



Exploration & Production

GENERAL SPECIFICATION

SUBSEA SYSTEMS

GS SPS 009

Corrosion protection of subsea stations
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1. Scope

This document defines the minimum requirements for the design, installation and commissioning of external cathodic protection and coatings of subsea production systems.

Cathodic protection shall be implemented using galvanic (or sacrificial) anodes.

This specification defines only specific aspects for subsea production systems, in complement to **GS COR 100**.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
ISO 8044	Corrosion of materials and alloys - Basic terms and definition
EN 12473	General Principles of cathodic protection in sea water
EN 12495	Cathodic protection for fixed steel offshore structures
BS 7361 - Part 1	Cathodic protection - Part 1: Code of practice for land and marine applications
ISO 12944-6	Paints and varnishes - Corrosion protection of steel structures by paint systems Part 6: Laboratory performance test methods

Professional Documents

Reference	Title
DNV RP-B401	Cathodic Protection Design
API RP 2SK	Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures
ASTM A 193	Alloy Steel and Stainless Steel Bolting Materials for High-Temperature Service
NACE MR 01.75	Sulphide Stress Cracking – Resistant metallic materials for oilfield equipment

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS SPS 001	Design philosophy and requirement for Subsea Stations
GS COR 100	Design of cathodic protection of offshore structures
GS COR 102	Design of cathodic protection of seal line by sacrificial anodes
GS COR 201	Supply of sacrificial anodes
GS COR 220	Three layer polyethylene external coating for pipelines
GS COR 221	Three layer polypropylene external coating for pipelines
GS COR 230	External laminated glass fibre/resin based coating for risers of sea-line
GS COR 231	External elastomer based coating for risers of sea-line
GS COR 350	External protection of offshore and related structures and equipment by painting
GS COR 420	External field joint coatings of pipelines
GS COR 501	Control of cathodic protection of submerged fixed structures
GS COR 502	Control by electrical measurements of cathodic protection of submerged pipelines

3. Qualification and Certification of Cathodic Protection design specialists

Design of cathodic protection systems to be installed on subsea production systems shall be carried out exclusively by competent specialised personnel. The qualification of each of the specialists working for such a design shall be demonstrated to the OWNER before commencement of the job. Therefore the verification of the formal Certification of the individuals shall be carried out as follows:

- Design work or verification to be carried out by level 3 certified personnel

Accepted Certification schemes are AFNOR Competence (Seawater Application Sector), APCE (Seawater Application Sector), Institute of Corrosion, NACE International. Any other Certification scheme should be approved by the OWNER.

Any use of non certified personnel for cathodic protection design shall be subject to the approval of the OWNER on a case by case basis (demonstration of competence through detailed curriculum vitae and description of experience).

4. Cathodic protection

This specification is a complement to **GS COR 100** and **GS COR 201**, dedicated to deep sub-sea conditions. Reference shall be made to these specifications for general requirements on cathodic protection, which are not included in this document.

4.1 Cathodic protection basis design data

Each subsea system shall be subjected to separate detailed cathodic protection design calculations.

4.1.1 Cathodic potential requirements

The potentials obtained by the cathodic protection performed with sacrificial anodes shall be within the limits here below:

- upper limit: -0.80 V ref. Ag/AgCl/sea water reference electrode
- more negative limit: -1.10 V ref. Ag/AgCl/sea water reference electrode.

Under anaerobic conditions (structures or components buried in marine sediments) with presence of sulphate reducing bacteria, a potential more negative than -0.90 V Ag/AgCl shall be considered.

4.1.2 Sea water resistivity

The seawater resistivity is specified in GS COR 100 §5.3. Note the requirement to increased resistivity for water depths greater than 150 m.

4.1.3 Current density requirements

Except if otherwise specified, the current density depends on water depth and geographical location as specified in GS COR 100 §5.2. Note the requirement to increased current densities for deep water application.

4.1.4 Coating breakdown factor

The coating breakdown factors to be applied are defined in **GS COR 100** §5.5 concerning thin coating such as painting and in **GS COR 102** §5.3 for thick film coating such as pipeline coating.

Stainless steel accessories such as hydraulic tubes and equivalent devices shall be considered as uncoated surfaces, even if painted. Protective effects of coatings on stainless steel equipment shall only be considered when coating is either devoted to thermal insulation or specially qualified for long term adhesion on stainless steels.

If other types of coating are used, the coating systems as well as the coating breakdown factor shall be submitted to COMPANY for approval.

4.1.5 Type of anodes

Sacrificial anode material is usually indium activated aluminium alloy.

Zinc anodes shall be used when and if the potential has to be limited due to hydrogen embrittlement risks, as long as the anode temperature is below 50°C.

In general, type of anode shall be flush-mounted on the structure in order to avoid risks of tangling of ROV cables. However, in case of high temperature fluids, anode location and design shall also be selected for preventing anode heating from hot areas either by conduction or convection (taking into account thermal insulation, if any). If anode heating cannot be fully prevented, anode sizing shall take into account corrected electrochemical efficiencies (as per **GS COR 102** §6.2) when aluminium anodes are applied.

For monitoring the unit current output during exploitation, some anodes shall be furnished with rod (or tube) inserts.

4.2 Additional requirements per equipment

4.2.1 Well-head subsea structures

In addition to the current required for the structure, an additional current of 8 A shall be applied for the protection of production wells.

4.2.2 Hot areas

The possible heating of anodes located close to high temperature areas (if any, despite thermal insulation) shall be evaluated, considering both convection effects in sea water and conduction effects by anode supports.

As far as possible, anode distance from hot areas, as well as the length of anode supports, shall be sufficient for preventing such heating. However, anode location shall not impair ROV free access to the SPS.

If anode heating cannot be fully avoided, maximum temperature of the concerned anodes shall be calculated (taking into account the thermal insulation applied) and their electrochemical efficiency shall be corrected accordingly (as per **GS COR 102** §6.2).

4.2.3 Umbilicals, flowlines and risers (UFL)

Due to the wide range of technical options for Umbilicals and Flowlines (production bundle, riser tower, catenary riser, etc.), as well as the variety of possible thermal insulating coatings, only general principles for external corrosion prevention are specified here below.

- Coating systems for both production and injection flowlines and pipelines are mainly based on three layer polypropylene or polyethylene coating, depending on maximum service temperatures, and possible addition of thermal insulating systems. Thermal insulating coatings are likely to act as screen regarding cathodic protection. The capability of cathodic currents to attain the whole metallic surface shall be demonstrated.
- External corrosion prevention without any cathodic protection can also be ensured. The adequacy of this prevention shall be demonstrated for each possible case indicated here below:
 - A sea water corrosion resistant alloy is used (including long term resistance to crevice corrosion)

- A fully protective coating is guaranteed to cover 100,00% of the metallic surface (no defect)
- The sea water volume is fully closed, and well controlled (initial chemical treatment and guaranty of no sea water renewal).
- **Specific case of flexible lines (flexible riser or jumper), if any:** the steel armour of flexible pipes is protected from external corrosion by an outer sheath (polyamide type). Cathodic protection is applied to the pipe to prevent corrosion if this outer plastic sheath is damaged. The extent of damage considered for the cathodic protection design shall be submitted to the COMPANY approval. The cathodic protection shall be provided by sacrificial anodes positioned near the termination pieces at each end of the flexible.
- **Specific case of Pipe-in-Pipe:** Cathodic protection only applies to the external pipe surface, since no water is present in the annular volume. The risks associated with possible water ingress at each joint must be evaluated and prevented accordingly.
- **Specific case of SCRs (Steel Catenary Risers):** Anodes shall be installed only at the part of the structure permanently in contact with the sea floor; this necessitates the use of high insulating coatings like 3 layer PE or PP in accordance with **GS COR 220** or **GS COR 221**. When possible, electrical continuity through flexible joints at the top of SCR should be ensured.

Note: When necessary, modelling of the system shall be carried out demonstrating that a right level of potential will be reached at each location during the whole design lifetime using a software approved by the OWNER (e.g. PROCOR, Corrocean).

4.2.4 Closed caisson foundation (CCF) for manifolds and templates

The cathodic protection by sacrificial anodes of the subsea structures must assure the protection of external surfaces of CCF, including the buried section.

In case of risks of corrosion of the internal surfaces, internal corrosion prevention shall be provided by cathodic protection (by zinc anodes).

4.2.5 Retrievable modules

Each retrievable module including jumper lines has its particular protection system based on a combination of corrosion protection coating and cathodic protection.

In case of poor electrical junction with the other modules, its own protection will be really assured.

4.2.6 Suction anchors and anchoring lines

Classification societies rules shall apply for the corrosion prevention of the anchoring system of the FPU, of the buoy (if any) and of the riser towers (if any). The general principles which apply are as follows:

- Suction anchors: corrosion allowance (generally 4 mm) plus cathodic protection. Painting/Coating only applied to upper areas, not dumped into soil as a result of suction.
- Chains: corrosion allowance according to **API RP 2 SK**. Generally, also 4 mm.
- Steel wire rope: in case a steel wire rope is used, it must be protected by lining, generally polyamide. Anodes shall be provided at the cable end loops.

- Inorganic wire ropes made of polypropylene, polyamide, etc., do not require corrosion protection.

4.3 Particular requirements

4.3.1 Risk of hydrogen induced cracking: Yield Strength/Hardness limitation

For CRA and high strength steel materials, the risk of hydrogen induced cracking is of main concern when cathodic protection is applied.

The bare material shall be chosen to withstand a negative potential limit of -1.05 V Ag/AgCl.

For submerged parts that may be exposed to cathodic protection, materials which would be coated shall be considered as exposed to cathodic protection unless it is demonstrated that the coating will remain tight for the specified design life. The following shall apply:

- For carbon and low alloy steels, SMYS shall not exceed **700 MPa** (725 MPa for bolts). The actual yield strength shall not exceed **950 MPa**. Alternatively, it may be verified that the actual hardness in base materials does not exceed **295 HB**.
- For carbon steel welds a limit of **300 HV5** applies
- For stainless steels and non-ferrous materials, resistance against hydrogen embrittlement shall be controlled by the actual hardness of the material which shall be in accordance with **NACE MR 01.75**.

Carbon steel bolts shall be made as per grade B7M of **ASTM A 193**.

4.3.2 Shielding effects

The cathodic protection design to be applied to the sub sea production systems (manifolds, well heads), shall be carried out in order to avoid shielding effect. Each case shall be analysed with a possible simulation of the cathodic protection.

4.3.3 Risk of water ingress under thermal insulation

For the various items covered by thermal insulation (if not adhesive), an evaluation shall be performed taking into account the possible renewal of the sea water into the interstices and the limitation of anodic current distribution. A cathodic protection simulation is required for the components where the thermal insulating system may limit the current distribution.

4.3.4 Electrical continuity

All components shall be joined electrically in order to obtain the same potential on them.

In case of risk of accidental isolation of some components, or if the junction is difficult to realize, the individual components shall be protected with their own protection systems.

The electrical continuity between all pieces and components of a same system to be protected shall be implemented in order to achieve a uniform and entire corrosion protection.

This electrical continuity shall be such that even the most tiny pieces such as bolts, washers, circlips in contact with seawater shall be electrically connected and thus protected by the corrosion protection system.

The verification of the electrical continuity shall be part of the final acceptance tests to be carried out before shipment of any individual component.

Mechanical connectors (jumpers to SPS, UFL to SPS, flowlines to risers) shall particularly guarantee this electrical connection.

4.3.5 Components left immersed in seawater before connections (connectors, etc.)

The corrosion risks associated with possible long term contact of components with sea water in case of long duration stand-by immersions shall be particularly considered and prevented.

Any component which will be left immersed during on site operations and before connection shall be designed to resist both to the fluid which it is aimed to contain and to the seawater environment in which it will be immersed.

The following situations shall be specifically considered:

- Corrosion due to water ingress inside connectors and piping with insufficient effect of cathodic protection, risk of crevice corrosion under metallic sealing rings, etc.
- Scale deposition on connecting devices as a result of cathodic protection effect.
- Trapping of any air volume (even of limited size of a few liters in bottom conditions) from the sea water level to the sea bottom shall be prevented by adequate laying/flooding operation. (The oxygen partial pressure in this volume being directly proportional to the bottom pressure - 100 times more at -1000 m than at atmospheric pressure -, the potential corrosivity of the water around this residual air volume can be very high, in the range of a few mm/yr, although it only concerns the immediate vicinity of the air volume). In addition, the air content trapped in this volume is in such amount and concentration that it cannot be consumed by oxygen scavengers, even when added at high concentration).

4.3.6 Interfaces/Interference

The possible interference between the different cathodic protection systems shall be evaluated at interfaces. The interference evaluation is particularly of importance in the case of a CP system based on impressed current for FPU.

The following items shall be taken into account:

- Electrical continuity
- Possible current drains (e.g. non protected chains)
- Possible over-protection (e.g. from the FPU impressed current system) or under-protection
- Coating disbonding and hydrogen embrittlement risk associated with too negative potential.

The interfaces are as follows:

- FPU/UFL
- FPU/chains/export lines
- Bottom of riser/flowlines
- Flowlines/SPS.

4.3.6.1 Bottom of riser/Flowlines

Electrical continuity is required. Solutions used for guarantying this electrical continuity shall be documented.



4.3.6.2 Flowlines/SPS

Electrical continuity is required. Solutions used for guarantying this electrical continuity shall be documented.

4.4 Cathodic Protection Monitoring

CP monitoring shall be based on potential measurements on particular test points and current outputs of some stand-off anodes.

The verification of the potential of the structure/equipment shall be performed after onsite installation of each structure. It shall apply to the installed structure as well as to the surrounding structures to which it has been connected.

The test points for potential measurements are made of 10 x 10 cm blasted and varnished steel plates. These test points, as well as stand-off anodes for current measurements will require ROV intervention for on site cathodic protection measurements. As a result, test points location and stand-off anodes (if any) shall be easily accessible to ROV's. ROV intervention procedures shall incorporate these operations and the necessary equipment for performing them.

Test surfaces shall be available on different parts of subsea equipment (both on SPS and UFL), in order to provide the necessary follow-up of cathodic potentials with time on each important component. These test pieces shall be preferentially made on structural elements, in direct contact with sea water.

Unless otherwise specified, these test points shall not be installed on any production component subjected to thermal insulation (e.g. connectors, production piping on SPS, etc.).

- Preventing cold points. In particular cases where CP measurements are required on thermally insulated surfaces, the test point shall be made of a plate fitted on the outside surface and electrically connected to the structure through the thermal insulating material. The design of this connection shall prevent cold bridging to the internal surface and water entry.

The cathodic protection monitoring devices shall be at least as described here below.

4.4.1 Risers (riser tower/Catenary riser)

In case of thermally insulated risers with no direct contact between the riser surface and the sea water, the CP monitoring of the riser shall be performed at least at both ends of the riser, by test plates connected through the thermally insulated coating.

In addition, a stand-off anode shall be installed at top and bottom of the riser for measurement of current drain during sub sea inspection.

4.4.2 Manifolds and well heads

The structures and equipment of the manifold and wellheads will be monitored by cathodic protection measurements on the structural parts. In addition, a stand-off anode is to be installed on each subsea unit for measurement of current drain during subsea inspection.

4.4.3 Jumpers

No Test plate shall be installed through the thermally insulated material for CP measurement: Preventing the risk of water ingress through connecting wires, particularly during laying operations.



4.4.4 Sea lines

The sea lines shall be monitored by regular cathodic protection measurements along the lines to verify the current output of these anodes, the potential, and to determine the degree of consumption (ref. **GS COR 502**). A preliminary measurement shall be performed after installation of the sealines.

5. Coating protection

5.1 General requirements

All the components of the subsea structures shall be coated in combination with cathodic protection in order to reduce the necessary current to have a good protection against external corrosion.

The external corrosion protection coating shall be qualified and well documented for the service life and service conditions specified for this project.

Some of the requirements in this document are relevant to the specific coating systems described herein only. Alternative coating systems, test methods and acceptance criteria are subject to COMPANY approval in accordance with section 1.3 in this document. The level of documentation and functional requirements described in this document shall comply with.

CONTRACTOR shall present a proposal for coating systems and the necessary qualification tests in order to document suitability to maximum temperatures at the maximum depth of the Project, including relevant material tests and acceptance criteria. The testing shall as a minimum, include the tests described in this document and shall concern thin coating as well as thick coating, with field joint coating. The external corrosion protection coating shall be documented to give the required service life within the defined service class, by accelerated qualification testing or long term successful service record.

For transportation, storage and installation, the minimum design temperature shall be -15°C for the corrosion protection coating.

The requirements stated in this specification apply both to factory applied coating as well as to field joint coating.

Further, the CONTRACTOR shall establish production procedures describing methods for surface preparation, coating application, inspection and testing which comply with the requirements of COMPANY's General Specifications.

COMPANY may select to witness procedure qualifications and other production tests.

No coating application shall commence before the coating system is fully qualified.

5.2 Thin coating or painting

The coating shall be applied according to **GS COR 350** with the specific requirements concerning:

- Quality of products and abrasives
- Surface preparation (Sa 3, roughness Ra 10/13 microns)
- Application of the successive coats according to the data sheets of the SUPPLIER,
- Inspection and testing of the final system.

Other systems may be proposed by the CONTRACTOR, if they comply with the test procedures described in document [ISO 12944](#) Part 6, for high durability in environment offshore immersed (Im 2) at local conditions, and with the cathodic disbondment test.

The ambient temperature is the seawater temperature.

For reason of visibility, the finish coat has to be of clear mat colour (yellow, white, grey, etc.).

In case of application of painting under thermal insulation as for Xmas-tree, valves, qualification tests shall be provided in parallel with qualification tests for thermal insulation products, in order to demonstrate the good adhesion between the two systems.

5.3 Thick coating

This coating concerns mainly corrosion coating on pipes applied in plant. The coating shall be in accordance with the documents [GS COR 220](#) or [GS COR 221](#), especially for the specific requirements concerning:

- Quality of products and abrasive
- Surface preparation (Sa 3, roughness $60 < R_z < 90$ microns)
- Application of the successive coats
- Inspection and testing of the final system.

Thickness coating shall be type "extra reinforced thickness" for deep-sea applications below 300 m depth.

In case of application of this coating under thermal insulation, qualification tests shall be provided in parallel with qualification tests for thermal insulation products, in order to verify the good adhesion between the two systems.

For field joint coatings, the joint product shall have the same performance as the main coating systems. Preferably, the same material shall be retained as the base coating. Requirements of [GS COR 420](#) shall be followed.

A finish coat with a clear and mat colour (yellow, white, grey, etc.) is required. Pigments giving this colour may be integrated in the final coat, or a finish coat (painting) has to be applied. In the two cases, qualification tests shall be also provided.

Riser coating shall be applied according to [GS COR 230](#) or [GS COR 231](#). Other types of coating, in case of specific riser design, have to be submitted to the COMPANY approval.

5.4 Export pipelines

Type of coating as per relevant GS.

For the oil export line, the combination of:

- A PP coating for the 1st kilometres (until $T < \text{limiting } T$ for PE coating)
- followed by a PE coating when T is compatible with PE resistance

shall be the base design case.

For pipelines laid with catenary riser, the mechanical resistance of the external coating at the bottom contact point shall be particularly addressed (abrasion risks). The solution envisaged shall be specifically documented and subjected to COMPANY approval.