages from 1 kV ( $U_m = 1,2$  kV) up to 30 kV ( $U_m = 3,6$  kV) – Part 1: Cables for rated voltages of 1kV ( $U_m=1,2$ kV) and 3kV ( $U_m=3,6$ kV).
- IEC 60502-2 (2005-03): Power cables with extruded insulation and their accessories for rated voltages from 1 kV ( $U_m = 1,2$  kV) up to 30 kV ( $U_m = 36$  kV) – Part 2: Cables for rated voltages from 6 kV ( $U_m = 7,2$  kV) up to 30 kV ( $U_m = 36$  kV).
- IEC 60228 (2004-11): Conductors of insulated cables.
- API Spec 17E (3rd Edition: July, 2003) & ISO 13628-5 (2002-10-15): Design and operation of subsea production systems - Part 5: Subsea Umbilicals.
- I-ET-3000.00-1500-71F-PAZ-001: Medium Voltage Subsea Electrical Connection Systems (PETROBRAS Technical Specification)

Variations or alternatives, if proposed, shall be submitted to PETROBRAS for approval before the umbilical detail design.

2.2 According to the umbilical Request of Material (RM) document specifications, the electrical three-core power cable shall be composed of three single core power cables, according to the table reproduced below for reference only.



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**ELECTRICAL POWER CABLE ELEMENT (REF. I-ET-3500.00-1500-721-PAZ-003)**

Number of conductors:	3		
Conductor cross section:	mm <sup>2</sup>		
Rated Voltage (U <sub>0</sub> /U (U <sub>m</sub> )):	kV		
Rated current at 45°C ambient temperature:	A		
Rated frequency:	Hz		
Max. voltage drop	%/km		
Insulation material	(specify)		
Longitudinal water ingress barrier in the single core cable conductor	<b>YES</b>		<b>NO</b>
Number of longitudinal water ingress barriers in the region of single core cable metallic layers	(specify)		



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**ELECTRICAL SYSTEM DATA**

Nominal Voltage (U)		kV			
Steady-state Voltage Variation (%)					
Transient Voltage Variation (%)					
Nominal frequency:		Hz			
Steady-state Frequency Variation (%)					
Transient Frequency Variation (%)					
3-phase steady-state short-circuit level		kA			
Maximum (t0+) Transient 3-phase short-circuit level (rms/peak values)		___ / ___ kA			
Grounding System	Isolated	YES		NO	
	High resistance	YES		NO	
	Low resistance	YES		NO	
	Solid grounded	YES		NO	



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**APPLICATION DATA**

Type	Subsea ESP	YES		NO	
	Multiphase Pump	YES		NO	
	Line Heating	YES		NO	
	Other	(specify)			
Subsea transformer:		YES		NO	
Subsea Termination Type & Interface	Electrical Connector	YES		NO	
	Electrical Penetrator	YES		NO	
	Electrical Cross-Over	YES		NO	
	INCLUDED in the umbilical scope of supply	YES		NO	
Subsea electrical connector / penetrator / crossover supplier name and Part Number (P/N):		(specify)			
Subsea load nominal shaft power		kW			
Subsea load nominal voltage		kV			
Subsea load nominal current		A			
Subsea load nominal frequency		Hz			
Electrical Power fed by Variable Frequency Drive		YES		NO	
Operational Output Frequency range		0 to ____ Hz			
Operational Output Voltage range		____ to ____ kV			
Maximum Operational Voltage		kV			
Maximum Operational Current at ____ Hz		A			
3-phase Max. Momentaneous short-circuit current		kA			
Maximum short-circuit duration time		ms			



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Maximum short-circuit phase-ground continuous current		A			
Application System Category	Category A	YES		NO	
	Category B	YES		NO	
	Category C	YES		NO	
Electrical cable grounded at subsea end		YES		NO	
Electrical cable grounded at platform end		YES		NO	

- 3.1 Each single core cable shall be rated according to IEC 60502-1 or IEC 60502-2 rated voltages.
- 3.2 Each single core cable shall be composed, at least, of conductor, conductor screen, insulation, insulation screen, individual metallic layer and polymeric outer sheath according to IEC 60502-1 or IEC 60502-2.
- 3.3 Two water blocking bedding tapes shall be applied, respectively, between the insulation screen and the single core cable metallic layer, and between the single core cable metallic layer and the single core cable outer sheath. The Supplier shall state in the umbilical proposal the designed technical characteristics related to these two mechanical barriers, explaining how this requirement will be addressed.
- 3.4 Each conductor shall be of annealed, stranded copper conductors, class 2, according to IEC 60228.
- 3.5 The conductors shall be longitudinally sealed to prevent water penetration (between the wires) along the electrical three-core 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.
- 3.6 Single core cables rated at 6/10 (12) kV and above shall have a non-metallic conductor screen consisting of an extruded semi-conducting compound, which may be applied on top of a semi-conducting tape. The extruded semiconducting compound shall be firmly bonded to the insulation.
- 3.7 Single core cable insulation shall be constituted by an extruded and vulcanized polymeric compound (EPR or XLPE), designed according to its rated voltage. For single core cables rated 3,6/6 (7,2) kV and above the insulation shall be rated for a maximum conductor temperature of no less than 90°C during normal operation (rated current and 45oC ambient temperature) and no less than 250°C for five (5) seconds with maximum short-circuit current flowing. Beside state the material used and maximum rated temperature, the umbilical Supplier shall include in the umbilical technical proposal the nominal thickness according to IEC 60502-1 or IEC 60502-2.

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- 3.8 The insulation screen shall be composed of an outer semi-conductive layer plus a metallic layer:
- 3.8.1 The outer semi-conductive layer shall be manufactured by a semi-conductive compound extruded directly over the insulation. For single core cables rated 6/10 (12) kV and above the outer semi-conductive layer shall be extruded simultaneously with the conductor semi-conductive screen and with the insulation in a triple-extrusion process;
- 3.8.2 The metallic layer over the outer semi-conductive layer shall be constituted by a braid of soft temper thinned copper wires. Such metallic layer shall be designed to conduct phase-ground short-circuit currents without damages.
- 3.9 The sheath around each single core cable shall be of a thermoplastic material that shall not degrade the quality of other materials with which it may be in contact in the lay-up. The single core cable outer sheath shall not be considered as a mechanical barrier against sea water intrusion. The single core cable outer sheath shall be designed so that the insulated power conductors are capable to operate in a fully flooded environment inside the umbilical. The sheath thickness and physical properties shall be suitably selected to not compress the inner single core cable layers due to shrinkage after extrusion. Also, extruded layers which are designed to assure water tightness at the interface between the single core cable and its connector, in order to assure such property, shall have their circularity controlled during manufacturing process. The umbilical Supplier shall state in the umbilical technical proposal how the single core cable design and manufacture procedures and/or process will accomplish the above features.
- 3.10 Each single core cable shall be easily identified by means of either color strips, sequential numbers or color coding (more than one type of marking is welcomed). Single core cable markings shall be stable under all environmental conditions for storage, handling and operation during the specified service life and shall not impair its insulation.
- 3.11 Fillers, if used in the construction of the electric three-core power cable, shall be of polymeric material and not cause or suffer chemical or mechanical degradation of any other material of the cable, specially the conductor insulation.
- 3.12 If not stated otherwise in the specific umbilical RM, the electrical three-core power cable shall comply with the following grounding premises:
- 3.12.1 The copper metallic layer (metallic shield) over the insulation shall be electrically connected to the umbilical armor wires at both ends (subsea end termination and platform end termination).
- 3.12.2 Technical characteristics of the grounding system design and technical data related to the expected/calculated short-circuit currents; maximum short-circuit current value (phase-phase and phase-ground) & respective duration time; continuous shortcircuit current phase-to-ground; protective devices; etc. are to be specified by PETROBRAS in the umbilical Request of Material (RM) or other specific document.
- 3.13 The electrical three-core power cable shall be provided with adequate mechanical strength to protect it against the effects of mechanical loads generated during manufacturing, handling, installation, operation and retrieval, expected during the umbilical specified service life.




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- 3.14 The electrical three-core power cable functional characteristics shall be assured by the umbilical Supplier during umbilical manufacturing, storage, transportation, handling, subsea installation, testing, operation and retrieval, during the specified umbilical service life.
- 3.15 Materials to be used in the electrical three-core power cable and in its accessories shall withstand the aging and degradation effects 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 connected to the platform facilities).
- 3.16 The electrical three-core power cable shall be designed and manufactured in such a way that fusion between polymeric layers and between insulation and copper core is avoided. The umbilical Supplier shall state in the umbilical technical proposal how the cable design and manufacture procedures and/or process will accomplish this feature.
- 3.17 Steel wires for armoring, if used in the electrical three-core power cable bundle, shall not degrade with corrosion. The umbilical 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 service life specified in the respective umbilical RM. The umbilical supplier shall present to PETROBRAS approval a report on the necessity (or not) of anti-corrosive treatment of cable armoring, if used, prior to the cable manufacture.
- 3.18 The electrical three-core power cable minimum bending radius shall be compatible with the dimensions of accessories such as pull-in heads and Vertical Connection Modules or Deployment Bases for which the cable may be stored during deployment or abandonment in the seabed.
- 3.19 For the umbilical subsea termination, the electrical three-core power cable shall be fitted with an electrical power connector, penetrator or crossover (all three single core cables in a three pins crossover/penetrator/connector) or individually (i.e each single core cable in a one pin electrical power connector/penetrator/crossover), according to the umbilical respective PETROBRAS RM. The umbilical RM shall specify if the power crossover/penetrator or connectors are to be part of the umbilical scope of supply;
- 3.20 For the umbilical topside termination, it shall be supplied a topside junction box (see item 4) or single core cable splices. Both cases shall include the field assembly after the umbilical installation.
- 3.21 The umbilical Supplier shall document all characteristics of the material used to manufacture the power cable element confirming that all kinds of possible degradation will not occur (including aging and corrosion).
- 3.22 The umbilical Supplier has total responsibility over the electrical three-core power cable elements qualification and testing, even when the electrical three-core power cable element itself and its qualification and testing is provided by Supplier sub-contractors.

#### **4 ELECTRICAL POWER CABLE SPLICES**

- 4.1 If the length of the umbilical requires the use of splices, the electrical three-core power cable shall be connected

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between each umbilical length inside diametrical joints or splice boxes according with the umbilical mechanical specifications;

4.2 The umbilical supplier shall provide this service as part of the umbilical installation, including in the umbilical scope of supply the qualified personnel, tools and materials required for each splice. The onshore and offshore field splice technique shall be qualified by the supplier for the required umbilical water depth. The umbilical supplier shall include in the umbilical technical proposal, at least:

4.2.1 A detailed splice design (including material specification to be used, dimensions etc.);

4.2.2 Detailed procedure to manufacture such splices;

4.2.3 The minimum, average and maximum time to accomplish a complete splice aboard the lay vessel.

4.2.4 The supplier shall include in the umbilical technical proposal a program to qualify a splice between the proposed single core cable to a PETROBRAS standard UTU interface cable.

## 5 ELECTRICAL POWER TERMINATION AND ACCESSORIES

5.1 Suitable protection caps to prevent water ingress in the electrical three-core power cable shall be supplied for the possibility that the electrical three-core power cable is not terminated during the pull-in operation and the umbilical needs to be abandoned on the sea bed.

5.2 If required the supply of electrical power connectors, penetrators and crossovers, technical specification I-ET-3500.00-1500-71F-PAZ-001 shall be fulfilled.

5.3 Umbilical Power Cable Junction Box:

5.4 The scope of supply shall include a power junction box (PJB) suitable for operation in hazardous area classified Zone 2, Group IIA, Class T3 according to IEC 60079. The PJB shall be certified by INMETRO as well as the certification authority nominated by PETROBRAS after the umbilical purchase order.


5.5 For applications with maximum operational VSD output voltage lower than 11kV, the PJB protection shall be "Ex e" (Increased Safety) according to IEC 60079-7.

5.6 For applications with maximum operational VSD output voltage equal or greater than 11kV, the PJB protection shall be "Ex d" (Flameproof) according to IEC 60079-0.

5.7 The minimum degree of protection provided by the PJB enclosure shall be IP56 according to IEC 60529.

5.8 The junction box shall provide the electrical connection between the respective surface cables and the umbilical electrical three-core power cables. It shall be made of Stainless Steel AISI 316-L and will be located next to umbilical topside hang-off point.

5.9 For the surface cables, it is foreseen the use of two (2) three-core, 12/20 kV cable with 120mm<sup>2</sup> cross section, stranding class 2 according to IEC 60228, with an outside diameter of 69,3 mm +/- 10%. (To be confirmed by

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PETROBRAS up to 45 days after the Umbilical purchase order). Insulation material foreseen will be EPR or XLPE.

- 5.10 Cable glands for all incoming cables shall be part of the scope of supply. Cable glands shall be compatible with the PJB hazardous area protection type and degree of protection, made of Stainless Steel AISI 316-L and suitable to earth the metallic armor under outer jacket.
- 5.11 The PJB internal space, layout and insulated cable connections and components shall be compatible with the umbilical electrical power cable specifications, the respective PETROBRAS RM and the IEC 60079 applicable parts. Each phase connection inside de PJB shall be easily identified with the same identification used in each umbilical power single core cable.
- 5.12 The PJB shall allow disconnection and reconnection of surface and subsea power cables maintaining its protection type and degree of protection. The PJB shall allow the performance of insulation resistance measurements of each of these cables when disconnected. The supplier shall provide procedures for safety disconnection and reconnection of surface and subsea cables.
- 5.13 The positioning and levels of the PJB in relation to the Armour Pot should be such that the minimum radius of curvature of the cable is not violated.
- 5.14 The integrity of all cable layers must be guaranteed throughout the entire installation process in the PJB. In case of any damage to the layers, they must be completely rebuilt according to the supplier's repair procedure.
- 5.15 The installation of the PJB must be arranged in a way that allows ergonomic access for maintenance personnel.

## 6 UMBILICAL TECHNICAL PROPOSAL


6.1 The supplier shall include in the umbilical technical proposal the designed or estimated data listed below, as a minimum. Standards and/or calculation methods used to estimate data shall be informed.

6.1.1 Single core cable:

- Cross section with each layer thickness and tolerances and material description;
- Minimum bending radius;
- Velocity of propagation (VOP);
- Electrical DC resistance at ambient temperature
- Temperature Coefficient of Resistance
- Electrical DC resistance at 90°C;
- Electrical AC resistance at 90°C on 60Hz;
- Capacitive reactance on 60Hz;
- Inductive reactance on 60Hz;
- Maximum current capacity x Ambient temperature Curve, for ambient temperatures varying from 4°C to 60°C in air without solar radiation, highlighting the following temperatures: 4°C, 25°C, 40°C, 55°C and 60°C;
- Water ingress barrier technical design to fulfill items 2.5 and 2.7 of this specification;
- Cable design and manufacture procedure to fulfill items 2.11 and 2.18 of this specification.

6.1.2 Three-core cable:

- Cross section with distances and tolerances between each single core cable;
- Minimum bending radius
- Fillers material, if used;

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- d) Electrical parameters with shield grounded at only one end:
- Electrical AC resistance at 90°C on 20 Hz; 40 Hz, 60 Hz and 80 Hz;
  - Capacitive reactance on 20 Hz; 40 Hz, 60 Hz and 80 Hz;
  - Inductive reactance on 20 Hz; 40 Hz, 60 Hz and 80 Hz;
  - Electrical AC resistance, Capacitive reactance and Inductive reactance on the following 60 Hz harmonic frequencies: 180; 300; 420; 540; 660; 780; 900; 1020; 1140, 1260, 1380 and 1500 Hz at 90°C;
  - Maximum current capacity x Ambient temperature Curve, for ambient temperatures varying from 4°C to 60°C in air without solar radiation, highlighting the following temperatures: 4°C, 25°C, 40°C, 55°C and 60°C;
- d) Electrical parameters with shield grounded at both ends:
- Electrical AC resistance at 90°C on 20 Hz; 40 Hz, 60 Hz and 80 Hz;
  - Capacitive reactance on 20 Hz; 40 Hz, 60 Hz and 80 Hz;
  - Inductive reactance on 20 Hz; 40 Hz, 60 Hz and 80 Hz;
  - Electrical AC resistance, Capacitive reactance and Inductive reactance on the following 60 Hz harmonic frequencies: 180; 300; 420; 540; 660; 780; 900; 1020; 1140, 1260, 1380 and 1500 Hz at 90°C;
  - Maximum current capacity in 4°C, 15°C, 40°C and 55°C ambient temperature;

6.1.3 Qualification program for the electrical three-core power cable elements, materials, accessories, splices, surface and subsea terminations (if required);

6.1.4 FAT program for the electrical three-core cable elements, materials, accessories, surface and subsea terminations (if required).

## 7 UMBILICAL DATABOOK

7.1 The supplier shall provide the as-built (measured) parameters listed in section 5 in the umbilical databook (except the Maximum Current Capacity x Ambient temperature Curve).

7.2 The umbilical databook shall include all qualification tests, FAT and field test reports.


## 8 GENERAL TEST REQUIREMENTS

8.1 The electrical three-core power cable and its accessories shall be subjected to the qualification tests hereafter specified prior to the umbilical manufacture.

8.2 As a general directive, the electrical and mechanical characteristics of the electrical three-core power cable, power connector, penetrator, crossover and other components to be tested shall be checked and documented before, during and after the mechanical resistance and hydrostatic pressure tests, whenever it is applicable.

8.3 If umbilical Supplier has already qualified the proposed electrical power connectors, penetrators, crossover and 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 to not repeat them. However, PETROBRAS, at its own discretion, may reject results of any tests whose procedures have not been previously approved by PETROBRAS or coming from tests that have not been witnessed by a PETROBRAS representative.

8.4 If a qualification of the components listed above is required by PETROBRAS, the umbilical Supplier shall submit the qualification test program for comments and approval at least 40 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.

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8.5 The umbilical 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, material, accessories, connectors etc., (ii) the control of manufacturing process of such items.

8.6 Preliminary test reports shall be sent to PETROBRAS immediately after performing each test.

## 9 QUALIFICATION TESTS


9.1 At least three samples of complete single core power cable shall pass through qualification tests.

9.1.1 For cables rated from 0,6/1 (1,2) kV to 1,8/3 (3,6) kV, the qualification tests shall comply with IEC 60502-1 tests listed below. Tests a) up to and including f) shall be applied successively to the same sample:

- a) Insulation resistance measurement at ambient temperature;
- b) Insulation resistance measurement at maximum conductor temperature;
- c) Voltage test for 4 hours;
- d) Impulse test for cables of rated voltage 1,8/3(3,6)kV;
- e) Measurement of the electrical resistance of conductors;
- f) Hydrostatic pressure test (item 8.1.3 of this specification)
- g) Conductor examination;
- h) Check of dimensions;
- i) Measurement of thickness of insulation;
- j) Measurement of thickness of non-metallic sheaths (including extruded separation sheaths, but excluding inner coverings);
- k) Tests for determining the mechanical properties of insulation before and after ageing;
- l) Tests for determining the mechanical properties of non-metallic sheaths before and after ageing;
- m) Additional ageing test on pieces of completed cables;
- n) Pressure test at high temperature on insulations and non-metallic sheaths;
- o) Ozone resistance test for EPR and HEPR insulations;
- p) Hot set test for EPR, HEPR and XLPE insulations and elastomeric sheaths;
- q) Water absorption test on insulation;
- r) Measurement of carbon black content of black PE oversheaths;
- s) Shrinkage test for XLPE insulation;
- t) Special bending test;
- u) Determination of hardness of HEPR insulation;
- v) Determination of the elastic modulus of HEPR insulation;
- x) Shrinkage test for PE oversheaths;

9.1.2 For cables rated from 3,6/6 (7,2) kV up to 18/30 (36) kV, the qualification tests shall comply with IEC 60502-2 tests listed below. Tests a) up to and including h) shall be applied successively to the same sample:

- a) Electrical resistance of conductors;
- b) Partial discharge test;
- c) Bending test followed by a partial discharge test;
- d) Tan  $\delta$  measurement;
- e) Heating cycle test followed by a partial discharge test;
- f) Impulse test followed by a voltage test;
- g) Voltage test for 4 hours;
- h) Hydrostatic Pressure Test (item 8.1.3 of this specification)
- i) Resistivity of semi-conducting screens;
- j) Measurement of thickness of insulation;
- k) Measurement of thickness of non-metallic sheaths (including extruded separation sheaths, but excluding inner coverings);
- l) Tests for determining the mechanical properties of insulation before and after ageing;
- m) Tests for determining the mechanical properties of non-metallic sheaths before and after ageing;
- n) Additional ageing test on pieces of completed cables;
- o) Pressure test at high temperature on insulations and non-metallic sheaths;
- p) Ozone resistance test for EPR and HEPR insulations;
- q) Hot set test for EPR, HEPR and XLPE insulations and elastomeric sheaths;

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- r) Oil immersion test for elastomeric sheaths;
- s) Water absorption test on insulation;
- t) Measurement of carbon black content of black PE oversheaths;
- u) Shrinkage test for XLPE insulation;
- v) Determination of hardness of HEPR insulation;
- w) Determination of the elastic modulus of HEPR insulation;
- x) Shrinkage test for PE oversheaths;
- y) Strippability test for insulation screen;
- z) Water penetration test.

9.1.3 Hydrostatic Pressure Test: the sample of the cable under qualification shall be subjected to a pressure equivalent to 1.1 times the umbilical specified maximum water depth for at least 24 hours. Routine tests (IEC 60502-1 item 15 and IEC 60502-2 item 16) shall be performed before and just after the hydrostatic pressure test. At the end, the sample must be dissected and no mechanical damages, layers shrinkage and/or water ingress shall be observed. The sample dissection shall be performed during the first 24 hours after the sample leaves the hyperbaric chamber. The test bench shall include a hyperbaric chamber with instrumentation to record the internal pressures, temperatures. A fluorescent fluid shall be used to allow the identification of water ingress inside the sample. If needed, the sample may be cut due to Hyperbaric chamber constraints.

## 9.2 Cable Splices:

9.2.1 At least three samples of each cable splice shall pass through qualification tests. These samples shall be prepared according to the written procedure and have their mechanical strength validated by a test to verify the specified design breaking load of the spliced cable

9.2.2 Each splice sample of cables rated from 0,6/1 (1,2)kV to 1,8/3 (3,6)kV shall pass through the qualification tests listed in item 8.1.1 from (a) to (f) of this specification.

9.2.3 Each splice sample of cables rated from 3,6/6 (7,2)kV to 18/30 (36)kV shall pass through the qualification tests listed in item 8.1.2 from (a) to (h) of this specification.

9.3 Subsea Cable Termination: All subsea electrical power connectors, penetrator or crossover in the scope of supply shall be designed and qualified according to technical specification I-ET-3500.00-1500-71F-PAZ-001.


## 9.4 Abandonment Cap:

9.4.1 Hydrostatic Test: at least three samples shall be tested in hyperbaric chamber filled with fluorescent liquid at 1,1 times the pressure equivalent to the umbilical specified maximum water depth during at least 24 hours, then the cap shall be removed and the cable stripped for visual inspection of signs of the fluorescent liquid ingress into the electrical cable.

## 10 FACTORY ACCEPTANCE TESTS (FAT)

10.1 The electrical three-core power cable FAT shall be performed after the manufacturing of the electrical cable.

10.2 Supplier shall submit to PETROBRAS the Quality Plan covering the full FAT program, including procedures and acceptance criteria, at least 40 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.

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10.3 For cables rated from 0,6/1 (1,2) kV to 1,8/3 (3,6) kV, the FAT shall comply with Routine tests and Sample Tests specified by IEC 60502-1 item 15 and item 16, and Hydrostatic Test, item 8.1.3 of this specification. Sample tests shall be performed in three samples.

10.3.1 The tests are listed below

Complete Cable

- a) Measurement of the electrical resistance of conductors (IEC 60502-1 item 15.2)
- b) Voltage Test (IEC 60502-1 item 15.3)

Three Samples

- c) Conductor examination (IEC 60502-1 item 16.4)
- d) Check of dimensions (IEC 60502-1 item 16.5 and 16.8)
- e) Hot Set for EPR, HEPR or XLPE (IEC 60502-1 item 16.9)
- f) Hydrostatic Test (item 8.1.3 of this specification)

10.4 For cables rated from 3,6/6 (7,2) kV up to 18/30 (36) kV, the FAT shall comply with Routine and Sample Tests specified by IEC 60502-2, item 16 and 17, and Hydrostatic Test, item 8.1.3 of this specification. Sample tests shall be performed in three samples.

10.4.1 The tests are listed below

Complete Cable

- a) Measurement of the electrical resistance of conductors (IEC 60502-2 item 16.2)
- b) Partial Discharge Test (IEC 60502-2 item 16.3)
- c) Voltage Test (IEC 60502-2 item 16.4)

Three Samples

- d) Conductor Examination (IEC 60502-2 item 17.4)
- e) Check of dimensions (IEC 60502-2 item 17.5 to 17.8)
- f) Voltage Test for cables of rated voltage above 3,6 / 6 (7,2) kV (IEC 60502-2 item 17.9)
- g) Hot Set for EPR, HEPR or XLPE (IEC 60502-2 item 17.5 to 17.10)
- h) Hydrostatic Test (item 8.1.3 of this specification)

10.5 Subsea Cable Termination: FAT of all subsea electrical power connectors, penetrator or crossover in the scope of supply shall be according to technical specification I-ET3500.00-1500-71F-PAZ-001.

10.6 Abandonment Cap:


10.6.1 Hydrostatic Tests: at least one sample shall be tested in hyperbaric chamber filled with fluorescent liquid at 1,1 times the pressure equivalent to the umbilical specified maximum water depth during at least 24 hours, then the cap shall be removed and the cable stripped for visual inspection of signs of the fluorescent liquid ingress into the electrical cable.

## 11 FACTORY ACCEPTANCE TESTS – COMPLETE UMBILICAL:

11.1 For cables rated from 0,6/1 (1,2) kV to 1,8/3 (3,6) kV, the FAT of the complete umbilical shall comply with tests specified by IEC 60502-1 item 15 (Routine tests), (a) and (b) from item 10.1.1 of this specification.

11.2 For cables rated from 3,6/6 (7,2) kV up to 18/30 (36) kV, the FAT of the complete umbilical shall comply with tests specified by IEC 60502-2 item 16 (Routine tests), (a), (b) and (c) from item 10.2.1 of this specification.

11.3 A TDR signature of the cable after complete umbilical manufacturing shall be measured. All TDR parameters

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and signal waveforms shall be part of the umbilical databook.

## 12 FIELD ACCEPTANCE TESTS – INSTALLED UMBILICAL:

- 12.1 Shall be made Insulation Resistance and Electrical Resistance Tests according to Petrobras requirements.
- 12.2 In all cases, a TDR signature of the complete cable after installation shall be measured. All TDR parameters and signal waveforms shall be part of the umbilical databook.

## 13 MANUFACTURING REQUIREMENTS

- 13.1 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.
- 13.2 For manufacturing, the maximum diameter variation of the cable extruded layers shall be defined in such way that the watertightness in the cable interface termination 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 shall be performed according to API Spec. 17E requirements.
- 13.3 The cable supplier shall provide a data book of the electrical cable, connectors, penetrators and crossovers, including documentation such as: material certificates; manufacturing records; testing records; documents required by the umbilical Quality Plan etc.
- 13.4 The manufacturing data book of each umbilical shall include at least a data sheet containing the following minimum parameters of the electrical cable:
- 13.4.1 All electrical parameters specified;
- 13.4.2 Physical:
- a) Single Core Cable Outer diameter and its tolerance (mm);
  - b) Each single core cable layer thickness and its tolerances (mm);
  - c) Three Core Cable Outer diameter and its tolerance (mm)
  - d) Axial strength (kN); e) Weight in air (kg/km);
  - f) Weight in seawater (kg/km);
  - g) Minimum bending radius – individual power cable elements (mm);
  - h) Minimum bending radius – umbilical (mm).
- 13.5 Supplier shall inform its experience with insulation material used, including in the technical proposal a list of subsea power cables previously supplied, at least with client name, project name, place of installation, water depth, date of installation.