

GENERAL SPECIFICATION

CORROSION

GS EP COR 103

Design of cathodic protection of offshore floating structures
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1. Scope

This document defines the minimum requirements for the design, calculation methods, selection of equipment and alloy materials, installation and commissioning of cathodic protection of floating structures (FPSO, buoys, etc). Both external cathodic protection of the structures and internal protection of integrated tanks such as ballast, cargo, slop tanks and process tanks are covered.

Except if formally accepted in a written form by Company, cathodic protection shall be implemented using galvanic (or sacrificial) anodes.

Galvanic and impressed current cathodic protection systems are defined in the present document.

This document also defines the cathodic protection monitoring systems, gives the rules for anode distribution and the requirements to avoid negative influence induced on metallic structures by high potential alloy anodes (as magnesium alloy) or impressed current anodes.

The requirements of the present document are superseding those of the reference documents, which have to be used when necessary for further information. Recommendations from EN standards related to floating offshore structures shall be followed when they are not in conflict with those of the present document. Other recommendations and especially those from [DNV-RP-B401](#) have also to be used in complement.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
DNV-RP-B101	Corrosion Protection of Floating Protection and Storage Units
DNV-RP-B401	Cathodic Protection Design
EN 12473	General principles of cathodic protection in sea water
EN 13173	Cathodic protection for steel offshore floating structures
IACS	Requirements concerning FIRE PROTECTION
ISO 15589-2	Petroleum and natural gas industries - Cathodic protection for pipeline transportation systems – Part 2 Offshore Pipelines

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP COR 100	Design of cathodic protection of offshore structures
GS EP COR 101	Design of internal cathodic protection of equipment and storage tanks
GS EP COR 102	Design of cathodic protection of sealine by sacrificial anodes
GS EP COR 201	Supply of sacrificial anodes
GS EP COR 202	Monitoring systems for cathodic protection of offshore structures
GS EP COR 351	External protection of structures and equipment by painting - Floating structures
GS EP COR 501	Control of cathodic protection of submerged fixed structures
GS EP SPS 029	Metallic Materials for Subsea Production Facilities
GS EP STR 631	CALM buoy terminals
GS EP STR 652	F(P)SO - Steel hull design requirements

3. Qualification and Certification of Cathodic Protection specialists responsible for the design

Design of cathodic protection systems to be installed on floating structures shall be carried out exclusively by competent specialised personnel. The qualification of each of the specialists working on such design shall be demonstrated to Company before commencement of the job.

The requirement for personnel qualification is given in [GS EP COR 100](#).

4. External cathodic protection of floating structure

4.1 Preliminary assumptions

4.1.1 Definition of zones

The zones of the floating structures are defined in [EN 13173](#). Reference can also be made to [GS EP STR 652](#) for F(P)SO's and to [GS EP STR 631](#) for buoys.

4.1.2 Risers - Insulating joints - Appurtenances

Risers of sea lines are not electrically insulated from the floating unit. An exception may be when either the pipelines or the floating unit are cathodically protected by impressed current. In this case, a Project Particular Specification shall be established specifying the need for and the nature of the insulating joint and its location.

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If the pipeline is protected by sacrificial anodes and if the unit is operating in shallow water, riser's cathodic protection shall be included in the cathodic protection design of the floating unit.

The surface of I or J-tubes, sump caissons, utility risers, etc. shall be included in the cathodic protection design of the floating unit.

Cathodic protection of SCRs (Steel Catenary Risers) is designed by including the risers in the design of the cathodic protection system for the associated pipelines in accordance with **GS EP COR 102**.

Any immersed metallic flanges, bolts and connectors of flexibles located at the interface with the topside structure shall be included in the cathodic protection design of the floating unit. Current drain to steel armouring in flexible risers shall be included as well.

4.1.3 Painting-Coating

All parts of the floating unit subject to cathodic protection are coated in accordance with **GS EP COR 351**. Other coatings or painting systems may be used subject to Company approval.

Anchor chains are, however, not coated and anchors are only partly coated.

In the case of impressed current system, a dielectric shield shall be installed around the impressed current anodes in order to avoid current wastage, to reduce cathodic disbondment of painting as well as hydrogen uptake in steel.

4.1.4 Other items of special concern

In the case where cathodic protection is provided by impressed current, sacrificial anodes shall be installed to protect areas which may be difficult to protect with the ICCP system. These areas include, but are not limited to sea water intake or outlet, moonpool, turret, tunnel for thrusters, etc.

Any item which is electrically insulated from the cathodic protection system with the exception of chains shall be equipped with its own anodes.

On buoys, the anchor chain may pass through hawse pipes which are submerged. In order to improve the corrosion protection inside the hawse pipe, holes shall be made in the pipe in order to allow for current to pass through. In order to reduce current demand and improve current distribution the hawse pipe shall be internally coated. The size of the holes and the distance between holes shall be designed by applying Company approved software models such as PROCOR, BEASY or equivalent.

4.2 Protection criteria

For carbon steel, the requirement for the potential achieved on the structure shall be in accordance with the following values:

- More negative than -800 mV/Ag/AgCl/sea water in aerated seawater
- More negative than -900 mV/Ag/AgCl/sea water in a seawater environment with a high content of sulphate reducing bacteria

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- For carbon steel with SMYS greater than or equal to 550 MPa, the potential shall remain more positive than -1100 mV/Ag-AgCl-sea water.
- For other materials, potential requirements shall be in accordance with [ISO 15589-2](#) Table 1 and material requirements shall be in accordance with [GS EP SPS 029](#) § 6 to avoid hydrogen embrittlement.

4.2.1 Current density

The current densities to be used are those given in chapter 5.2 of [GS EP COR 100](#) increased by 10%.

Current densities at mid-life (maintenance) shall be used to calculate the minimum anode weight in case of cathodic protection by sacrificial anodes.

In the case of cathodic protection by sacrificial anodes the current densities at the beginning of life (before polarisation) / at the end of life (re-polarisation), are used to verify that the chosen anodes are capable of supplying sufficient current to polarise the structure / re-polarise the structure, if necessary.

In the case of cathodic protection by impressed current, the greatest value obtained for the current requirement (I_i) between the current density at the beginning of life, mid-life and at the end of life shall be used to define the characteristics of the equipment (rectifiers, anodes, etc.).

For equipment such as risers operating at elevated temperatures, current densities shall be increased by 1 mA per °C above 25°C.

When flexible risers are used, a current drain corresponding to a current density of 0.5 mA/m² based on the external riser surface shall be used.

4.3 Resistivity

The resistivity of sea water as a function of geographic location is given in chapter 5.3 of [GS EP COR 100](#).

4.4 Surface to be protected

The surface area to be considered for cathodic protection sizing is the total external surface of the floating structure and its appurtenances in contact with seawater when the unit is fully loaded (design draught).

Anchor chains are not included as the electrical continuity between individual links is not sufficient. Instead, chains are designed with a corrosion allowance. A current drain to the chains shall, however, be taken into account in the sizing of cathodic protection of the floating units. The length of chain to be considered for current drain shall be 60 meters. The current densities given in chapter 4.3 shall be used to calculate the drain.

4.5 Coating breakdown factors

Coating breakdown factors which are applicable for floating units can be found in chapter 5.5 of [GS EP COR 100](#).

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4.6 Cathodic protection by sacrificial anode systems

4.6.1 Sacrificial alloy

Indium activated aluminium alloy anodes shall normally be used.

Notes:

- For structures sensitive to hydrogen embrittlement special precautions must be taken in accordance with **GS EP SPS 029**. Additionally, reduction of cathodic protection on the sensible material by means of -but not limited to- coating, increasing the distance from aluminium anodes, electrical insulation, etc. shall be studied on a case by case basis.
- Aluminium anodes unit weight shall be 3 kg minimum.

The composition, quality requirements, and control of aluminium and zinc alloy anodes are given in **GS EP COR 201**.

4.6.2 Characteristics of the sacrificial alloy

Cathodic protection calculations shall take into account the potential and practical consumption (m) values guaranteed by the anode Supplier and verified during qualification of the manufacturing procedure. If the values are unknown at the time of calculation, a conservative value shall be chosen.

These values are given in chapter 6.2 of **GS EP COR 100**.

4.6.3 Utilisation factor u

The utilisation factor which shall apply can be found in chapter 6.3 of **GS EP COR 100**.

Note: The performance of anodes becomes unpredictable if the utilisation factor value is higher than those stated in **GS EP COR 100**.

4.6.4 Installation and location of anodes

Stand-off anodes or flush-mounted anodes can be used for floating units. If flush-mounted anodes are used, the surface of the anodes facing the structure to be protected shall be painted.

The insert diameter and thickness are defined as a function of the weight of the anode, the environmental conditions, and the installation conditions of the structures. Minimum requirements are given in **GS EP COR 201**.

The anodes shall be welded to the structure. Any other mean of fixation shall be subject to Company approval. When required for mechanical reasons, anodes shall be welded to doubler plates with additional reinforcement by gussets if necessary. The minimum requirements are given in **GS EP COR 201**.

4.6.5 Calculation of cathodic protection

As indicated in Section 4.3, the calculation is based on the current requirement (I_l) at mid-life or the quantity of anodes in order to obtain the required current for re-polarisation at the end of life.

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The current requirement (I_t) for the entire structure is the sum of the currents for individual parts:

- Current requirement for uncoated surfaces, if any
- Current requirement for coated surfaces
- Current drain to chains
- Current drain to flexibles, if any.

The sizing of the sacrificial anodes system for floating units follows the same principle as for offshore structures as outlined in chapter 6.5.1 and 6.5.2 in [GS EP COR 100](#).

4.6.5.1 Distribution and location of anodes

Based on the theoretical number of anodes defined by current requirement calculations of the different zones of the structure, practical distribution of the anodes shall take into consideration the following factors:

- Anodes shall be uniformly distributed on the structure
- Anodes shall be located as symmetrically as possible on the structure
- Anodes shall be located nearer complex and critical points
- No anodes shall be located on the boot topping i.e. the section of the hull between light and fully loaded levels, which will be intermittently immersed.

When necessary (in case of any doubt on the right location of anodes) or in case of complex or elongated structures, numerical modelling shall be carried out to demonstrate that an adequate level of potentials will be reached at each location during the whole design lifetime using a software approved by Company (e.g. PROCOR, BEASY, or equivalent).

Due to the fabrication process of floating units such as FPSO's an even distribution of anodes may be difficult to achieve. If this is the case, attenuation calculations or numerical modelling must be carried out in order to verify that sufficient cathodic potentials will be achieved on the entire surface of the unit.

As a rule of thumb a surface of 1000 m² of coated surface should be protected by a minimum of seven anodes.

4.6.6 Verification of the protection

The suitability of the chosen anodes sizes, dimensions and number must be verified for the entire lifetime of the structure.

Note: Anode resistance formula is given in Recommended Practice [DNV-RP-B101](#), table B16.

The verification of potential for floating units is identical to offshore structures and is described in chapter 6.7 of [GS EP COR 100](#).

Equivalence between potentials according to Zn or Ag-AgCl-seawater reference electrode are given in [EN 12473](#).

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4.6.7 Measurements after structure installation

Measurements shall be performed, according to the principles given in [GS EP COR 501](#), after commissioning and in the first three to six months of operation. The results shall demonstrate the effectiveness of the cathodic protection system.

The subsequent schedule of routine inspections shall be drawn up by Contractor at the request of Company.

4.7 Cathodic protection by impressed current anode systems

Impressed current shall only be used when requested by Company. The design of the impressed current system shall be as described in [GS EP COR 100](#). If impressed current is used, a complementary cathodic protection system (ref. [GS EP COR 100](#)) shall be installed in order to protect the structure during the construction/installation phase.

5. Internal cathodic protection of tanks

Internal corrosion protection in tanks which are an integrated part of the hull of the floating unit such as ballast tanks, cargo tanks, slop tanks and process tanks shall be by a combination of coating and cathodic protection using sacrificial anodes. The coating shall be in accordance with [GS EP COR 351](#) and the design of cathodic protection shall be in accordance with [GS EP COR 101](#).

The cathodic protection design of ballast, cargo and slop tanks shall be made for the lifetime of the installation.

5.1 Design criteria and main parameters

5.1.1 Potential level for protection

For mild steels, the level for protection shall be in accordance with the following values:

- More negative than -0.8 V/Ag-AgCl-seawater for seawater
- More negative than -0.9 V/Ag-AgCl-seawater for water at high temperature, for acid water (pH < 6), or water containing bacteria or H₂S.

5.1.2 Coating breakdown factor

Coatings with thickness 400 microns in agreement with [GS EP COR 351](#), system P206, shall be used. Coatings breakdown factors to be used are category IV, chapter 5.5 of [GS EP COR 100](#).

5.1.3 Sacrificial alloy selection

According to [IACS](#) magnesium anodes are not allowed in cargo tanks or in tanks adjacent to cargo tanks.

Aluminium anodes shall in general only be installed at the bottom and on stringers but not on walls. If aluminium anode is installed on walls, its potential energy shall not be above 28 kg.m ([IACS](#) requirement).

If the electrolyte temperature is above 25°C, practical consumption of the alloy shall take into account the service temperature of the equipment.

In absence of H₂S, aluminium alloys or special zinc alloys for high temperature (Noranode or similar) shall be used if temperature exceeds 50°C.

If the electrolyte is an effluent containing H₂S, aluminium alloys are accepted, but efficiency shall be reduced by 1% for every 20 ppm of H₂S. Zinc anodes are accepted, with specially qualified composition if temperature exceeds 50°C (Noranode or similar).

For aluminium anode calculations, the following formula shall be used in order to take into account the reduction in electrochemical efficiency at elevated anode temperature:

$$\varepsilon = 2433 - 27 (T - 20)$$

If the electrolyte is an effluent containing SRB, efficiency shall be additionally reduced by 25%.

5.1.4 Surfaces to be protected

Only surfaces which can be wetted with water, i.e. seawater, produced water, drain water or a mixture of these shall be considered in the cathodic protection sizing calculations.

Stainless steel surfaces or other metallic items such as for instance heating coil in slop tanks, which are not electrically isolated from the structure to be protected, shall be included in the cathodic protection design.

Design shall notably take into account not only the additional surface to be protected for the anodes mass calculation, but also the modification in current distribution due to the significant additional bare metallic surfaces. As such, anodes location shall be studied in order to minimize potential attenuation.

Note: Carbon steel tubes like ballast wall crossing spools shall be equipped with internal anode in complement of coating.

5.2 Parameters for study of the system

Data for a cathodic protection study by Contractor are specified in the Project Particular Specification and shall include, but not be limited to:

- Electrolyte characteristics in normal operation: composition (dissolved gases, H₂S, CO₂), conductivity, pH, temperature (average and variations), pressure, water levels (minimum, maximum and average), maximum velocity when applicable
- Current density to be used for bare steel according to electrolyte data
- Monitoring policy for cathodic protection.

In case of lack of data specified in the Project Particular Specification, the study is established with the following current density hypothesis:

- 200 mA/m² for bare steel surface in contact with a reservoir water (high salinity and corrosivity) at ambient temperature
- 80 mA/m² for bare steel surface immersed in sea water at ambient temperature
- The current density shall be increased according to the electrolyte temperature by 1 mA/m² per °C over 25°C.

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5.3 Contractor's design responsibility

Contractor shall include in its design dossier:

- Marked construction drawings of the structure to be protected, showing the type of metals or alloys and mounting details of all internal parts, type and characteristics of the coating systems for the surfaces to be protected
- Calculation basis for cathodic protection design
- Type and characteristics of selected anodes and monitoring systems
- Location and position of cathodic protection equipment.

5.4 Current demand for protection

The evaluation of the current demand shall take into account all metallic surfaces, permanently or intermittently exposed to the electrolyte, bare and coated, coatings breakdown factor, and relevant current densities as defined in Section 5.1 and 5.2 for the entire lifetime of the floating unit.

5.4.1 Sacrificial anodes

Sacrificial anodes selection shall consider:

- Compatibility with the electrolyte (composition, temperature)
- Available space
- Current distribution in confined areas.

The quantity and size of anodes are calculated as described in **GS EP COR 101** chapter 5.2.

The anodes shall be flush-mounted or stand-off types, with a trapezoidal or half-cylindrical section.

In tanks containing a mixture of water and hydrocarbons such as cargo, slop and process tanks the anodes shall normally be located at the bottom of the tanks unless specified otherwise in the Project Particular Specification.

In tanks containing only water such as ballast tanks the anodes shall be installed at all levels.

For flush-mounted anodes, the surface facing the structure shall be coated.

The utilisation factor shall be as given in **GS EP COR 100** chapter 6.2.

The final sizes of selected anodes shall meet both minimum weight and DC current output requirements to achieve the required protection level according to water level and characteristics.

The anodes shall be installed by welding. Any other type of fixation such as for instance by bolting shall be subject to Company approval.

Ballast tanks are not filled with water all the time during operation. A shorter anode lifetime could be considered in the design of ballast tanks, subject to Company approval. In any case the shorter lifetime shall only apply to the calculation of mean (average) current and not to the calculation of DC current requirement at final condition.

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Anodes shall be supplied in accordance with **GS EP COR 201**.

6. Cathodic protection monitoring system

6.1 Cathodic protection monitoring

The monitoring system shall consist in the installation of reference electrodes in order to verify the level of cathodic protection. Monitored anodes may also be installed.

Reference electrodes and monitored anodes shall be connected by cables to a monitoring panel located in a technical room.

Reference is made to **GS EP COR 202** for requirements for electrodes, cabling, voltmeter, etc.

Permanent electrodes' position, type and number together with installation details shall be defined by Contractor in the detailed design of the cathodic protection system, and approved by Company.

The engineering and installation of the monitoring system shall include cable routing and any penetration of hull, decks and walls. The preferred solution shall be not to penetrate the hull, but to run the cables externally.

6.2 Number of monitoring systems

6.2.1 Monitoring of external hull cathodic protection

For monitoring of an FPSO a minimum of 9 reference electrodes shall be installed externally on the hull. Three electrodes shall be installed on port side, three electrodes on starboard side and three electrodes shall be installed on the flat bottom. Along each side, one electrode shall be installed forward, one at midship and one in the aft. On the flat bottom the electrodes shall be installed on the centre line.

For other floating structures, such as buoys, reference electrodes shall also be installed. The number and location shall be detailed in the Project Particular Specification.

6.2.2 Internal monitoring in tanks

As a minimum:

- Permanent reference electrodes shall be installed in each tank. In one specific ballast tank, the permanent reference electrodes shall be installed at three different vertical levels
- Monitored anodes shall be installed in one of each tank type, i.e. there shall be one in one ballast tank, in one slop tank and in one cargo tank.

For slop tanks and cargo tanks, monitoring electrodes and anodes shall be installed in the water phase at the very bottom of the tanks.

6.3 Reference electrodes

The reference electrode shall be made of zinc, however, a combined Zn and Ag/AgCl electrode can be accepted. The electrode shall be completely isolated electrically from the structure and located as far as possible from the sacrificial anodes.

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The zinc alloy shall have a chemical composition complying with Z2 type in accordance with **GS EP COR 201** chapter 3.1.2.

6.4 Monitored anodes

One (or several) anode(s) can be fitted to monitor their output current. The anode is isolated from the structure with isolating joints and output current is monitored through a calibrated shunt (ref. **GS EP COR 202**).

7. Quality assurance procedures

7.1 General

At the beginning of the engineering, a Quality Plan must be prepared by Contractor, detailing all the actions related to cathodic protection calculations, the definition of systems to be installed, purchasing, checking and reception of materials, and the commissioning on site. These shall be described in detailed procedures.

All calculations, systems, and materials used shall be approved by Company.

7.2 Materials

In the technical part of the QA Dossier, calculations, characteristics, identification of materials and apparatus used for the cathodic protection system shall be specified, such as:

- Sacrificial anodes checked in factory by Contractor
- Coating
- Reference electrodes
- Monitored anodes, if any
- Cables and wiring plans
- Impressed current DC sources and anodes, if any
- Insulating joints and shunts, if any.

7.3 Technical file

The technical file submitted by Contractor at the end of the work shall include:

- The characteristics of the structure to protect
- The detailed calculations of the cathodic protection on paper format as well as electronic format
- The systems installed
- The data sheets and test certificates of materials
- The detailed drawings of the different systems
- The current output, voltage output, and potential values obtained during the commissioning.