



Exploration & Production

## GENERAL SPECIFICATION

### CORROSION

#### GS COR 102

|                                                                            |
|----------------------------------------------------------------------------|
| <b>Design of cathodic protection of sea line by<br/>sacrificial anodes</b> |
|----------------------------------------------------------------------------|

| 02   | 10/03 | Modifications of Tables 2 and 3 – Change of Group name and logo                                                       |
|------|-------|-----------------------------------------------------------------------------------------------------------------------|
| 01   | 10/02 | General revision - Modification of coating breakdown factors - Requirement of Certification for specialised personnel |
| 00   | 02/01 | First issue                                                                                                           |
| Rev. | Date  | Notes                                                                                                                 |



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## 1. Scope

The aim of the present specification is to define the hypotheses, calculation methods and sacrificial materials to be used for the design of the cathodic protection systems for sea lines, using sacrificial anodes.

## 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                                                                 |
|-----------|-----------------------------------------------------------------------|
| EN 12473  | Guidelines for cathodic protection in sea water                       |
| EN 12474  | Cathodic protection of sea lines                                      |
| ISO 13623 | Petroleum and natural gas industries - Pipeline transportation system |

### Professional Documents

| Reference    | Title                                                                                                    |
|--------------|----------------------------------------------------------------------------------------------------------|
| DNV RP-B401  | Cathodic protection design                                                                               |
| NACE RP 0675 | Control of external corrosion on offshore steel pipelines                                                |
| NACE RP 0394 | Application, performance and quality control of plant-applied, fusion-bonded epoxy external pipe coating |

### Regulations

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

### Codes

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

### Other documents

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

## Total General Specifications

| Reference  | Title                                                                            |
|------------|----------------------------------------------------------------------------------|
| GS COR 100 | Design of cathodic protection of offshore structures                             |
| GS COR 201 | Supply of sacrificial anodes                                                     |
| GS COR 210 | Insulating joints                                                                |
| 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 401 | Installation of anodes on submerged pipelines                                    |
| GS COR 420 | External field joint coatings of pipelines                                       |
| GS COR 502 | Control by electrical measurements of cathodic protection of submerged pipelines |

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

Design of cathodic protection systems to be installed on sea-lines 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:

- Conventional design work to be carried out by level 2 certified personnel
- Complex design work or verification to be carried out by level 3 certified personnel.

Accepted Certification schemes are AFNOR Compétence (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. Coating of sea lines

The cathodic protection design depends on the external coatings of the sea line, applied on the tubes in a plant and on the field during pipeline construction at girth weld areas. It concerns anti-corrosion coatings and also other kinds of coatings like concrete weight coatings, joint infills, thermal insulation coatings.

## 5. Calculation of the cathodic protection system

### 5.1 Principle

Submerged pipelines are protected using a system which is designed independently of the systems used to protect the structures or installations to which they are connected.

No electrical insulation is installed between the sea line and the structures, except:

- Where different protection systems are used between the sea line and the onshore or offshore installations (cathodic protection by impressed current, cathodic protection by sacrificial anodes)
- Where the sea line is connected to other operators' installations.

The cathodic protection of the conventional risers shall be included in the cathodic protection calculation of the supporting jacket, as specified in **GS COR 100**.

Cathodic protection of SCRs (Steel Catenary Risers) is designed in the frame of the associated pipelines in accordance with the present **GS COR 102**.

### 5.2 Data required for calculation of cathodic protection

#### 5.2.1 Protective potentials

For the cathodic protection of steel submerged in sea water or buried in mud, the potential of polarisation must be more negative than -800 mV measured relative to a Ag-AgCl/seawater measurement electrode. It shall be more negative than -900 mV/Ag-AgCl/sea water in an environment with a high content of sulphate reducing bacteria.

**Note 1:** For the onshore parts, the measured potential of the steel must be more negative than -850 mV relative to a saturated Cu-CuSO<sub>4</sub> reference electrode.

**Note 2:** The cathodic protection may have detrimental effects on some susceptible materials and cause Hydrogen Embrittlement due to the discharge of hydrogen atoms at the metal surface. DNV recommended practice document RP B401 gives the minimum limitations and precautions to be taken to avoid the risk of hydrogen induced stress cracking.

#### 5.2.2 Resistivity of sea water

The resistivity of seawater as a function of geographic location is given in Table 1. For other locations, the cathodic protection design shall be based on resistivity measurements carried out in the location of the sea line installation.

**Table 1 - Mean resistivity of seawater**

| Geographic area   | Cameroon<br>Nigeria | Congo<br>Gabon<br>Angola<br>Italy | The<br>Netherlands | Norway<br>Argentina | Gulf Of<br>Mexico | Libya | Indonesia<br>Persian<br>Gulf |
|-------------------|---------------------|-----------------------------------|--------------------|---------------------|-------------------|-------|------------------------------|
| Resistivity (Ω.m) | 0.22                | 0.20                              | 0.29               | 0.33                | 0.20              | 0.23  | 0.19                         |

When the sea-line is buried in mud, an average resistivity of 100 Ω.cm shall be considered, except when more adapted values are known and documented.

Generally, it is assumed that resistivity is constant as a function of depth. In case of significant variations, especially for deep water pipelines (water depth over 100 m), the job specification shall reflect these variations. For deepwater structures in West Africa a sea water resistivity of 0.30  $\Omega \cdot m$  shall be used.

### 5.2.3 Current density

The “Maintenance current density” is used to determine the net weight of anode alloys needed for the protection of the sea line. The required values are indicated in Table 2, together with the initial (polarisation) and final (repolarisation) values. The final value is generally the dimensioning step for the verification of the number and dimensions of anodes.

**Note:** For sea lines transporting hot fluids, the design current density (initial, mean and final) shall be increased by 1 mA/m<sup>2</sup> per °C when the metal/environment interface is assumed to exceed 25°C (EN 12474).

**Table 2 - Protection current density for bare steel exposed to sea water at ambient temperature**

| Area                              |               | Current density (mA/m <sup>2</sup> ) |             |                           |
|-----------------------------------|---------------|--------------------------------------|-------------|---------------------------|
|                                   |               | Initial<br>(Polarisation)            | Maintenance | Final<br>(Repolarisation) |
| North Sea (sector North of 57°N)  |               | 180                                  | 90          | 120                       |
| North Sea (Sector South of 57°N)  |               | 150                                  | 90          | 100                       |
| Mediterranean Sea                 |               | 150                                  | 70          | 90                        |
| Gulf of Guinea                    | Shallow water | 130                                  | 90          | 100                       |
|                                   | Deep water    | 250                                  | 100         | 100                       |
| Gulf of Mexico                    |               | 110                                  | 70          | 80                        |
| Persian Gulf                      |               | 130                                  | 70          | 90                        |
| Indonesia                         |               | 110                                  | 70          | 80                        |
| Buried zone (ambient temperature) |               | 25                                   | 20          | 20                        |

### 5.3 Coating breakdown factor as a function of time

The coating breakdown factor is used to estimate the current density reduction as a function of the selected coating system and the defined lifetime.

The coating breakdown factors at mean life and end of life to be taken in the calculation as a function of the various plant and field joint coatings are given in the Table 3. They are considered for a lifetime of 20 years and may be linearly extrapolated for another value of design lifetime.

For the sections coated with heat insulating systems, GRE or elastomers in accordance with GS COR 230 and GS COR 231 resp. the coating breakdown factor shall be: mean value 0.5%, final value 1%.

## 6. Protection by sacrificial anodes

### 6.1 Anode materials

Anode materials can be chosen from two types of alloys, based on aluminium or zinc. For service temperatures over 50°C aluminium based alloys must be selected (see [DNV RP B401](#) § 6.6 Table 6.6.1). The selected anode material shall be in accordance with [GS COR 201](#).

### 6.2 Electrochemical properties of anodes

Cathodic protection shall be calculated taking into account the potential and the practical consumption values guaranteed by the anode SUPPLIER. If the values are unknown before the calculation, a conservative value shall be chosen:

- Practical consumption at ambient temperature:
  - 3.6 kg/A.year for aluminium indium alloy anodes
  - 11.2 kg/A.year for zinc alloy anodes

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

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

$\varepsilon$  is anode electrochemical efficiency in Ahr/kg

T is temperature in °C.

- Potential:
  - -1050 mV/Ag-AgCl/sea water for aluminium indium alloy anodes
  - -1000 mV/Ag-AgCl/ sea water for zinc alloy anodes.

**Table 3 - Coating breakdown factors (CBF %) for a lifetime of 20 years**

| Plant coating     | Concrete | Field joint         | Infill | Mean | Final |
|-------------------|----------|---------------------|--------|------|-------|
| <b>Bituminous</b> | Yes      | Tapes               | No     | 9    | 13    |
|                   |          |                     | Yes    | 7    | 10    |
|                   |          | Heat-shrink sleeves | No     | 8    | 11    |
|                   |          |                     | Yes    | 6    | 9     |
| <b>3LPE</b>       | No       | Tapes               | NA     | 6    | 9     |
|                   |          | Heat-shrink sleeves | NA     | 4    | 7     |
|                   |          | PE reconstituted    | NA     | 3    | 5     |
|                   | Yes      | Tapes               | No     | 4    | 6     |
|                   |          |                     | Yes    | 3    | 4     |
|                   |          | Heat-shrink sleeves | No     | 3    | 5     |
|                   |          |                     | Yes    | 2    | 3     |
|                   |          | PE reconstituted    | No     | 2    | 3     |
|                   |          |                     | Yes    | 1    | 2     |
| <b>3LPP</b>       | No       | Tapes               | NA     | 5    | 8     |
|                   |          | Heat-shrink sleeves | NA     | 3    | 5     |
|                   |          | PP reconstituted    | NA     | 2    | 4     |
|                   | Yes      | Tapes               | No     | 4    | 6     |
|                   |          |                     | Yes    | 3    | 4     |
|                   |          | Heat-shrink sleeves | No     | 3    | 5     |
|                   |          |                     | Yes    | 2    | 3     |
|                   |          | PP reconstituted    | No     | 2    | 3     |
|                   |          |                     | Yes    | 1    | 2     |
| <b>FBE</b>        | No       | Tapes               | NA     | 15   | 30    |
|                   |          | Heat-shrink sleeves | NA     | 13   | 28    |
|                   |          | FBE                 | NA     | 12   | 26    |
|                   | Yes      | Tapes               | No     | 8    | 12    |
|                   |          |                     | Yes    | 6    | 10    |
|                   |          | Heat-shrink sleeves | No     | 7    | 10    |
|                   |          |                     | Yes    | 5    | 8     |
|                   |          | FBE                 | No     | 6    | 8     |
|                   |          |                     | Yes    | 4    | 7     |

### 6.3 Weight and dimensions of anode bracelets

The net weight of anodic material (anodes) needed to protect the sea line during its design lifetime is calculated according to annex B of European standard [EN 12474](#).

The utilisation factor for the anode bracelets installed to protect the sea-line will be  $u = 0.85$ .

The average current during the lifetime of the installation is estimated after polarisation for a section L calculated using the reducing curves method described in annex C of the standard [EN 12474](#).

## 6.4 Distribution and number of anode bracelets

The anodes are distributed along the sea line in order to achieve uniform current distribution.

Separate from the anodes distributed along the sea line, supplementary anodes are installed in order to take into account the possible interferences (risers, spool pieces, branch connections, crossing of sea lines, etc).

There shall normally be six anodes per kilometer. This distribution may be increased in case of specific conditions (temperature, etc).

Non-corrosive half shells may be installed between anodes and pipes in order to limit the temperature of the anode: they may be composite SVR or equivalent material, with a thickness (10 mm in general) defined by the CONTRACTOR for take into account the reduction of the electrochemical efficiency.

**Note:** Another solution may be used in shallow waters to avoid high temperature at the anodes, installing anodes outside the sea-line, connected with cables. Such kind of specific design has to be approved by the OWNER.

Cathodic protection of SCRs is carried out from anodes located only on the sea bottom. When necessary, modelling of the CP system has to 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). For areas not easily submitted to the cathodic protection current, like underneath eventual anti-vortex strakes installed for improving the stability in the upper part of SCR, TSA (Thermal Sprayed Aluminium) coating has to be used.

## 7. Verification of protection

The verification of the protection system after laying of the sea-line shall be performed according to the recommendations described in **GS COR 502**.

The chosen verification procedure shall be described and approved by the OWNER.

## 8. Technical file

The detailed technical study shall be approved by the OWNER. It shall at least comprise:

- Hypotheses considered for the calculation
- Chosen anode material
- Anode bracelet dimensions
- Detailed calculations verifying that the protection is assured for the life of the sea line.