PETROBRAS	TECHNICAL SPECIFICATION		I-ET-0000.00-0000-940-P9U-001
	CLIENTE:	-	FOLHA: 1 de 9
	PROGRAMA:	RIGID OFFSHORE PIPELINES	-
	ÁREA:	-	-
-	TÍTULO:	CATHODIC PROTECTION DESIGN	EDD / EDR
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DATA	28/06/2018	07/05/2020	21/06/2021	01/07/2021	13/09/2022	13/07/2023
EXECUÇÃO	UP65	C5FP	C5FP	C5FP	C5FP	C5FP
VERIFICAÇÃO	RHEL	UPL2/SG5H	UPL2	UPL2/SG5H/BEJ8	UPL2/TS8H	BEJ8
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1. INTRODUCTION

1.1. SCOPE

This Technical Specification presents the minimum requirements to the Cathodic Protection (CP) design of rigid subsea pipelines' external surface, and it is only applicable to the CP design of CMn-steel pipelines using galvanic anodes.

This Technical Specification also includes a design strategy to mitigate detrimental effects of CP potential in titanium top connectors, including, but not limited to, Titanium Stress Joint (TSJ) and Titanium Internal Pull-in Tube (TiPT).

The CP design of other pipeline materials (e.g. stainless steel, CRA), pipeline internal surface and subsea structures are not included within the scope of this Technical Specification.

1.2. GENERAL

The review and approval by Petrobras of any document related to Cathodic Protection Design shall only indicate a general requirement and shall not relief Contractor of his obligations to comply with the requirements of the contract. Any errors or omissions noted by Contractor shall be immediately brought to Petrobras' attention.

All deviations to this Technical Specification and other referred specifications or attachments listed in the Contract shall be made in writing and shall require written approval by Petrobras prior to executing the work.

All documents shall be issued in accordance with the latest revision of Petrobras Standards: N-381 [1], N-1710 [2] and N-2064 [3].

1.3. DEFINITIONS

The following definitions are adopted in this Technical Specification:

CONTRACTOR	The company responsible for the cathodic protection design of subsea pipelines
CP	Cathodic Protection
CRA	Corrosion Resistance Alloy
FPU	Floating Production Unit
FSHR	Free Standing Hybrid Riser
HDD	Horizontal Directional Drilling
HISC	Hydrogen Induced Stress Cracking
ISO	International Standard Organization
OD	Outside Diameter
SCR	Steel Catenary Riser

SLWR	Steel Lazy Wave Riser
TiPT	Titanium Pull-in Tube
TSJ	Titanium Stress Joint

2. DESIGN CODES

The latest revision of DNV-RP-F103 [4] and ISO 15589-2 [5] shall be considered on the CP design of subsea pipelines. The N-1935 [6] standard presents some specific data related to Brazilian coast and, therefore, shall also be fulfilled.

3. DESIGN METHODOLOGY

The CP design of subsea pipelines shall be based on the methodology presented in [5], considering the mandatory requirements presented in [6] and in this Technical Specification.

When the anode design is based on bracelet anodes (two semicircular sections) and the pipeline is not intentionally buried (by trenching, rock-dumping, etc.), the CP design shall be performed considering the following scenarios:

- both pipeline and anodes completely exposed to seawater if the expected (calculated) embedment is less than 50% of pipe OD (including external coating);
- both pipeline and anodes completely buried if the expected (calculated) embedment is higher than or equal to 50% of pipe OD (including external coating).

On the other hand, in case the anode design is based on half-shell anodes (one semicircular section) and the pipeline is not intentionally buried (by trenching, rock-dumping, etc.), the CP design shall be performed considering that anodes are fully buried, and the pipeline completely exposed to seawater.

The spacing between anodes shall be according to [6]. In case the mass of an individual anode is great enough in order to cause difficulty on its installation, two anodes can be installed side by side with a minimum distance between these anodes of 12m (or one pipe joint). Such distance can only be reduced if it is demonstrated by calculation or numerical simulation that interference effects can be disregarded.

When adopting anode sled, depending on proximity of anodes on the array, anodes will experience mutual interference, which reduces its capacity to provide current. Therefore, it shall be demonstrated by calculation or numerical simulation that interference effects can be disregarded, or this effect shall be taken into account in order to obtain the initial and final resistance of the anode sled array and, hence, to calculate the required mass and number of anodes.

All calculations shall be presented in MATHCAD format including all steps of the calculation methodology.

4. DESIGN REQUIREMENTS

The following design requirements shall be fulfilled in addition to the ones presented in references [5] and [6].

4.1. GENERAL PARAMETERS

Environmental resistivity shall be in compliance with the value recommended in [5]. However, seawater resistivity adopted on the design shall not be less than 0.25 Ωm.

4.2. COATING BREAKDOWN FACTOR

Coating breakdown factors shall be calculated using the methodology and data specified in [5]. The obtained values shall be considered as minimum, but they must not be used for the pipeline section inside an HDD, since a higher quantity of damages is expected in this case. For an HDD section the mean and final coating breakdown factors shall be defined on a case-by-case basis by PETROBRAS at the beginning of the Basic Design.

For other types of coatings not listed in tables 3 and 4 of [5], coating breakdown factors shall be submitted for Petrobras approval and shall be based on field data.

Coating breakdown factors of accessories (flanges, bends, bolts, nuts, etc.) coated with other types of coatings, such as painting, shall be obtained from [7].

4.3. TITANIUM TOP CONECTOR

For cathodically protected risers connected to the FPU through a titanium-made top connector, such as TiPT and TSJ, CONTRACTOR shall guarantee the protective potential at the riser top steel section to be positive to -850mV. Once risers are normally protected by CP system based on galvanic anodes, expected protective potential at the riser top steel section shall be assessed via attenuation models by numerical simulation using Boundary Element Method. Design premises and results of numerical simulations shall be submitted for Petrobras approval.

4.4. DESIGN LIFE

Design life shall take into account a period for pre-lay, wet storage and recovery of the pipeline. This design life increment depends on project specific requirements and, when not specified, shall be at least 1 (one) year.

Cathodic protection system shall be operating for the whole period of pipeline's pre-lay, wet storage and recovery.

5. PIPELINES WITH INCREASED ANODE SPACING

In cases where the anodes cannot be equally spaced throughout the pipeline and the distance between anodes is greater than 300m, such as for risers and HDD sections, the CP design shall fulfill the requirements of Section 8.2 of [6] and the specific ones presented in this section of PETROBRAS Technical Specification. In all cases the cathodic protection of pipeline sections with anode spacing greater than 300m shall be demonstrated using the attenuation calculation according to Section 6.7 of [4] or Annex B of [5]. The attenuation calculations shall take into accounting the voltage drop across the connection system between anode and pipeline.

When the FSHR concept is adopted, bracelet anodes are not allowed. In this case anodes shall be installed on subsea structures such as anode sledges, riser bases, etc.

In case the CP design of SLWR and SCR adopts bracelet anodes, they shall be concentrated on the flowline section, i.e., the section resting over the seabed and stable.

In case the CP design of HDD sections adopts bracelet anodes, they shall be concentrated on the first pipes immediately after the end of the HDD section. In both cases, i.e. when adopting bracelet anodes or anode sledges, in order to verify the effectiveness of the cathodic protection over the length of the HDD section, numerical simulations using Boundary Element Method shall be carried out and submitted for Petrobras approval. Sensitivity analyses regarding the distance between adjacent anodes shall also be performed. Numerical simulations shall consider the variation in soil resistivity along HDD route. Laboratory tests shall be performed in order to obtain steel polarization curves on the applicable environment. Otherwise, CONTRACTOR shall justify the polarization curves proposed based on field proven results. Previous experience on performing such simulations shall be demonstrated.

When adopting anode sled, mechanical connection for electrical continuity is allowed (e.g. clamps). In this case, measurement of the electrical resistance of the connection system shall be carried out in order to verify if it is in accordance with the design requirements; the voltage drop across the connection system shall not exceed 50 mV.

When cable-to-pipe connections rely on mechanical contact, checks shall be performed after installation in order to demonstrate electrical continuity (e.g. the measurement of potential on both the anode and the pipeline immediately adjacent to the attachment point).

In case of adopting stand-off or flush mounted anodes to be installed on subsea structures appropriate anode fabrication and design shall comply with [7].

6. ANODE MANUFACTURING AND INSTALLATION

Galvanization of aluminum anode steel core is acceptable, provided that anode manufacturer demonstrate that it does not influence anode chemical composition.

Anode installation shall comply with [8] and [6], which provides additional requirements to [5]. Additionally, the requirements presented in this section shall also be fulfilled.

In case of adopting long electrical copper cables, a duct tape or similar (approved by Petrobras) shall be applied over these cables in order to prevent snagging.

When adopting anode sled, and the electrical continuity relies on mechanical connection (e.g. clamps, connection collars, etc.), at least two connection devices shall be employed (i.e two clamps, two connection collars, etc.). Each of connection device shall be connected to the pipeline through two independent cables.

Due to the possibility of damage to the external protective coating system during installation process, and subsequent exposure of the bare steel to the environment, the connection of the anode sled to the pipeline shall be performed immediately after the pipeline lay.

The gaps between anode half-shells and between anode and concrete shall be filled with solid polyurethane (density higher than 1100 kg/m^3) and the electrical cable shall be completely covered by the filling material.

The type of electrical connection shall be defined taking into consideration the susceptibility of the linepipe material to HISC, as per [8].

CONTRACTOR shall include a procedure to protect (corrosion protection) the welding anode area. This procedure shall include at least: steel surface cleaning, corrosion protection material specification, corrosion protection material application and curing time of the corrosion protection material.

The material used to protect the welding anode area shall be Acothane or better and shall be submitted for Petrobras approval. Application and adhesion qualification tests shall be performed as pre-production tests. Qualification tests shall be performed at least 90 days before pipeline installation in case a different material is proposed.

7. PRE-PRODUCTION TESTS (PPT)

Pre-production tests shall be performed in accordance with [5] and shall also fulfill the requirements presented in [6]. At least two half shells (one complete anode) from the same heat shall be tested during the PPT.

The PPT shall include an electrochemical performance test, following requirements from Appendix E of [5]. Additionally, a chemical analysis of the anode alloy shall be also carried out during PPT, as per Section 10.3 of [5].

If all acceptance criteria described in [5] are fulfilled, then the PPT is considered acceptable. Otherwise, the PPT shall be restarted using other two half shells from a new anode heat.

Petrobras shall be previously informed of tests schedule in order to witness these tests.

8. INITIAL SURVEY

The post-lay survey shall include not only the visual inspection of coatings, anodes, skids and other components of cathodic protection system, but also the determination of the potential along the pipeline and the current output of galvanic anodes, as per reference [9]. The measurements shall be performed in a sufficient period after the connection of anode sled to pipeline in such way to confirm that pipeline is protected along its entire length. This information will be used as a baseline for later surveys.

Potential measurements should be performed preferentially along pipeline route, at regular intervals of length. When impossible or impractical, such measurement could be performed at specific locations of the pipeline. These locations shall be submitted for Petrobras approval.

For anode sleds or similar, potential measurements shall be performed at a point downstream of the connection point to the pipeline. The objective such practice is to attest electrical continuity of connection devices such as clamps, connectors, cables, etc.

Potential measurement at riser top needs special attention, once results could be jeopardized by a possible electrical interference with CP system.

For titanium top connectors, after pull-in and CP system commissioning, a potential measurement shall be performed at the top riser steel section immediately beneath the top connector, to attest that protective potential is positive to -850mV.

Despite of the potential measurement, all risers with titanium top connectors shall be permanently monitored for protective potential. Ref. [12] presents requirements for potential monitoring of existent platforms, where a new riser will be installed as part of a revitalization program, for example. For new platforms (not constructed), the potential monitoring system shall be as per ref. [13].

9. REFERENCES

[1] N-381, *EXECUÇÃO DE DESENHOS E OUTROS DOCUMENTOS TÉCNICOS EM GERAL*.

[2] N-1710, *CODIFICAÇÃO DE DOCUMENTOS TÉCNICOS DE ENGENHARIA*.

[3] N-2064, *EMISSÃO E REVISÃO DE DOCUMENTOS DE PROJETO*.

[4] DNV-RP-F103, CATHODIC PROTECTION OF SUBMARINE PIPELINES BY GALVANIC ANODES.

[5] ISO 15589-2, PETROLEUM AND NATURAL GAS INDUSTRIES – CATHODIC PROTECTION OF PIPELINE TRANSPORTATION SYSTEM – PART 2: OFFSHORE PIPELINES.

[6] N-1935, *PROJETO DE SISTEMA DE PROTEÇÃO CATÓDICA POR CORRENTE GALVÂNICA – DUTO SUBMARINO*.

[7] DNV-RP-B401, CATHODIC PROTECTION DESIGN.

[8] DNV-ST-F101, SUBMARINE PIPELINE SYSTEMS.

[9] DNV-RP-F116, INTEGRITY MANAGEMENT OF SUBMARINE PIPELINE SYSTEMS.

[10] DNV-RP-F201, DESIGN OF TITANIUM RISERS.

[11] I-ET-0000.00-0000-290-P9U-005, TITANIUM PULL-IN TUBE SPECIFICATION.

[12] I-ET-3000.00-5529-850-PEK-009, TIPT RISER MONITORING SYSTEM (TRMS) – RISER SCOPE FOR FPU HULLSIDE UMBILICAL SOLUTION.

[13] I-ET-3000.00-5529-850-PEK-008, TIPT RISER MONITORING SYSTEM (TRMS) – RISER SCOPE FOR FPU HULLSIDE CONDUIT CABLING.