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TECHNICAL SPECIFICATION

I-ET-3000.00-1519-29B-PZ9-002

REV.: A

SHEET: 2 of 9

TITLE: **LOW VOLTAGE/SIGNAL ELECTRIC CABLES AND TERMINATIONS FOR SUBSEA UMBILICAL SYSTEMS**

SUB/ES/EDD/EDF

INTERNA

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1 OBJECTIVE

1.1 This TECHNICAL SPECIFICATION defines the minimum requirements for the design, manufacture, qualification and acceptance tests of low voltage electric twisted pairs cables and terminations for subsea umbilical systems.

2 NORMATIVE REFERENCES

2.1 Unless otherwise specified, the latest revision of references shall be considered.

Ref.	Document Nr	Rev.	Title/Description
[1]	API 17E	-	Specification for Subsea Umbilicals
[2]	ISO 13628-5	-	Petroleum and natural gas industries -- design and operation of subsea production systems -- part 5: subsea umbilicals
[3]	MIL-STD-1344	-	Test methods for electrical connectors
[4]	MIL-STD-202G	-	Test method standard electronic and electrical component parts
[5]	I-ET-3000.00-1500-29B-PAZ-006	-	Qualification for power, control and injection umbilicals

3 TERMS AND DEFINITIONS

3.1 AIB: Accredited Inspection Body

3.2 DWD: Design Water Depth. Water depth specified by PETROBRAS for which umbilical shall be designed independently of operational water depth.

3.3 LV: Low Voltage

3.4 MBR: Minimum Bending Radius

3.5 ROV: Remote Operated Vehicle

3.6 Shall: Mandatory action

3.7 Umbilical(s): group of functional components, such as electric cables, optical fibre cables, hoses, and tubes, laid up or bundled together or in combination with each other.

3.8 Umbilical System: Umbilical, complete with end terminations and other ancillary equipment

4 GENERAL REQUIREMENTS

4.1 Electric cables and terminations shall comply with all requirements of [1] and this TECHNICAL SPECIFICATION. In case of conflict this TECHNICAL SPECIFICATION prevails over [1].

4.2 Electric cables and terminations shall be designed for umbilical system DWD.

5 ELETRIC CABLES

5.1 Requirements herein presented are for electric cables and splices.

5.2 Parameters presented in Table 5-I shall be accomplished.

Table 5-I

Electric cable conductors cross-sectional area				
	2,5 mm ²	4 mm ²	6 mm ²	10 mm ²
Voltage rating	0.6 / 1.0 (1.2) kV			1.8 / 3.0 (3.6) kV
Rated operating frequency (power)	50/60 Hz			
Rated operating frequency (signal)	0 to 30 kHz	0 to 100 kHz		
Max. conductor DC resistance	Reference [2]			
Min. insulation resistance	Reference [1]			
Operating temperature	- 10° C to + 40°C			
Max. reference attenuation	0.65 dB/km at 1kHz	0.48dB/km at 1kHz 0.80dB/km at 10kHz	0.40dB/km at 1kHz 0.83 dB/km at 10kHz 1.35 dB/km at 30kHz	0.20 dB/km at 1kHz 0.40 dB/km at 10kHz 0.90 dB/km at 50kHz 1.30 dB/km at 100kHz
Max. cross talk	-63dB at 1kHz	-90dB at 10kHz	-60dB at 10kHz	

- 5.3 Environmental conditions for materials selection and specification shall include, at least, seawater, marine growth, UV radiation and hydrogen generated by electric cables and umbilical armoring and umbilical cathodic protection.
- 5.4 Design and manufacture shall minimize gaps and voids within layers so to reduce air or other gas accumulation. Fillers, if used, shall be made of polymeric material.
- 5.5 Electric cables shall have an abrasion protection outer sheath. Abrasion protection sheath shall be over the most external layer that makes interface with terminations.
- 5.6 Conductors shall be protected from external environment by at least two mechanical barriers.
- 5.7 Conductors shall have longitudinal water block material (within strands) to minimize water migration in case of conductors flooding.
- 5.8 Single or double shield can be required in MATERIAL REQUISITON. For double shield, one shall be an electric tinned cooper and the other a magnetic steel.
- 5.9 The conductors shall be individually identified. Identification may be numbers, letters or insulation color and shall be visible in umbilical system electric cables pigtaills.

6 TERMINATIONS

- 6.1 Parameters presented in Table 6-I shall be accomplished. Shock and vibration resistance shall be compatible with umbilical system handling, installation and operation.

Table 6-I

Max operating temperature	60° C
Min operating temperature	2° C
Contact capacity	> 10 Amperes/contact
Voltage rating phase to ground	1000 VAC rms (1414 VAC peak)
Voltage rating phase to phase	2000 VAC rms (2828 VAC peak)
Insulation resistance (terminations not connected)	> 5 GΩ @ 20°C

6.2 ELECTRIC CONNECTORS AND CROSSOVERS

- 6.2.1 As an input for the design, the subsea equipment electric cables (PETROBRAS supply) are pressure balanced oil filled (PBOF) hose type with female JIC 8 (JIC 37°) - 3/4" - 16 UNF fitting.

- 6.2.2 Any element under continuous exposure to external environment shall be made of high corrosion resistant alloy. Contact pins shall be made of high corrosion resistant alloy.
- 6.2.3 All energized parts shall be protected from external environment by at least two mechanical barriers.
- 6.2.4 Assembly to the umbilical electric cable shall be pressure balanced. Pressure balance fluid characteristics shall withstand rated voltage and contact with energized parts.
- 6.2.5 Electric contacts between connectors shall have pressure balanced lubricating system.
- 6.2.6 A water block to stop water penetration and a gas-blocking feature to minimize gas permeation, as per [1], shall be included even if connector and crossover pigtails conductors are not used.
- 6.2.7 It shall be designed and have features to allow for testing all external environment mechanical barriers after assembly completion to umbilical electric cable and subsea equipment electric cable.
- 6.2.8 It shall be designed and have features to allow for oil filling and testing the pressure balanced oil filled hose of subsea equipment electric cable.
- 6.2.9 Mechanical interface with subsea equipment electric cable shall be a male JIC 8 (JIC 37°) - 3/4" - 16 UNF fitting.
- 6.2.10 Solder cups of penetrator for interface with subsea equipment electric cable conductors shall have 2.5mm² minimum section. Necessary sleeves and boots for this interface are part of connector and crossover.
- 6.2.11 Connectors shall be designed for at least 30 dry connection and disconnection sequences.
- 6.2.12 Connectors shall have alignment, coupling and locking systems.
- 6.2.13 Crossovers shall be composed by two integrated parts insulated by a penetrator. One part to be terminated to the umbilical electric cable and the other to the subsea equipment electric cable.
- 6.2.14 Electric cables to pin connections shall comply with Table 6-II.

Table 6-II

	Electric cable pair		Connector/crossover pin
Four ways connector/crossover	Conductor 1		1
	Conductor 2		2
	Shield 1		3
	Shield 2 (for cable with two shields)		4
Seven ways connector/crossover	Pair 1	Conductor 1	1
		Conductor 2	2
	Pair 2	Conductor 1	3
		Conductor 2	4
	Pair 3	Conductor 1	5
		Conductor 2	6
Three pairs copper shields (for cables with two shields, steel shields may not be terminated in connector/crossover)			7

6.3 ABANDONMENT CAPS

6.3.1 Conductors shall be protected from external environment by at least two mechanical barriers.

6.3.2 It shall be designed and have features to allow for testing all external environment mechanical barriers after assembly completion to umbilical electric cable.

6.3.3 It shall be designed and have features to allow for insulation test to be performed from opposite end of electric cable.

7 QUALIFICATION

7.1 The qualification shall be performed for each specific electric cable and termination design. Modifications in dimensions, lay angles, manufacturing process, materials, sealing systems, etc., configures a new design.

7.2 The qualification shall be followed by an Independent Verification Agent (IVA) that shall: witness all qualification tests, review all qualification documentation and issue a final Independent Review Certificate (IRC) summarizing the results of the whole qualification process in a technical report demonstrating that products accomplish the requirements.

7.3 The tests procedures, with acceptance criteria, shall be submitted to PETROBRAS for analysis and approval at least 60 days prior to test's execution. Tests shall not be performed without PETROBRAS approval. PETROBRAS, at its own discretion, may reject tests which procedures have not been previously approved.

7.4 ELECTRIC CABLES

7.4.1 All tests in [1] and additional requirements presented in Table 7-I shall be accomplished. Tests #8 and #9 are not applicable for splices and #10 and #11 are exclusive for splices.

Table 7-I

Tests		Requirements
#1	DC insulation resistance	- Test pressure: 1,5 x DWD
#2	High-voltage DC	- Test pressure: 1,5 x DWD - Electric tests: 20kV for minimum 5 minutes. Tests between conductors and between conductors and shield
#3	Inductance	- Test frequencies: 50Hz, 60Hz, 1kHz, 5kHz, 10kHz, 15.5kHz, 30kHz, 55kHz, 80kHz, 100kHz.
#4	Capacitance	
#5	Attenuation (measured or calculated)	
#6	Characteristic impedance	
#7	AC Resistance	
#8	Dynamic bending-tension	- Sampling: Minimum 3 samples of complete electric cable - Test plan: 50 cycles of complete reversed bending under tension. Bending shall be the minimum radius in electric cable and in umbilical manufacture. Tension shall be the maximum in electric cable and in umbilical manufacture. Electric continuity shall be monitored during test. - Electric tests after bending-tension test: Insulation resistance, conductor resistance and high-voltage DC - Visual inspection after electric tests: Samples shall be striped to conductors - Acceptance criteria: i. Maintain electric continuity during bending-tension test ii. Maintain electric parameters in electric tests after bending-tension test. iii. No visual damages, cracks, strands conductors ruptures or kinks in visual inspection after electric tests

#9	Conductors water blocking	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples (samples length to be agreed) - Test pressure: 1,1 x DWD - Test plan: One end of the samples under the test pressure and the other end under atmospheric pressure, for 72h. - Characterization: Water migration length
#10	Dynamic bending-tension for splices	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples of complete electric cable splice - Test plan: 5 cycles of complete reversed bending under tension. Bending shall be the minimum radius in electric cable and in umbilical manufacture. Tension shall be the maximum in electric cable and in umbilical manufacture. Electric continuity shall be monitored during test. - Electric tests after bending-tension test: Insulation resistance, conductor resistance and high-voltage DC - Visual inspection after electric tests: Samples shall be striped to conductors - Acceptance criteria: <ul style="list-style-type: none"> i. Maintain electric parameters in electric tests after bending-tension test ii. No visual damages, cracks, strands conductors ruptures or kinks in visual inspection after electric tests
#11	Tensile for splices	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples of complete electric cable splice - Test plan: Tension applied until loss of performance (loss of electric continuity, loss of insulation, cable break, splice layers failure, structural layers failure, outer sheath failure...). Conductor resistance and insulation resistance shall be monitored during test. - Acceptance criteria: Splice or cable failure shall occur in a tension above the specified design criteria.

7.5 ELECTRIC CONNECTORS AND CROSSOVERS

- 7.5.1 Tests presented in Table 7-II and Table 7-III shall be accomplished. Tests in Table 7-II can be performed in connector/crossover only. Tests in Table 7-III shall be performed for each specific assembly. Assembly being connector/crossover + umbilical electric cable.
- 7.5.2 Procedures for assembling connector/crossover on electric cable for tests in Table 7-III shall be the same as those used in umbilical system final assembly.
- 7.5.3 For new connector/crossover all tests in Table 7-II and Table 7-III shall be accomplished.
- 7.5.4 For new electric cables (new assemblies) only tests in Table 7-III shall be accomplished.

Table 7-II

Tests		Requirements
#1	Insulation resistance	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples - Test plan: As per [4], method 302, condition B - Acceptance criteria: minimum insulation resistance of 5GΩ
#2	Dielectric withstanding voltage	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples - Test plan: As per [4], method 301 - Test voltage: 1,5 x Voltage rating phase to phase
#3	Durability	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples - Test plan: 30 dry connections/disconnections - Acceptance criteria: No connections/disconnections failures
#4	Thermal shock	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples - Test plan: As per [3], method 1003.1, 5 cycles between +1°C and +70°C
#5	Humidity	<ul style="list-style-type: none"> - Sampling: Minimum 3 samples - Test plan: As per [3], method 1002.2, 240h

Table 7-III

Tests		Requirements
#1	First seawater barriers	- Sampling: Minimum 3 samples - Final test pressure: 1,5 x DWD - Cycle test pressure: atm to 1,5 DWD - Test plan: Samples subjected to 3 cycles test pressure before final test pressure. Final test pressure for 72 hours. All first seawater barriers shall be subjected to test pressures. Electric cable outer sheath shall have a simulated damage to be flooded in its interstices. - Acceptance criteria: No water ingress into the connector/crossover.
#2	Second seawater barriers	- Sampling: Minimum 3 samples - Test pressure: 1,5 x DWD - Test plan: Samples in test pressure for 72 hours. All second seawater barriers shall be subjected to test pressure. Insulation resistance, as per [4], method 302, condition B, shall be monitored during test. - Acceptance criteria: minimum insulation resistance of 1GΩ

7.6 ABANDONMENT CAPS

7.6.1 Tests presented in Table 7-IV shall be accomplished for each specific assembly. Assembly being abandonment cap + umbilical electric cable.

7.6.2 Procedures for assembling abandonment cap on electric cable for tests shall be the same as those used in umbilical system final assembly.

7.6.3 For new abandonment caps or electric cables all tests in Table 7-IV shall be accomplished.

Table 7-IV

Tests		Requirements
#1	Water ingress	- Sampling: Minimum 3 samples - Final test pressure: 1,5 x DWD - Cycle test pressure: atm to 1,5 DWD - Test plan: Samples subject to 3 cycles test pressure before final test pressure. Final test pressure for 72 hours. Electric cable outer sheath shall have a simulated damage to be flooded in its interstices. - Acceptance criteria: No water ingress into the abandonment cap

8 ACCEPTANCE TESTS

8.1 ELECTRIC CABLES

8.1.1 All tests in [1] and additional requirements presented in Table 8-I shall be accomplished.

Table 8-I

Tests		Requirements
#1	High-voltage DC	Tests between conductors and between conductors and shield
#2	Inductance	- Test frequencies: 50Hz, 60Hz, 1kHz, 5kHz, 10kHz, 15.5kHz, 30kHz, 55kHz, 80kHz, 100kHz
#3	Capacitance	
#4	Attenuation (measured or calculated)	
#5	Characteristic impedance	
#6	AC Resistance	
#7	Cross-talk	- Test frequencies: 1 kHz to 100 kHz
#8	Time Domain Reflectometry (characterization)	- VOP, pulse width, pulse type, amplitude and gain shall be registered in test result
#9	Conductors water blocking	- Test plan to be agreed based on qualification - Acceptance criteria: Cable shall maintain water blocking as qualification

8.2 ELECTRIC CONNECTORS AND CROSSOVERS

8.2.1 Tests in Table 8-II shall be accomplished. Tests shall be performed on 100% of terminations.

Table 8-II

Tests		Requirements
#1	Insulation resistance	- Test plan: As per [4], method 302, condition B - Acceptance criteria: minimum insulation resistance of 5GΩ
#2	Dielectric withstanding voltage	- Test plan: As per [4], method 301 - Test voltage: 1,5 x Voltage rating phase to phase
#3	Connection (for connectors only)	- Test plan: Pairs of connectors shall be connected and disconnected to verify alignment, tolerances and connections mechanisms

9 DOCUMENTATION

9.1 The minimum information of documentation shall accomplish Table 9-I and Table 9-II.

Table 9-I

Document		Minimum information
#1	Electric cable data-sheet	- Electric cable section with all layers of components, structural elements and fillers - All layers, from conductors to cable outer sheath, diameters and thickness with tolerances - All layers, from conductors to cable outer sheath, materials - Minimum bending radius of each electric pair - Minimum bending radius of complete electric cable - Electric cable maximum tensile load - Electric cable DWD
		- Open and Short Circuit Equivalent Impedance versus frequency - RLC parameters per unit of length (pul) versus frequency - Attenuation per unit of length (pul) versus frequency - Characteristics impedance - VOP
#2	Electric cable data book	- Materials certificates and traceability - Nonconformity reports - Factory acceptance test results
#3	Qualification report	- Electric cable data-sheet - Reference to this TECHNICAL SPECIFICATION - Reference to test procedures - Tests results - Calibration certificates of all measuring devices used in the tests - Verification comments issued by IVA

Table 9-II

Document		Minimum information
#1	Termination drawing	- Principal dimensions - Construction materials - Electric cables that termination is qualified - Termination DWD
#2	Termination data book	- Materials certificates and traceability - Nonconformity reports - Factory acceptance test results
#3	Qualification report	- Termination drawing - Reference to this TECHNICAL SPECIFICATION - Reference to termination assemblies procedures used for tests - Reference to test procedures - Tests results - Calibration certificates of all measuring devices used in the tests - Verification comments issued by IVA