	TECHNICAL SPECIFICATION		No. I-ET-3000.00-1500-956-PEK-001
	CLIENT:	PETROBRAS E&P	SHEET: 1 of 13
	JOB:	COATING – SUBSEA EQUIPMENT	–
	AREA:	SUBSEA INSTALLATIONS	NO SCALE / A4
SUB/ES	TITLE:	COATING ASSESSMENT - REQUIREMENTS FOR SUBSEA EQUIPMENT	PUBLIC
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INDEX OF REVISIONS

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1. INTRODUCTION

1.1. OBJECTIVE

- 1.1.1. The purpose of this document is to define the minimum technical requirements for coating systems applied for subsea equipment.
- 1.1.2. This Technical Specification is based on guidelines and requirements of the international standard Norsok M-501 (ref. [1]) and Petrobras Standard N-2037 (ref. [2]) and shall be read in conjunction with them. Its purpose is to complement, clarify and modify specific requirements of these codes related to coating systems to be applied to subsea equipment.
- 1.1.3. The requirements herein presented are based on Petrobras experience in the definition of parameters from its subsea projects track record applied for subsea equipment coating.

1.2. SCOPE OF THE DOCUMENT

- 1.2.1. This specification applies to subsea equipment/structures, as per defined in item 2.2 and, their components, such as:
- Connection Systems, including the caps and their tools.
 - Valves.
 - Swivels.
 - Panels for ROV intervention and other interfaces.
 - Other specific components as informed in the MATERIAL REQUISITION.
- 1.2.2. The following items for subsea structures and components, which are within the scope of this Technical Specification, are:
- General coating systems requirements.
 - Requirements for coating systems for corrosion protection.
 - Requirements for thermal insulation systems.
- 1.2.3. The coating systems shall be suitable to withstand the operational and design parameters (e.g., design temperature, cool down time and thermal insulation requirements) set forth in the RM / specific datasheet from each Petrobras subsea project, which refers for this Technical Specification.
- 1.2.4. For requirements related to the application of wet thermal insulation on subsea equipment, see reference [3].

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2. TERMS, DEFINITIONS AND ABBREVIATIONS


2.1. VERBAL TENSES

2.1.1. The following definitions apply to the use of the content within this document:

- a. “Shall” - is used to indicate that a provision is mandatory.
- b. “Should” - is used to indicate that a provision is not mandatory but is recommended as good practice.
- c. “May” - is used to indicate that the adoption of a provision is based on the discretion of the user of this Technical Specification.
- d. “Shall not” - Forbidden action or requirement.

2.2. DEFINITIONS

- 2.2.1. **CONTRACTOR** - Company directly awarded by PETROBRAS to supply components, structures, and/or part or whole subsea system. CONTRACTOR may award sub-suppliers to deliver part of the scope of work.
- 2.2.2. **MATERIAL REQUISITION** - Project document intended for the procurement of materials that establishes all technical requirements and complementary instructions necessary for this objective. It lists all attachments that composes the scope of supply, such as Technical Specifications, Project Description, Technical Standards, Drawings, Data Sheets, etc.
- 2.2.3. **PRE-PRODUCTION TEST (PPT)** - Series of tests performed immediately before the start of production, designed to demonstrate that the requirements of a previously qualified coating system are achieved, as outlined in this Technical Specification.
- 2.2.4. **PROCEDURE QUALIFICATION TEST (PQT)** - Series of tests designed to demonstrate that the coating materials, coating applicator, coating equipment and coating procedure can meet the requirements as outlined in this Technical Specification.
- 2.2.5. **SUBSEA EQUIPMENT / SUBSEA STRUCTURE** – System constituted by components (e.g., valves, chokes, connectors, pumps, instruments, etc.) for subsea application. Its purpose is to fulfill specific function (e.g., safety barrier, collector, distributor, interconnection, chemicals injection, monitoring, flow control, etc.) during the design life of an oil & gas offshore field development. For purposes of this TECHNICAL SPECIFICATION, the terms subsea equipment and subsea structure are considered equivalent and can be used interchangeably to designate PLETs, PLEMs, In-Line Tees, Wyes, Valves, ESDVs, WCTs, manifolds, connectors, UTAs and P&B systems, and their associated components and tools. Sleepers, Anode skids, In-Line Anchors (pipeline and

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anchoring accessories), and Anchoring systems (suction and torpedo piles) are not considered as subsea equipment / structure and are not part of the scope of this document.


2.2.6. **SUPPLIER / SUB-SUPPLIER / APPLICATOR / MANUFACTURER** - Part awarded by CONTRACTOR to deliver whole or part of the scope of coating work. SUPPLIER may award part of the scope of work to SUB-SUPPLIER. For APPLICATOR and MANUFACTURER definitions see item 5.6.

2.2.7. **TECHNICAL SPECIFICATION** - Document that contains technical requirements that CONTRACTOR, SUPPLIER and its SUB-SUPPLIERS shall fulfill.

2.3. ABBREVIATIONS

2.3.1. All terms defined in ref. [1] and ref. [2] apply, in addition to the following:

CDT	Cool Down Time
CFD	Computational Fluid Dynamic
CPS	Coating Procedure Specification (same APS – Application Procedure Specification)
CPT	Coating Procedure Test (same as PQT)
EPCI	Engineering, Procurement, Construction, and Installation
ESDV	Emergency Shut Down Valve
ET	Technical Specification
FEA	Finite Element Analysis
IVB	Independent Verification Body
P&B	Process and Boosting System
PLET	Pipeline End Termination
PLEM	Pipeline End Manifold
PPT	Pre-production Test
PQT	Procedure Qualification Trial1/ Process Qualification Test
RM	Material Requisition
UTA	Umbilical Termination Assembly (“UDEH – Unidade de Distribuição Eletro-Hidráulica”)
UV	Ultraviolet
WCT	Wet Christmas Tree (“ANM – Árvore de Natal Molhada”)
WD	Water Depth

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3. REFERENCES

3.1. GENERAL

- 3.1.1. The documents listed in sections below are essential for the use of this TECHNICAL SPECIFICATION.
- 3.1.2. The latest edition of the codes and specs below shall be adopted, unless otherwise stated.
- 3.1.3. In case it is noted any conflict between this Technical Specification and the aforementioned documents, the following precedence order shall be respected:
- This Technical Specification.
 - NORSOK M-501 (ref. [1]).
 - N-2037 (ref. [2]).
 - Any questions regarding the conflicts between the requirements shall be clarified and registered through the issue of a formal Technical Query to PETROBRAS.

3.2. CODES AND STANDARDS


<i>Ref</i>	<i>Designation</i>	<i>Title</i>
[1]	NORSOK M-501	Surface preparation and protective coating, 2012.
[2]	N-2037	<i>Pintura de equipamentos submersos em água do mar</i>
[3]	I-ET-3000.00-1500-431-PEK-001	Wet Thermal Insulation for Subsea Equipment, rev. 0.
[4]	ISO 12736	Petroleum and natural gas industries – Wet thermal insulation coatings for pipelines, flowlines, equipment and subsea structures, 2014.
[5]	ET-3000.00-1500-600-PEK-006	<i>Requisitos gerais de equipamentos submarinos</i>
[6]	I-ET-3000.00-1500-610-PEK-003	PLET, PLEM and In-line equipment
[7]	ET-3000.00-1500-940-PEK-001	<i>Projeto de Proteção Catódica para Equipamentos Submarinos</i>
[8]	API RP 17H	Remotely Operated Tools and Interfaces on Subsea Production Systems
[9]	ASTM D4285	Test Method for Indicating Oil or Water in Compressed Air
[10]	ASTM D4940	Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blast Cleaning Abrasives
[11]	ISO 12944-9	Paints and varnishes – Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures

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<i>Ref</i>	<i>Designation</i>	<i>Title</i>
[12]	ISO 8501-1	Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness - Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
[13]	ISO 8503-1	Surface roughness characteristics of blast-cleaned steel substrates - Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces
[14]	ISO 4628-2 ISO 4628-3 ISO 4628-4 ISO 4628-5 ISO 4628-6	Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance. Part 2 - Assessment of degree of blistering Part 3 - Assessment of degree of rusting Part 4 - Assessment of degree of cracking Part 5 - Assessment of degree of flaking Part 6 - Assessment of degree of chalking
[15]	ISO 19840	Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces
[16]	ISO 4624	Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces - Second Edition
[17]	NACE SP0188	Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
[18]	API 6A	Wellhead and Christmas Tree Equipment

4. GENERAL REQUIREMENTS FOR COATING SYSTEMS


- 4.1. Selection of the coating material: CONTRACTOR shall define the materials to be used in accordance with ref. [1], [2], [3] and in accordance with design data presented in the MATERIAL REQUISITION (maximum and minimum design temperatures, maximum WD, CDT requirement, etc.).
- 4.2. The coating design shall consider conditions due to installation and storage temperature: the equipment may be exposed to temperatures ranging from 3 °C (on seabed) to 50 °C (on vessel deck). However, during storage under sunlight exposure the equipment surface temperature may be as high as 85 °C. CONTRACTOR shall consider these values for coating design purposes if project specific data are not available.

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- 4.3. The coating design shall consider conditions due to long term storage: the top coating shall be UV stabilized for, at least, one year exposed to sun, in Brazil.
- 4.4. The sealing areas and/or surfaces with relative movement shall not be painted, as per requirements of ref. [5] and ref. [6].
- 4.5. The surfaces/areas which coating systems that do not have an anti-corrosion function (e.g., lubrication, anti-fouling, etc.) shall be considered as unprotected (bare area) for cathodic protection calculation purposes.
- 4.6. Brush and paint roller are accepted only for coating strips and repair. Any damage on coating system shall be repaired using an approved method (to be proposed by CONTRACTOR for PETROBRAS approval).
- 4.7. Coating colors: unless otherwise specified in the MATERIAL REQUISITION, the following colors shall be used on structure, as per ref. [5]: white for subsea equipment, red for padeyes and yellow for removable parts (connection systems, modules, etc.). The color code (Munsell or RAL) shall adhere to orientations from ref. [8].
- 4.8. CONTRACTOR shall meet the general requirements for coating presented in ref. [5] not yet mentioned herein this technical specification.
- 4.9. The process parameters defined during the PQT shall be used during production. The range defined for each parameter during PQT shall be respected during production; otherwise, a new PQT shall be performed.

5. REQUIREMENTS FOR ANTICORROSION PROTECTIVE COATING SYSTEMS

- 5.1. CONTRACTOR shall fulfill all the requirements presented within this Technical Specification. The subsea equipment and its components shall be externally coated according to item 4.3 of ref. [2] (alternative C) with additional and modified painting requirements of ref. [1], as per presented on this section.
- 5.2. As per table A.7 in ref. [1]: coating system no. 7C shall be selected for submerged carbon and stainless steel which application temperature > 50 °C (piping and structures with contact with process fluid, in general); coating system no. 7B may be selected for submerged carbon and stainless steel which application temperature < 50 °C, if no selected coating system no. 7C.
- 5.3. The coating system shall always be used in combination with cathodic protection. The cathodic protection system shall fulfill the requirements of ref. [7].

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- 5.4. Any protective coating systems used for submerged carbon steel components shall be in accordance with ref. [1]. Additional and modified requirements to ref. [1] are presented in following paragraphs. The ref. [1] paragraph number is given with a section sign “§” before each subitem below.
- 5.5. §2.1 (Addition) – The following standards shall also be considered:
- ASTM D4285 (Test Method for Indicating Oil or Water in Compressed Air).
 - ASTM D4940 (Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blast Cleaning Abrasives).
- 5.6. §3.1 (Addition) – The following terms and definitions shall also be considered
- Applicator: party to whom the coating work has been contracted.
 - Manufacturer: manufacturer of coating “raw” materials purchased by Applicator.
- 5.7. §4.2 (Addition) – Steel subject to surface preparation on site shall be in accordance with rust-grade B according to ref. [12].
- §4.5 (Addition) – Only coating system no. 7B and no. 7C shall be selected.
- §4.5 (Modification) – The minimum coating film thickness shall be 450 µm. The coating system shall be pre-qualified in accordance with clause 10.
- 5.8. §4.7 (Modification) – No shop primer shall be left on the surface.
- 5.9. §6.1 (Addition) – Prior to blast cleaning, the surface shall be preheated to remove all moisture. Steel surface shall be kept at least 3 °C above the dew point and below 85 °C.
- 5.10. §6.2 (Modification) – Blasting abrasives and pressurized air system shall be kept dry and free from injurious contaminants, including salts, oil and grease. Recycled blasting material shall be checked for cleanliness and size at regular intervals (to be specified in CPS/CPT and recorded in the Daily Log). Checking of oil contamination and soluble contaminants shall be carried out according to ref. [9] and ref. [10], respectively. Special precautions shall be taken to avoid contamination of blasting materials for stainless steel line pipe (to be specified in CPS).
- Conditioning of grit during production shall be described in the CPS/CPT.
- 5.11. §6.2 (Modification) – The cleanliness of the blast cleaned surface shall be in compliance with ref. [11], Sa 2½ or Sa 3 and to surface profile “medium (G)” as defined in ref. [13] with an acceptance criteria of 50 µm to 100 µm, Ry5 measured by methods for quantitative

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analysis as per surface roughness tester, surface profile replica tape plus thickness gauge or surface profile gauge. The use of surface profile comparator is not allowed.

- 5.12. §6.3 (Addition) – Surface subjected to blasting and accepted for coating shall be coated within a period of four hours. Whenever it is raining or the relative humidity of the air is greater than 85%, the maximum waiting period shall be reduced to two hours. Whenever oxidation or another type of contamination occurs, the surface shall be cleaned and blasted again according to cleaning procedure and the coating shall be applied prior to any surface contamination.
- 5.13. §7.2 (Addition) – Compressed air shall be free of oil, condensed moisture or any other contaminants and shall conform to the requirements of ref. [9].
- 5.14. §7.3 (Modification) – After paint system is completely cured, visual and holiday inspection shall be performed to confirm that coating is free from pinholes, blisters and holidays. The entire painted surfaces shall be inspected.
- 5.15. §10.1 (Addition) – It is recommended that Applicator presents reports from internal tests performed prior to the specific pre-qualification tests.

§10.1 (Modification) – Prior to commencement of work, pre-qualification of the proposed product as coating system shall be performed in accordance with Table 1. The results from the qualification tests are valid for the same curing time of each layer of the coating system.

Table 1 – Pre-qualification tests for coating materials

TEST	ACCEPTANCE CRITERIA
Seawater immersion test duration 4200 hours according to ISO 12944-9 ref. [11] (historical test data with the same conditions are acceptable)	M ≤ 3.0 mm for coating system with Zn (R) primer ¹ M ≤ 8.0 mm for coating system with primer other than Zn (R)
Complete coating system thickness	Minimum of 450 µm and maximum 650 µm according to ISO 19840 ref. [15]
Holiday detection	No holidays @ 2.3 kV according to ISO 29601 or 2.5 kV according to ref. [17]
Adhesion according to ISO 4624 ref. [16] (method for testing from one side only, using a single dolly shall be used and test carried out when coating system is fully cured)	No single measurement less than 12 MPa Cohesive failure of substrate is not permitted. Three specimens for the adhesion test shall be prepared according to the requirements of ISO 4624 ref. [16]. Re-testing is required if the failure occurred at the adhesive/coating interface. Two new specimens shall be tested and both shall be approved.

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TEST	ACCEPTANCE CRITERIA
Cathodic disbondment according to ISO 12944-9 ref. [11] (Steel temperature: maximum operating steel temperature; Electrolyte: 3.5% NaCl Electrolyte; Temperature: 30 °C; Potential: -1.2 V SCE Oxygen concentration: 8×10^{-6} ; Diameter circular coating holiday: 6 mm; Duration: 4 weeks).	The equivalent diameter of the disbonded area shall ≤ 10 mm.


1 – See ref. [11] for M and Zn (R) definition

- 5.16. §10.2.2 (Modification) – Prior to commencement of work, the paint operator shall pass the pre-qualification test described in Table 2. The results from the qualification test are valid for maximum 12 months without regular coating work.
- 5.17. §10.2.5 (Modification) – Coating inspectors on yard shall attend to at least the level 2 of NACE, FROSIO or ABRACO certification. At least one coating inspector level 3 shall be available at any time for supervision of works.

Table 2 - Pre-qualification tests for paint operators

TEST	ACCEPTANCE CRITERIA
Visual examination after complete curing of coating system ref. [14].	No Blistering according to ref. [14] part 2 No Rusting according to ref. [14] part 3 No Cracking according to ref. [14] part 4 No Flaking according to ref. [14] part 5 No Chalking according to ref. [14] part 6
Complete coating system thickness	Minimum of 450µm and maximum of 650 µm according to ref. [15]
Adhesion according to ref. [16] (method for testing from one side only, using a single dolly shall be used and test carried out when coating system is fully cured).	No single measurement less than 12 MPa. Cohesive failure of substrate is not permitted. Three specimens for the adhesion test shall be prepared according to the requirements of ref. [16]. Re-testing is required if the failure occurred at the adhesive/coating interface. Two new specimens shall be tested.


- 5.18. §10.3.1 (Addition) – CPS shall be qualified and approved prior to any production activity starts.
- 5.19. §10.3.2 (Addition) -- In case of coating qualification already performed for other applications/scenarios, the CONTRACTOR shall issue the qualification report (dossier) for PETROBRAS evaluation and approval. The tests reports shall be presented stamped and signed by an IVB.

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- 5.20. §10.3.2 (Addition) -- In case the presented qualification report covers a part of the tests required by this specification and applicable references, but not all, a Qualification Gap Analysis shall be issued for PETROBRAS evaluation. This gap analysis shall present the design and test parameters comparison between previous and current project. Based on this report, the required tests to complement the qualification will be detailed.
- 5.21. §11 (Addition) – Routine batch verifications shall be included, as required in ISO 12944-9 ref. [11].
- §11 (Modification) – Holiday detection shall be performed as per NACE SP0188 ref. [17]. No indications shall be verified with tested at 2.5 kV as recommended by table 1 of ref. [17]. Testing frequency shall be 100% of all surfaces.

6. REQUIREMENTS FOR THERMAL INSULATION SYSTEMS

- 6.1. If required thermal insulation coating for subsea equipment, shall be in accordance with ref. [3]. The subsea equipment shall be externally coated with a combination of anticorrosion and thermal insulation systems. The minimum cool down time shall be as per presented in MATERIAL REQUISITION / specific datasheet of each subsea project. The fulfillment of the requirements shall be demonstrated by a full-scale test in accordance with ref. [3].
- 6.2. A qualification dossier in accordance with section 7, and ref. [3] and ref. [4] shall be submitted to PETROBRAS for analysis and approval, including the track record of supplying of the coating system for PETROBRAS project. The qualification dossier shall be supplied to PETROBRAS prior to any coating activity starts.
- 6.3. The selection of the thermal insulation system shall consider the compatibility with the anticorrosion coating herein specified, unless otherwise informed in the MATERIAL REQUISITION.
- 6.4. Geometry of thermal insulation: the geometry of the insulation material shall be smooth and continuous around the piping and other insulated parts of the equipment. The thickness of the thermal insulation shall be as constant as possible. The subsea equipment and their components shall be designed to guarantee their required functionality and performance even after the application of thermal insulation.
- 6.5. Specifically for the thermal insulation design (including thermal layer thickness) and material selection, CONTRACTOR shall consider all relevant parameters such as, but no limited to: creep, field joint coating efficiency, manufacturing tolerances, etc. Spreadsheets, FEA/CFD

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thermal analysis and native files of numerical analysis attached to a thermal insulation design report shall be supplied to PETROBRAS verification and approval.

- 6.6. Equipment with thermal insulation shall provide inspection points for measuring the thickness of the production/annular flow piping and for cathodic protection measurement when this piping is not made of special metallurgy (Trim HH, as defined in ref. [18]). The dimensions, quantity and location of inspection points will be defined during project execution phase.

7. REPORTS, RECORDS AND DOCUMENTATION

- 7.1. CONTRACTOR shall submit to PETROBRAS the relevant documentation as required in ref. [1]. Additionally, by using this Technical Specification, the following information shall also be documented and issued for PETROBRAS evaluation, as a minimum:
- a. ITP for each coating system.
 - b. PQT procedures and their respective reports.
 - c. PPT procedures and their respective reports, as applicable.
 - d. Material Data Sheet for each coating system.
 - e. Applicator/Painter certificates
 - f. Qualification dossier from previous qualifications, as applicable. This dossier shall include a gap analysis.
 - g. General Arrangement and detailed drawings depicting each surface/area where the coating systems are applied on subsea equipment and/or component.
 - h. List of coating work documentation to be included in project Databook (procedures, reports, datasheets, certificates, gap analysis, etc.).