PETROBRAS	**TECHNICAL SPECIFICATION**	**Nº:** I-ET-3010.00-5267-750-P4X-001	
	CLIENT:		**SHEET** 1 **of** 20
	JOB:		--
	AREA:		
DDP-SRGE	**TITLE:** **TECHNICAL SPECIFICATION FOR CATHODIC PROTECTION**		INTERNAL
			ESUP

MICROSOFT WORD / V. 2016 / I-ET-3010.00-5267-750-P4X-001_B.DOCX

INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ISSUE
A	REVISED ACCORDING ICCP COMMENTS
B	ITEMS REVIEWED ARE MARKED IN GRAY

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	MAR/10/20	OCT/30/20	APR/14/21						
DESIGN	ESUP	ESUP	ESUP						
EXECUTION	MARLON	MARLON	CXO5						
CHECK	FERNANDORT	GBMATTER	NTX1						
APPROVAL	LUCIANARM	LUCIANARM	UPDM						

SUMMARY

1. INTRODUCTION

This document aims to present the PETROBRAS Mandatory Requirements applicable to the Cathodic Protection Design for Offshore Production Unit, which shall be addressed by concerned parts during the Unit Design stages. Furthermore, this document will be a guide for future studies and analysis on the Executive Design, the Detailing, Construction, Installation, Operation and Demobilization Design of the Unit.

This Technical Specification determines the requirements for the design, assembly and pre-operation of cathodic protection systems for offshore Stationary Production Units (UEP), such as: Semisubmersible (SS) unit, Floating Production, Storage and Offloading (FPSO) units; Floating, Storage and Offloading (FSO) units, Ships and Fixed Platforms.

A specific document shall consider these orientations on the occasion of the documentation issuance for the Executive Design (or Detailed Design) execution.

Mandatory Requirement is the provision defined as the most adequate and which application shall be performed in compliance with this Guideline.

2. NORMATIVE REFERENCE

The following related documents are essential to the application of this guideline. For dated references, only mentioned editions shall be considered. For undated references, the most recent editions of such documents (amendments included) shall be considered.

- **DNVGL-RP-B101 -** Corrosion Protection of Floating Production and Storage Units;
- **DNVGL-RP-B401 -** Cathodic Protection Design;
- **DNVGL-CG-0288 -** Corrosion Protection of Ships;
- **IEC 60079** - Electrical apparatus for explosive atmospheres;
- **IEC 60092-502 -** Electrical Installations in Ships Part 502: Tankers – Special Features;
- **IEC 60688** - Electrical Measuring Transducers for Converting A.C. Electrical Quantities to Analogue or Digital Signals;
- **IEC 61892-7** - Mobile and Fixed Offshore Units – Electrical Installations, Part 7 Hazardous Area;
- **MIL-A 18001 K -** Anodes, Corrosion Preventive Zinc Flat Disc and Rod Shaped.
- **NR-10 –** Brazilian Regulatory Norms - Electrical Safety -Installations and Services

3. TERMS AND DEFINITIONS

The terms and definitions indicated below shall be adopted for the purpose of this Guideline:

- Coating Efficiency (E) – Fraction of the surface effectively protected by the anticorrosive coating in order to restrict the reduction of the protective current on a specified structural area.
- Cofferdam – Empty, unmanned and normally closed compartment placed below the water level in a vessel that allows the electric interconnection from the reference anodes and electrodes to their electric cables inside the vessel, restraining the entrance of sea water to its interior.
- CPS - Cathodic Protection System.
- Final Anode-Electrolyte Contact Resistance (R_i) – Anode-electrolyte contact resistance as the anode has its dimensions reduced in consequence of consumption through its life cycle.
- Final Current (I_f) - Current intensity needed for protection against a possible polarization of a structure at the end of the life cycle adopted for the cathodic protection system.
- Final Current Density (D_f) - Current intensity, by area unit, required for protection and possible repolarization of a certain structure at the end of its life cycle, adopted for the cathodic protection system.
- Final Current Produced by the Anode ($\bar{I}_f$) – Current intensity produced by an anode as the anode has its dimensions reduced in consequence of consumption through its life cycle.
- Final Efficiency (E_f) - Efficiency of the coating in at the end of the life cycle adopted for the CPS.
- Initial Anode-Electrolyte Contact Resistance (R_i) – Anode-Electrolyte resistance with anode in its initial dimensions.
- Initial Current (I_i) – Current intensity needed for polarization of a structure submitted to cathodic protection to adequate formation of the calco-magnesian layer.
- Initial Current Density (D_i) – Intensity of the current, by area unit, needed for polarization of a structure submitted to cathodic protection, with the adequate formation of the calcomagnesian scaling.
- Initial Current Produced by the Anode ($\bar{I}_i$) – Current intensity produced by an anode in its initial dimensions.

- Initial Efficiency (E_i) - Efficiency of the coating in at the beginning of the structure operation.
- Jacket – Structural part of a fixed platform ranging from the foundation to just above sea level and above which the deck and/or modules are installed.
- Location Tests – Prior operation CPS test performed at the offshore floating unit location.
- Mean Current (I_m) - Current intensity needed for keeping the polarization of a structure through the life cycle of the cathodic protection system.
- Mean Current Density (D_m) – Current intensity, by area unit, needed for keeping the polarization of a structure through the life cycle of the cathodic protection system.
- Mean Efficiency (E_m) – Efficiency of the coating in the middle of the life cycle adopted for the CPS.
- Mudmat – Wood or steel panel used to support a structure in the seabed. In the case of jackets, the support is temporary until the definitive piling is completed.
- Polarization Time – Time required for achieving to a stable electrochemical potential protection of a structure submitted to cathodic protection.
- Sea Chest – Opening made in the vessel hull for aspiration or discharge of sea water used in several services and systems on the vessel.
- Sea Tests – Tests performed to check the functioning of the offshore floating unit's CPS in a region close to the shipyard.
- Turret – Mooring structure from the vessel to the seabed, internally or externally incorporated to the vessel hull by one or more bearings, that allows the free rotation of the vessel around the axis of this structure, providing the alignment of the vessel with the result of the environmental efforts.
- Velocity Factor – Cathodic protection current correction factor due to the relative velocity between the electrolyte and the structure to be protected.
- Vessels – SS, FSO and FPSO units and ships are considered vessels.

4. DESIGN OVERALL CRITERIA

4.1. Cathodic Protection Types That Apply

4.1.1. Impressed current cathodic protection system shall be adopted in vessel hulls, unless there are technical restrictions that make it impossible to be applied. In this case, the alternative shall be submitted for PETROBRAS' approval.

4.1.2. For retrofitting systems, the cathodic protection type may be changed, due to a technical and economic evaluation performed.

4.2. The needing for installing a temporary CPS to the vessel hull until the definitive one is in operation shall be considered. This system shall be executed in compliance to the provisions of item 5.3 of this guideline.

4.3. The design shall comply with safety premises, taking the offshore unit hazardous areas plan into account.

4.4. The life cycle of the vessel, or time period between dockings, as defined by PETROBRAS.

4.5. The detrimental effects of cathodic protection for different kinds of materials and for coating shall be taken into account, in accordance to DNVGL-RP-B401 (Item Detrimental Effects of CP).

4.6. In the vessel CPS measurement all the submerged area at maximum operating draught including steel cables, propellers, chain cables and accessories that maintain metallic contact with each other or with the vessel hull shall be considered.

NOTE: For chain and/or cables steel made, an area equivalent to their metallic length limited to 30 meters shall be considered.

4.7. The Coating Breakdown Factors for Cathodic Protection Design from DNVGL-RP-B401 shall be fulfilled. It shall be considered that in this guideline, as in other PETROBRAS standards, the "Coating Efficiency" (E) parameter is adopted, while DNV adopts the "coating breakdown factor" (F) parameter. The relation between both parameters is the following:

$$E = 1 - F$$

4.8. The welded connections shall be performed by qualified welders and shall be approved by the classification society in accordance with the qualification welding procedure.

4.9. The impressed current cathodic protection system shall be tested as described in item 6.

5. IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM

5.1. Definitive Cathodic Protection System

The definitive cathodic protection system for protection of vessel hulls shall be in compliance with the requirements provided in the following items.

5.1.1. Areas to be Protected

The CPS shall be designed for the protection of the entire hull submerged surface, taking item 4.7 of this guideline into consideration.

5.1.2. Materials and Equipment

5.1.2.1. Anodes

The design shall preferably use mixed metal oxide (MMO) coated inert titanium anodes. Any specification concerning another anode shall be submitted in advance for PETROBRAS' approval.

5.1.2.2. Reference Electrodes

Zinc reference electrodes shall be in compliance with MIL-A 18001K.

5.1.2.3. Rectifiers

Rectifiers shall be in compliance with the requirements defined in item 5.2.

Identical rectifiers are recommended for a same vessel.

5.1.3. Specific Criteria for Design, Construction and Assembly

5.1.3.1. Reference anodes and electrodes must be distributed over the submerged surfaces, below the minimum draft, in order to guarantee the range of cathodic protection potential described on DNVGL-RP-B101.

5.1.3.2. Anodes shall be equipped with a cable or stem, in order to enable its connection with the main electric cable.

5.1.3.3. Around and under the anodes, on the surface to be protected, an dielectric shield coating shall be applied, having a thickness of at least 4 mm (dielectric shielding), and length of at least 2 m around the anode.

NOTE: In case there is any metallic structure installed within a 2 m radium from the anode, it shall be properly coated with the same insulator coating.

5.1.3.4. Installing anode and reference electrodes electric cables outside the hull shall be avoided on stationary units.

5.1.3.5. In the case it is not possible to comply with 5.1.3.4 and the anodes or reference electrodes need to be installed in region of the tanks holding explosive atmospheres (cargo tanks and adjacent compartments and slop tanks), the following aspects shall be considered:

a) penetration of electric cables in the hull shall take place in the nearest non-classified area, minimizing the length of the external submersible installation.

b) the installation of electric cable shall be in compliance with the following:

- the electric cables shall be isolated and be abrasion, ozone and weather resistant (emersed installation). The submersed electric cables shall also be adequate for complete immersion in sea water. The cables shall be installed in cable beds that protect them from damaging.
- in the tide variation zone, only vertical sections of cables can be installed, to minimize the injury of the sea on the installation.

5.1.3.6. At least two impressed current cathodic protection units shall be installed. Each unit shall be comprised of one rectifier and its respective anodes and reference electrodes, in order to promote a better distribution of the current along the hull, and shall fulfill the following requirements:

a) have at least two reference anodes. One of them shall be installed three meters away from one of the anodes, while the other shall be installed as far as possible from the anodes;

b) allow the connection of any reference electrode to its respective rectifier, allowing the automatic control of the electrochemical structure potential.

c) the rectifiers shall be installed in a sheltered and easily accessible place, with temperature inferior to 45ºC, protected from marine atmosphere. In case the place is a classified area, the rectifier shall be in compliance with IEC 60092-502 (group IIA, temperature T3 – 200ºC). For some kinds of chemical cargos and byproducts such as liquefied petroleum gas (GLP) and liquefied natural gas (GNL) the classification in other groups and temperature classes shall be evaluated.

5.1.3.7. All the reference anodes and electrodes shall be positioned, at least, three meter below the minimum draught level, to ensure operational continuity of the impressed current cathodic protection system.

5.1.3.8. A numerical simulation of the potential distribution shall be performed for hull cathodic protection designs in order to confirm the absence of harmful electrochemical potential in the hull and in other components adjacent to it.

5.1.4. Design Parameters

The parameters to be considered during the CPS designing shall be the following:

a) Resistivity of electrolyte : 25 Ω.cm or as per DNV RP-B401 provided that the environment variables are known (temperature and salinity);

b) current density: as per initial, mean and final current density tables of the DNV-RP-B401 and B101 for environmental conditions (climate region and depth);

c) coating efficiency: as per item 4.9;

d) velocity factor: as per Table 2.

Table 2 – Velocity Factor X Structure/Electrolyte Relative Velocity

Speed (m/s)	Velocity factor
0 to 1,5	1,0
1,5 to 3,5	1,1
> 3,5	1,2

5.1.5. Designing

5.1.5.1. Life cycle values, coating breakdown factor, cathodic protection current density, electrical resistivity of electrolyte and velocity factor, which are defined in items 4.4, 4.9, and 5.1.4, shall be used for CPS designing.

5.1.5.2. Calculate I_i by the following formula:

$$I_i = S.D_i.(1-E_i).f_v$$

Where:

I_i - initial current, in A;

S - surface area to protect, in m²;

D_i - initial current density, in A/m²;

E_i - initial coating efficiency;

f_v - velocity factor.

5.1.5.3. Calculate I_m by the following formula:

$$I_m = S.D_m.(1-E_m).f_v$$

Where:

I_m - mean current, in A;

S - surface area to protect, in m²;

D_m - mean current density, in A/m²;

E_m - mean coating efficiency;

f_v - velocity factor.

5.1.5.4. Calculate I_f by the following formula:

$$I_f = S.D_f.(1 - E_f).f_v$$

Where:

I_f - final current, in A;

S - surface area to protect, in m²;

D_f - final current density, in A/m²;

E_f - final coating efficiency;

f_v - velocity factor.

5.1.5.5. Choose the greater value among I_i, I_m and I_f and define the quantity and the nominal current of each rectifiers (I_n).

5.1.5.6. Check with supplier the maximum current (I_{max}) at which each anode can operate according to the life cycle time adopted for cathodic protection system, as per item 4.4, and the type of anode chosen, should be, preferably, Mixed Metal Oxide (MMO),

5.1.5.7. Calculate the minimal quantity of anodes (n) per rectifier, by the following formula:

$$\mathrm{n} \geq \frac{I_n}{I_{\max}}$$

Where:

n - minimal quantity of anodes;

I_n - rectifier nominal current, in A;

$I_{\max}$ - maximum current in which the anode can operate (in A).

5.1.5.8. Calculate, per anode, the electric cable resistance (R_{cabo}) that connects the rectifier to the anode as below:

$$R_{cabo} = R_E \times L$$

Where:

R_{cabo} - resistance of the electric cable that connects the rectifier to the anode (Ω);

R_E - electrical resistance of the chosen cable per unit length (Ω/m);

L - cable length (m).

NOTE: The selected electric cable shall be compatible with the current to be drained by the anode.

5.1.5.9. Calculate the anode-electrolyte contact electrical resistance (R_{anodo}) by the following formula, for plain rectangular anodes:

$$R_{anodo} = \frac{\rho}{2\,L_e}$$

Where:

R_{anodo} - anode-electrolyte contact electrical resistance (Ω);

ρ - electrical resistivity of electrolyte, in Ω.m;

L_e - average between length and width of the MMO plain anode, in m.

NOTE: This formula is used when the length of the anode is, at least, twice its width.

5.1.5.10. Calculate anode branch resistance (R_{ramal}) as:

$$R_{ramal} = R_{cabo} + R_{anodo}$$

5.1.5.11. Calculate the equivalent resistance (R_{eq}) resulting from parallel branches of anodes in the same rectifier.

5.1.5.12. Calculate rectifier minimum output voltage (V_{min}), by the formula:

$$V_{\min} \geq I_n \times R_{eq}$$

Where:

$V_{\min}$ - rectifier minimum output voltage, in V;

- rectifier nominal current, in A;

R_{eq} - resistance resulting from the parallel branches of anodes (R_{ramal}) in the same rectifier, in Ω.

5.1.5.13. Define rectifiers input nominal voltage (V_N), considering the availability of the vessel's electric system.

5.2. Rectifiers

This guideline presents technical requirements and recommended practices.

5.2.1. Technical requirements

5.2.1.1. The rectifiers to be installed in classified areas shall comply with the proper normative requirements and their respective compliance certificate shall be issued. For electric installation on fixed and floating offshore units, as per IEC 61892-7, the rectifier shall comply with IEC 60079 and a compliance certificate allowing its use in explosive atmospheres shall be issued.

5.2.1.2. The rectifier shall be full wave type for total load operation in continuous service.

5.2.1.3. The rectifier shall be air cooled and designed to operate in tropical climate, where temperatures varies from -10 to +45ºC and relative humidity is 95% at 25 ºC.

5.2.1.4. Equipment efficiency must be 60% or greater for single phase rectifiers and 80% or greater for three-phase rectifiers where load varies from 50 to 100% of its nominal value.

5.2.1.5. The maximum temperature reached by the casing with diodes and thyristors shall not exceed 100ºC.

5.2.1.6. The rectifier shall operate in both modes: manual or automatic.

5.2.1.7. Manual operation shall allow the continuous adjustment of the output voltage, ranging from zero to its nominal value.

5.2.1.8. Automatic operation shall be constant potential type, which control is based on keeping electrolyte-structure potential close to *previously adjusted* fixed reference value.

5.2.1.9. Rectifier shall contain basically the following components:

- Ammeters and voltmeters for measuring input current and voltage (AC) and output current and voltage (DC) on the equipment; the class of accuracy for both devices is 1.5%
- DC digital voltmeter (minimal internal impedance = 20MΩ) for measuring the reference electrode potential. For rectifiers with more than one reference electrode, a assignment switch shall be provided for individual measuring of each reference electrode and another one to select the electrode reference to automatically control the rectifier;
- DC ammeter provided with switch for measuring total current and individual current in each anode;
- 1.5% class of accuracy digital hour meter to record operation hours;
- Ammeters, voltmeters and hour meters shall be provided with a LCD with backlight;
- Manual/automatic operation switch;

- Output current limiting circuit, within the limits of its nominal value;
- Potentiometer to adjust operation points in manual and automatic modes, installed inside the equipment, in easy accessible places, and properly identified.

5.2.1.10. Rectifier's front panel shall be provided with:

- AC and DC voltmeters (for input and output voltage and reference electrode potential) and ammeters, with their respective measurement switches;
- Assignment switches for pilot reference electrode to automatically control rectifier and read electrochemical potential;
- Switch to turn the sound alarm off;
- Switches for bulbs testing.

5.2.1.11. A device to send the following information to the Control and Remote Supervision Station shall be provided:

- “Powered Rectifier”;
- “Non-Powered Rectifier”;
- “System Failure”, comprising the following failures: super-protection, sub-protection, overcurrent (DC) and overvoltage (DC);
- Voltage (AC);
- Output voltage (DC);
- Output current per anode;
- Total output current;
- Voltage in each reference electrode.

5.2.1.12. A transparent insulation protection shall be supplied for power supply busbar in alternate current and output in direct current to avoid electric shock or short-circuit.

5.2.1.13. Electronic cards shall be supplied with protection against offshore climate conditions (“tropicalization” treatment – protection coating)

5.2.1.14. Rectifier fuses, transient suppression devices and input & output terminal blocks shall be placed in a safe and accessible position.

5.2.1.15. The rectifier shall be provided with a grounding terminal for 25 mm^2 minimum section copper cable connected inside or outside the box. The structure and the doors shall be electrically connected to the rectifier box. If oil rectifier should be considered, the terminal shall be located outside the box.

5.2.1.16. Rectifiers installed in non-classified areas shall be provided with lighting inside their casings, which will be automatically on by opening the door for maintenance and inspection services.

5.2.1.17. Rectifiers installed in non-classified area shall be provided with a universal socket outlet installed on the front panel and supplied by a 300W transformer, with two output voltages (127 V_{ca} e 220 V_{ca}) for instruments and equipment during maintenance and inspection services.

5.2.1.18. Anticorrosive painting, coating, shall be that proper to the environment where the equipment will be installed.

5.2.1.19. All internal and external components shall be identified according to the design electrical diagrams.

5.2.1.20. An identification label made of anticorrosive material shall be attached to the external part of equipment's front door providing the following information:

- Petróleo Brasileiro S.A. - PETROBRAS;
- Purchase document number;
- Manufacturer's name;
- Rectifier's type and model;
- Serial number;
- Year and month of manufacture;
- Input voltage;
- Frequency;
- Number of phases;
- Nominal output voltage;
- Nominal output current.

5.2.1.21. For each rectifier supplied, spare parts shall also be supplied in a quantity corresponding to the one used in two years of operation.

5.2.1.22. The rectifier shall be provided with a copy of the electrical diagrams, properly protected against humidity and handling by a plastic cover or similar, placed in an opening in the internal part of the door.

5.2.1.23. Cathodic Protection Rectifiers shall comply with requirements of NR-10.

5.2.1.24. Cathodic Protection Rectifiers shall communicate with Electrical System Automation according to I-ET-3010.00-5140-797-P4X-001 - Electrical System Automation Architecture and I-DE-3010.00-5140-797-P4X-001 - Electrical System Automation Architecture Diagram.

5.2.1.25. Cathodic Protection Rectifiers shall exchange signals with Electrical System Automation according to I-LI-3010.00-5140-797-P4X-001 - Electrical System Automation Interface Signals List.

5.2.2. Inspections and routine tests on rectifiers shall be carried out according to the instructions provided by PETROBRAS specific documentation (standard and/or rule).

5.2.3. Documentation

5.2.3.1. The technical proposal shall include the following documents:

a) List of spare parts;

b) Preliminary dimensional drawings showing side, front, top and bottom views;

c) List of components;

d) Certificate of equipment compliance for utilization in classified areas (as applicable).

5.2.3.2. During the process of approval of the rectifier design, the manufacturer shall supply the necessary documentation (type and number of copies as informed for each case), including, at least, the following information:

a) dimensional drawings showing all views, sections and details;

b) List of materials informing the number, manufacturer and specification of all components and accessories;

c) electrical and electronic diagrams;

d) dimensions and type of connection devices of the equipment;

e) installation, operation and maintenance manual.

5.2.3.3. Upon delivery of equipment, provide the following documents (type and number of copies as informed for each case):

a) warranty certificate;

b) All approved documents related to the design;

c) components and accessories technical catalogues;

d) final manufacture tests results.

5.3. Temporary Cathodic Protection System

The temporary cathodic protection system – for protection of vessel hull – shall be in compliance with the requirements presented in items 5.3.1 to 5.3.3.

5.3.1. The temporary CPS can be impressed-current or galvanic type and shall operate whenever the hull is in contact with sea water and the definitive system is not in operation. If

a galvanic current CPS should be adopted, then the criteria established in item 6 herein shall be adopted as well.

5.3.2. It is not necessary to have anodes welded on or bolted to the hull, except if the system is used during unit tripping and towing. [Recommended Practice]

5.3.3. If a galvanic current CPS using suspended anodes should be adopted, then the following precautions shall be taken:

a) contact between electrical cable and hull shall be made with connector preferably interconnected with accessories such as fenders, anchor cradles and hand rails to avoid damage to hull painting or structure; [Recommended Practice]

b) the top of the anode shall be located at least 1.5 m below the bottom of the hull or keel;

c) anodes shall be uniformly distributed around the hull.

6. PROCEDURES FOR PRE-OPERATION OF IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM

6.1. General

6.1.1. It shall be performed 3 series of tests of pre-operation of Cathodic protection System: Shipyard tests, sea tests and location tests. The results of those tests shall be properly recorded.

6.1.2. The criteria for assessment of cathodic protection to be adopted is the electrochemical potential. The values of measured electrochemical potentials shall meet the range set out in 4.5.

6.1.3. The reference voltmeters and electrodes Ag/AgCl $_{seawater}$ or zinc used in measuring the electrochemical potential shall be calibrated.

6.1.4. The measurement of hull electrochemical potential along the external surface of the hull shall be performed with silver-silver chloride (Ag/AgCl $_{seawater}$) or zinc reference portable electrode, completed by the reference fixed electrode reading in vessels. Moreover, measurements close to reference fixed electrodes shall be performed for the purpose of comparing the values only.

NOTE 1: The descent points for measurement with portable electrodes shall be chosen so that there is a uniform distribution of them around the submersed hull area. After that, the points shall be marked on the deck as a reference for future measurements.

NOTE 2: The reference portable electrode shall be placed next to the middle of the vessel draught and the as close as possible to the hull, limited to the maximum distance of five meter.

NOTE 3: During the measurement, the negative terminal of the Voltmeter shall be connected to the reference electrode cable.

NOTE 4: In order to convert the electrochemical potential readings with different electrodes (Zn and Ag/AgCl seawater), the following approach:

$P_{Ag/AgCl} = P_{Zn} - 1050$ (mV)

6.2. Shipyard Tests

The Cathodic Protection System shall be submitted to component checks and functional testing.

6.2.1. Component Checks:

a) Rectifiers:

- Power supply;
- Connection to the electric cables of anodes, electrodes and ground cables (hull);
- Polarity: Positive pole connected to the anode cable and negative pole connected to the ground cable;

b) Electric cables:

- Electrical continuity;
- Electrical insulation;
- Connection to the anodes, reference electrodes and ground (hull);

c) Anodes and reference electrodes:

- Electrical insulation (if they are emerged);
- Sealing;

d) *cofferdam*:

- Tightness;
- Paraffin embedding;

e) Grounding system for propeller shaft and rudder.

6.2.2. Functional Tests

The test consists in energizing the cathodic protection system, with anodes and reference electrodes submersed, in which the following parameters shall be checked:

a) Voltage and supply current (AC);

b) Voltage and output current (DC);

c) Instrument operation and alarm testings of the rectifier panel;

d) Current in each anode;

e) Electrochemical potential

f) Commutation – automatic to/from manual mode;

NOTE: All referenced measurements shall be performed using calibrated instruments and calibration certificate issued by an accredited laboratory.

6.3. Sea tests

The test consists in checking the cathodic protection system operation in conditions closer to operating conditions. The following procedures shall be performed:

a) Perform the tests that have not been executed in the shipyard test;

b) Evaluate the effectiveness of the cathodic protection system through the measurement of electrochemical potential, as per 6.1.4;

c) Check the performance of the rectifier's automatic adjustment control in relation to the vessel draft.

6.4. Location tests

The applicable tests for checking the cathodic protection system in the operating conditions. The following procedures shall be performed:

a) Perform all procedures specified for the sea tests; the parameters assessment shall be performed seven days after the cathodic protection system was energized, sufficient period of time for structure polarization to take place;

b) After the polarization of the structure, the following parameters shall be monitored for five succeeding days:

- Voltage and supply current (AC);
- Voltage and output current (DC);
- Current in each anode;
- Electrochemical potential measured by reference electrodes;

c) On a three-month basis of definitive operation of cathodic protection system, an underwater visual inspection shall be performed in order to provide a detailed survey of the potentials in points to be determined by PETROBRAS.

7. DOCUMENT REQUIREMENTS

The documentations shall include at least the following information:

a) History information, design parameters and complete calculations, including formulas;

b) Drawings providing the general arrangement of anodes, electrodes, cables and supports;

c) Drawings detailing the anodes, electrodes and support fastener;

d) Drawings of route and details for fastening the electrical cables of cathodic protection system;

e) Components certificates of cathodic protection system: Rectifiers, anodes, reference electrodes, electric cables and accessories;

f) Electrical diagrams of rectifiers and control panels;

8. RECTIFIER MANUALS

g) Dimension drawings and of details of anodes and reference electrodes;

h) Drawings of route and details for fastening the electrical cables of cathodic protection system;

i) Spare part list;

j) Pre-operation report;

Operation, maintenance and inspection procedures.