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|                 | <b>TECHNICAL SPECIFICATION</b>           |  |        |        |        | No.: I-ET-3000.00-1519-29B-PZ9-002 |                 |        |        |  |
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TITLE: **LOW VOLTAGE/SIGNAL ELECTRIC CABLES AND TERMINATIONS FOR SUBSEA UMBILICAL SYSTEMS**

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

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**1 SCOPE**

- 1.1 This TECHNICAL SPECIFICATION defines the minimum requirements for the design, manufacture, qualification and acceptance tests of low voltage/signal electric twisted pair cables and terminations for subsea umbilical systems.
- 1.2 The electric cables conductors cross sectional area, the number of individually screened twisted pairs and screen type, single screen or double screen, are presented in MATERIAL REQUISITON.

**2 NORMATIVE REFERENCES**

- 2.1 Unless otherwise specified, latest revisions references shall be considered.

| Ref. | Standard/Code                 | Title  | Rev./Ed. |
|------|-------------------------------|--|----------|
| [1]  | API 17 E                      | 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 ABBREVIATIONS AND DEFINITIOS**

- 3.1 DWD: Design Water Depth. Water depth defined by PETROBRAS for which umbilical shall be designed independently of operational water depth.
- 3.2 MBR: Minimum Bending Radius
- 3.3 Shall: Mandatory action
- 3.4 Umbilical System: Umbilical, complete with end terminations and other accessories and ancillary equipment
- 3.5 VOP: Velocity of propagation of the electromagnetic wave



**4 GENERAL REQUIREMENTS**

- 4.1 The electric cables and terminations shall be designed, manufactured and tested according to reference [1] and this TECHNICAL SPECIFICATION.
- 4.2 The requirements presented in this TECHNICAL SPECIFICATION are complementing and, in case of conflict, prevails over the requirements of reference [1].

**5 ELETRIC CABLES DESIGN REQUIREMENTS**

- 5.1 The electric cables shall comply with electric characteristics presented in Table 5-1.

**Table 5-1 - Electric cables characteristics**

| <b>Electric cable conductors cross-sectional area</b> |                     |   |   |  |
|---|---------------------|---|---|--|
|   | 2,5 mm <sup>2</sup> | 4 mm <sup>2</sup>                       | 6 mm <sup>2</sup>   | 10 mm <sup>2</sup>   |
| <b>Voltage rating</b>                                 | 0.6 / 1.0 (1.2) kV  |   |   | 1.8 / 3.0 (3.6) kV   |
| <b>Nominal Operation Frequency (power)</b>            | 50/60 Hz            |   |   |  |
| <b>Nominal Operation Frequency (signal)</b>           | 0 to 30 kHz         | 0 to 100 kHz                            |   |  |
| <b>Max DC conductor resistance</b>                    | Reference [2]       |   |   |  |
| <b>Min insulation resistance</b>                      | Reference [1]       |   |   |  |
| <b>Operation Temperature</b>                          | - 10° C to + 40°C   |   |   |  |
| <b>Max attenuation</b>                                | 0.65 dB/km at 1kHz  | 0.48dB/km at 1kHz<br>0.80dB/km at 10kHz | 0.40dB/km at 1kHz<br>0.83 dB/km at 10kHz<br>1.35 dB/km at 30kHz | 0.20 dB/km at 1kHz<br>0.40 dB/km at 10kHz<br>0.90 dB/km at 50kHz<br>1.30 dB/km at 100kHz |
| <b>Max cross talk</b>                                 | -63dB at 1kHz       | -90dB at 10kHz                          | -60dB at 10kHz  |  |

- 5.2 The electric cables characteristics shall be guaranteed for the specified umbilical system service life, considering manufacturing, storage, transportation, handling, installation, recovery, testing, and operation.
- 5.3 All electric cables construction materials shall be selected considering environmental resistance for the specified umbilical system service life. Environmental conditions includes, at least, seawater, marine growth, UV radiation and hydrogen generated in electric cables and/or umbilical armoring and/or umbilical cathodic protection.
- 5.4 The electric cables design shall minimize gap and voids between layers to reduce air and gas accumulation in electric cable.

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- 5.5 Fillers, if used, shall be of polymeric material.
- 5.6 The electric cables shall have at least two barriers to protect conductors against seawater. The electric cable outer sheath shall not be considered as a barrier.
- 5.7 Electric cables may have single or double screen. When double screen is required, the cable shall have one electrostatic screen and one electromagnetic steel screen. Screen type is informed in MATERIAL REQUISITION.
- 5.8 The conductors shall have a longitudinal water blocking material (within strands) to minimize water migration in case of conductors flooding.
- 5.9 The conductors shall have individual identification. Identification may be numbers, letters and/or insulation color. Identification shall withstand handling and installation of electric cables and umbilical system.
- 5.10 The electric cable splices shall meet all the requirements presented in this Section 5.

## 6 ELECTRIC TERMINATIONS DESIGN REQUIREMENTS

- 6.1 The electric terminations shall comply with characteristic presented in Table 6-I and have shock and vibration resistance compatible with umbilical system handling, installation and operation.

Table 6-I - Terminations characteristics

|  |                              |
|--|------------------------------|
| <b>Max operating temperature</b>                   | 60° C                        |
| <b>Min operating temperature</b>                   | 2° C                         |
| <b>Contact capacity</b>                            | > 10 Amperes/contact         |
| <b>Voltage rating phase to ground</b>              | 1000 VAC rms (1414 VAC peak) |
| <b>Voltage rating phase to phase</b>               | 2000 VAC rms (2828 VAC peak) |
| <b>Insulation resistance (without connections)</b> | > 5 GΩ @ 20°C                |

### 6.2 ELECTRICAL CONNECTORS AND CROSSOVERS

- 6.2.1 The crossovers are standardized electrical/mechanical accessory for interface between umbilical system electrical cables and subsea equipment electrical cables. The quantity of crossovers for each electrical cable is presented in MATERIAL REQUISITION.

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- 6.2.2 The connectors and crossovers shall be designed for umbilical system design life.
- 6.2.3 The connectors and crossovers parts, including contact pins, that may have continuous or temporary contact with seawater shall be made of high corrosion resistant alloys.
- 6.2.4 The connectors and crossovers shall be pressure-compensated in the connections with electric cable.
- 6.2.5 The pressure-compensated oil/dielectric fluid shall not degrade when in contact with energized parts and its dielectric strength shall be compatible with the connector and crossover rated voltage.
- 6.2.6 The connectors and crossovers shall be designed to be assembled and tested onshore and offshore.
- 6.2.7 The connectors and crossovers energized parts shall be protected against seawater by a minimum of two barriers.
- 6.2.8 The connectors and crossovers that interfaces with subsea equipment oil filled electric cable shall have a male JIC 8 (JIC 37°) - 3/4" - 16 UNF fitting mechanical interface.
- 6.2.9 The connectors and crossovers that interfaces with subsea equipment oil filled electric cable shall have solder cups of at least 2.5mm<sup>2</sup> in its penetrators. The necessary sleeves shall also be included in the scope of supply.
- 6.2.10 The connectors and crossover that interfaces with subsea equipment oil filled electric cable shall have a filling and testing aperture to fill and test the subsea equipment oil filled electric cable.



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6.2.11 It shall be detailed how it will be accomplished the following requirement of reference [1] for connectors and crossovers: The splice between the umbilical conductor core and the electrical connector pigtail conductor core shall include a water block to stop water penetration and incorporate a gas-blocking feature to minimize gas permeation into the pigtail conductor core. The capability to withstand internal pressure shall be better than or equal to that of the conductor insulation.

6.2.12 It shall be detailed how the requirement of reference [1], presented in 6.2.11, will be accomplished if electrical connector pigtails conductors are not used for interface with umbilical conductors.

6.2.13 The connectors and crossovers shall have the standard configurations for electric cables to pins presented in Table 6-II.

**Table 6-II - Standard configurations for cables to pins**

|                                      | <b>Electric cable pair</b>            | <b>Connector/crossover pin</b> |   |
|--------------------------------------|---------------------------------------|--------------------------------|---|
| <b>Four way connector/crossover</b>  | Conductor 1                           | 1                              |   |
|                                      | Conductor 2                           | 2                              |   |
|                                      | Shield 1                              | 3                              |   |
|                                      | Shield 2 (for cable with two Shields) | 4                              |   |
| <b>Seven way connector/crossover</b> | 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 shields                   | 7                              |   |

6.2.14 The connectors shall be wet mate handmade assembly type.

6.2.15 The connectors shall be designed for at least 30 dry connections and disconnections.

6.2.16 The connectors shall have aligning, coupling and locking systems.

6.2.17 The crossovers shall be designed in two integrated parts insulated by a penetrator. One part is terminated in the umbilical electric cable and the other parts is terminated in the subsea equipment oil filled electric cable.

6.2.18 The crossovers seawater barriers design shall allow to be tested separately during qualification and final assembly.





### 6.3 ABANDONMENT CAPS

- 6.3.1 The abandonment caps shall be designed to prevent seawater ingress into the electric cables at umbilical system DWD.
- 6.3.2 The abandonment caps shall have a barrier to protect electrical conductors against seawater in case of electric cable outer sheath damage.
- 6.3.3 The abandonment caps shall be designed to be assembled and tested onshore and offshore.
- 6.3.4 The abandonment caps design shall allow electric cable insulation test from the opposite extremity of umbilical.

## 7 QUALIFICATION

- 7.1 The qualification shall be performed for each specific electric cable and termination design. Modifications in cross section, dimensions, lay angles, manufacturing process, materials, sealing systems and 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 tests 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 The qualification tests for electric cables shall be according to reference [1] and complementary tests/requirements presented in Table 7-I, except test #10 and #11. All tests described in reference [1] shall be performed. Table 7-I presents only complementary tests/requirements to the reference [1].

7.4.2 The qualification tests for electric cables splices shall be according to reference [1] and complementary tests/requirements presented in Table 7-I, except tests #8 and #9. All tests described in reference [1] shall be performed. Table 7-I presents only complementary tests/requirements to the reference [1].

**Table 7-I – Complementary test/requirements for electric cables**

| Tests |                           | Requirements   |
|-------|---------------------------|--|
| #1    | DC insulation resistance  | - Test pressure: 1,5 x DWD   |
| #2    | High-voltage DC           | - Test pressure: 1,5 x DWD<br>- Electric tests: 20kV for minimum 5 minutes. Tests between conductors and between conductors and screen   |
| #3    | Inductance                | - Test frequencies: 20 Hz to 1 MHz   |
| #4    | Capacitance               |  |
| #5    | Attenuation               |  |
| #6    | Characteristic impedance  |  |
| #7    | AC Resistance             |  |
| #8    | Dynamic bending-tension   | - Sampling: Minimum 3 samples of complete electric cable<br>- Bending-tension test plan: 50 cycles of complete reversed bending. Bending radius shall be the minimum bending radius that electric cable will be exposed in electric cable and umbilical manufacture. Tension of 1/3 of cable breaking load. Electric continuity shall be monitored during test.<br>- Electric tests after bending-tension test: Insulation resistance, conductor resistance and high-voltage DC<br>- Visual inspection after electric tests: Samples shall be striped to conductors<br>- Acceptance criterias:<br>i. Maintain electric continuity during bending-tension test<br>ii. Maintain electric parameters in electric tests after bending-tension test<br>iii. No visual damages, cracks, strands conductors ruptures or kinks in visual inspection after electric tests |
| #9    | Conductors water blocking | - Sampling: Minimum 3 samples (samples length to be agreed)<br>- Test pressure: 1,1 x DWD<br>- Test plan: One end of samples under test pressure and other end under pressure to be agreed, for 72h.<br>- Characterization: Water migration length   |



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|     |                                     |  |
|-----|-------------------------------------|--|
| #10 | Dynamic bending-tension for splices | <ul style="list-style-type: none"> <li>- Sampling: Minimum 3 samples of complete electric cable splice</li> <li>- Bending-tension test plan: 5 cycles of complete reversed bending. Bending radius shall be the minimum bending radius that splice will be subjected in electric cable and umbilical manufacture. Tension shall be the maximum tension that splice will be subjected in electric cable and umbilical manufacture.</li> <li>- Electric tests after bending-tension test: Insulation resistance, conductor resistance and high-voltage DC</li> <li>- Visual inspection after electric tests: Samples shall be striped to conductors</li> <li>- Acceptance criterias:             <ul style="list-style-type: none"> <li>i. Maintain electric parameters in electric tests after bending-tension test</li> <li>il. No visual damages, cracks, strands conductors ruptures or kinks in visual inspection after electric tests</li> </ul> </li> </ul> |
| #11 | Tensile for splices                 | <ul style="list-style-type: none"> <li>- Sampling: Minimum 3 samples of complete electric cable splice</li> <li>- Tensile 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...).</li> <li>- Acceptance criteria: Maximum tensile load of splice shall be equal or greater than electric cable</li> </ul>  |

**7.5 ELECTRIC CONNECTORS AND CROSSOVERS**

7.5.1 The qualification tests for connectors and crossovers shall be according to Table 7-II and Table 7-III. Supervision of the umbilical SUPPLIER is required whenever teste are performed by sub-suppliers or third parties.

7.5.2 The tests presented in Table 7-II can be performed in terminations only, and shall be performed for each type/model of connectors and crossovers.

7.5.3 The tests presented in Table 7-III shall be performed in a specific assembly termination type/model - electric cable type/model.

7.5.4 For new terminations design, all tests presented in Table 7-II and Table 7-III shall be performed.

7.5.5 For new electric cables design, only tests presented in table Table 7-III are required.

7.5.6 For all qualification tests, the procedures used for connectors and crossovers assembly in the electric cables shall be the same procedures used in the final assembly of the umbilical system.



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**Table 7-II – Tests for terminations**

| Tests |                                 | Requirements   |
|-------|---------------------------------|--|
| #1    | Insulation resistance           | - Sampling: Minimum 3 samples<br>- Test plan: According to reference [4], method 302, condition B<br>- Acceptance criteria: minimum insulation resistance of 5GΩ |
| #2    | Dielectric withstanding voltage | - Sampling: Minimum 3 samples<br>- Test plan: According to reference [4], method 301<br>- Test voltage: 1,5 x Voltage rating phase to phase                      |
| #3    | Durability                      | - Sampling: Minimum 3 samples<br>- Test plan: 30 dry connections/disconnections<br>- Acceptance criteria: No connections/disconnections failures                 |
| #4    | Thermal shock                   | - Sampling: Minimum 3 samples<br>- Test plan: According to reference [3], method 1003.1, 5 cycles between +1°C and +70°C   |
| #5    | Humidity                        | - Sampling: Minimum 3 samples<br>- Test plan: According to reference [3], method 1002.2, 240h  |

**Table 7-III – Test for termination-electric cable assembly**

| Tests |                          | Requirements   |
|-------|--------------------------|--|
| #1    | First seawater barriers  | - Sampling: Minimum 3 samples<br>- Final test pressure: 1,5 x DWD<br>- Cycle test pressure: atm to 1,5 DWD<br>- 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.<br>- Acceptance criteria: No water ingress into the termination |
| #2    | Second seawater barriers | - Sampling: Minimum 3 samples<br>- Test pressure: 1,5 x DWD<br>- Test plan: Samples in test pressure for 72 hours. All second seawater barriers shall be subjected to test pressure. Insulation resistance, according to reference [4], method 302, condition B, shall be monitored during test.<br>- Acceptance criteria: minimum insulation resistance of 1GΩ  |

**7.6 ABANDONMENT CAPS**

7.6.1 The qualification tests for abandonment caps shall be according to Table 7-IV. Tests shall be performed in a specific assembly abandonment cap type/model - electric cable type/model.

7.6.2 For new abandonment cap and/or electric cable design, all tests presented in Table 7-IV shall be performed.

7.6.3 For all qualification tests, the procedures used for abandonment caps assembly in the electric cables shall be the same procedures used in the final assembly of the umbilical system.



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**Table 7-IV - Tests for abandonment caps**

| Tests |               | Requirements   |
|-------|---------------|--|
| #1    | Water ingress | <ul style="list-style-type: none"> <li>- Sampling: Minimum 3 samples</li> <li>- Final test pressure: 1,5 x DWD</li> <li>- Cycle test pressure: atm to 1,5 DWD</li> <li>- Test plan: Samples subject to 3 cycles test pressure before final test pressure.</li> </ul> Final test pressure for 72 hours. Electric cable outer sheath shall have a simulated damage to be flooded in its interstices.<br>- Acceptance criteria: No water ingress into the abandonment cap |

## 8 ACCEPTANCE TESTS

### 8.1 ELECTRIC CABLES

8.1.1 The acceptance tests for electric cables shall be according to reference [1] and complementary tests/requirements presented in Table 8-I. All tests described in reference [1] shall be performed. Table 8-I presents only the complementary tests/requirements to the reference [1].

**Table 8-I - Complementary tests/requirements for electric cables**

| Tests |  | Requirements   |
|-------|--|--|
| #1    | High-voltage DC                              | Tests between conductors and between conductors and screen   |
| #2    | Inductance                                   | - Test frequencies: 20 Hz to 1 MHz   |
| #3    | Capacitance                                  |  |
| #4    | Attenuation                                  |  |
| #5    | Characteristic impedance                     |  |
| #6    | AC Resistance                                | - Test frequencies: 1 kHz to 100 kHz   |
| #7    | Cross-talk                                   |  |
| #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<br>- Acceptance criteria: Cable shall maintain water blocking as qualification |

### 8.2 ELECTRIC CONNECTORS AND CROSSOVERS

8.2.1 The acceptance tests for connectors and crossovers shall be according to Table 8-II. Tests shall be performed on 100% of terminations. Supervision by the umbilical SUPPLIER is required whenever tests are performed by sub-suppliers or third parties.



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**Table 8-II - Connectors and crossovers acceptance tests**

| Tests |                                  | Requirements  |
|-------|----------------------------------|---|
| #1    | Insulation resistance            | - Test plan: According to reference [4], method 302, condition B<br>- Acceptance criteria: minimum insulation resistance of 5GΩ |
| #2    | Dielectric withstanding voltage  | - Test plan: According to reference [4], method 301<br>- 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 be according to Table 9-I and Table 9-II.

**Table 9-I - Minimum information for electric cable documents**

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

**Table 9-II - Minimum information for terminations documents**

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