



Exploration & Production

GENERAL SPECIFICATION

CORROSION

GS EP COR 102

Design of cathodic protection of sealine by sacrificial anodes

07	01/2012	Editorial changes
06	01/2011	Changes in current densities, minimum anodes thickness
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1. Scope

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

2. Reference documents

The reference documents listed below form an integral part of this General Specification and apply when they are not in conflict with those of the present document. 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. Should some requirements of these documents differ, those from [ISO 15589-2](#) prevail.

Standards

Reference	Title
EN 12474	Cathodic protection of sealines
ISO 15589-2	Petroleum and natural gas industries - Cathodic protection of pipeline transportation system - Offshore pipelines

Professional Documents

Reference	Title
DNV-RP-B401	Cathodic protection design
DNV-RP-F103	Cathodic protection of submarine pipelines by sacrificial anodes
NACE SP0169	Control of external corrosion on Underground or Submerged Metallic Piping Systems

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
ISBN 88 7398 020 1	Cathodic Protection - Luciano Lazzari, Pietro Pedefferri - Polipress

Total General Specifications

Reference	Title
GS EP COR 100	Design of cathodic protection of offshore structures
GS EP COR 201	Supply of sacrificial anodes
GS EP COR 220	Three layer polyethylene external coating for pipelines
GS EP COR 221	Three layer polypropylene external coating for pipelines
GS EP COR 222	Fusion Bonded Epoxy (FBE) external coating for pipelines
GS EP COR 223	Bituminous hot applied external pipeline coatings
GS EP COR 225	Polyethylene and Polypropylene coatings for bends and fittings
GS EP COR 226	Materials for thermal insulation of pipeline, piping and subsea components
GS EP COR 230	External laminated glass fibre/resin based coating for risers of sea line
GS EP COR 231	External elastomer based coating for risers of sea line
GS EP COR 401	Installation of anodes on submerged pipelines
GS EP COR 420	External field joint coatings of pipelines
GS EP 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 for sealines shall be carried out exclusively by competent and specialised personnel. The qualification of each of the specialists working for such a design shall be demonstrated to Company before commencement of the work.

Verification of the formal Certification of the individuals shall be carried out as follows:

- Conventional design work to be carried out by certified personnel at level 2 for all certification schemes except for NACE International where it shall be level 3.
- Complex design work or verification to be carried out by certified personnel at level 3 for all certification schemes except for NACE International where it shall be level 4.

Accepted certification schemes are AFAQ AFNOR Compétence (Seawater Application Sector), APCE (Seawater Application Sector), Institute of Corrosion, NACE International. Any other certification scheme shall be approved by Company.



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

4. Coating of sealines

Cathodic protection design depends on external coatings of the sealine, as manufactured in the plant, and on field joint coatings installed at girth weld areas during pipeline construction. Company General Specifications applicable to pipeline coatings are [GS EP COR 220](#), [GS EP COR 221](#), [GS EP COR 222](#), [GS EP COR 223](#), [GS EP COR 225](#), [GS EP COR 226](#), [GS EP COR 230](#), [GS EP COR 231](#) and [GS EP COR 420](#).

5. Calculation of the cathodic protection system

5.1 Principle and general requirements

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

No electrical insulation shall be installed between the sealine and the structures, except:

- Where different protection systems (cathodic protection by impressed current versus cathodic protection by sacrificial anodes) are used for the sealine and the onshore or offshore installations
- Where the sealine is connected to third party installations.

Unless otherwise stated, all the requirements of [ISO 15589-2](#) Standard shall be applicable. As a complement, requirements of [EN 12474](#), [DNV-RP-F103](#) and [NACE SP0169](#) are applicable when they are not in conflict with the present General specification and [ISO 15589-2](#).

Cathodic protection of conventional risers shall be included in the cathodic protection design calculation of the supporting jacket, as specified in [GS EP COR 100](#).

Cathodic protection of SCRs (Steel Catenary Risers) shall be included in the cathodic protection design of the associated pipeline in accordance with [GS EP COR 102](#).

5.2 Data required for cathodic protection calculations

5.2.1 Protective potentials

For steel submerged in seawater or buried in mud, the polarisation potential shall be more negative than -900 mV versus Ag-AgCl/seawater reference electrode, to take into account the possible presence of sulphate reducing bacteria.

Note 1: For onshore sections, the potential of the steel shall be more negative than -850 mV versus a saturated Cu-CuSO₄ reference electrode.

Note 2: Cathodic protection may have detrimental effects on some materials and cause Hydrogen Embrittlement due to the discharge of hydrogen atoms at the metal surface. Document [DNV-RP-B401](#) gives minimum precautions to be taken to avoid the risk of hydrogen induced stress cracking.

5.2.2 Resistivity of seawater

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 at the location of interest.

Table 1 - Mean resistivity of seawater

Geographic area	Cameroon Nigeria	Congo Gabon Angola Italy	The Netherlands	Norway Argentina	Gulf of Mexico	Libya	Indonesia Persian Gulf
Resistivity ($\Omega.m$)	0.22	0.20	0.29	0.33	0.20	0.23	0.19

When the sealine is buried in mud, and in the absence of documented values, an average resistivity of 1 $\Omega.m$ shall be considered.

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 Project Particular Specification shall reflect these variations.

For deepwater structures in West Africa a seawater resistivity of 0.30 $\Omega.m$ shall be used.

5.2.3 Current density

The current density to be used for cathodic protection design of submerged carbon steels shall be as per [DNV-RP-B401](#) (January 2005), Annex A.

The calculation methodology is given in [DNV-RP-B401](#) (January 2005), § 6.3.

Anode design shall fulfill both the total anode weight requirement (based on the mean current density) and the final (or initial for bare pipe) current output requirement (based on the -900 mV potential criterion and the final current density).

Nonetheless, the driving parameter for the design shall be the anode weight (mean current requirement), so the anode size shall be adapted accordingly.

Note: For sealines transporting hot fluids, the design current density (initial, mean and final) shall be increased by 1 mA/m² per °C when the metal/environment interface is assumed to exceed 25°C ([EN 12474](#)).

5.3 Coating breakdown factor as a function of time

The coating breakdown factor is used to estimate the decrease of current density depending on the selected coating system and the design lifetime.

Coating breakdown factors at mean life and end of life shall be chosen from Table 2 depending on the plant applied coating and field joint coatings used. These coatings breakdown factors are considered for a lifetime of **30** years. Other values may be used if fully documented and approved by Company, especially for other design lifetimes.

Note: Coating breakdown factor values given in [DNV-RP-F103](#) shall be in no case considered whatever the situation.



For sections coated with heat insulation systems, GRE, or elastomers in accordance with **GS EP COR 230** and **GS EP COR 231** 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 based on aluminium or zinc. For service temperatures over 50°C aluminium based alloys shall be selected. The selected anode material shall be in accordance with **GS EP 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 these are unknown before the calculation, the following conservative values shall be used:

- Practical consumption at ambient temperature (i.e. electrochemical capacity times efficiency):
 - 3.6 kg/A.year for aluminium indium anodes
 - 11.2 kg/A.year for zinc anodes.

Note 1: 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:

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

ε is the anode electrochemical efficiency in Ahr/kg

T is the temperature in °C.

Note 2: The values given above already take into account the decrease of electrochemical efficiency of aluminium due to installation in sea mud.

- Closed circuit potential:
 - -1050 mV/Ag-AgCl/seawater for aluminium indium anodes
 - -1000 mV/Ag-AgCl/seawater for zinc anodes.

Table 2 - Coating breakdown factors (CBF %) for a lifetime of 30 years

Plant coating	Concrete	Field joint	Infill	Mean	Final
Bituminous	Yes	Tapes	No	9	13
			Yes	7	10
		Heat-shrink sleeves	No	8	11
			Yes	6	9
3LPE	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
3LPP	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
FBE	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 bracelet anodes

The anodes net weight needed to protect the sealine during its design lifetime shall be calculated according to annex B of European standard [EN 12474](#). As a simplified approach, the pipe coating resistance (or transversal insulating resistance) will be considered as negligible. For specific calculations (especially current attenuation), it may be necessary to choose adequate values for such coating resistance. These shall be approved by Company.

The utilisation factor for the bracelet anode installed to protect the sealine shall be $u = 0.85$.
A minimum anode thickness shall be used for each anode size as per Table 3.

Table 3 - Minimum anode thickness

Anode ID (mm)	Anode length (mm)	Minimum thickness (mm)
0-200	< 400	30
0-200	400-600	40
0-200	> 600	45
200-500	< 300	35
200-500	300-600	40
200-500	> 600	45
500-700	< 300	40
500-700	300-600	45
500-700	> 600	50
> 700		50

6.4 Distribution and number of bracelet anodes

The anodes shall be distributed along the sealine in order to achieve uniform current distribution.

There shall normally be six anodes per kilometer. The number of anodes per km shall be increased in case of specific conditions (high temperature, etc.).

One may justify an increase of the distance between anodes, (e.g. to reduce hazards related to anode attachments on H embrittlement sensitive steels). In this case, the spacing between anodes shall be checked to demonstrate that potential attenuation is acceptable. This may be done using various methods, such as the one recommended in chapter 4 of the book "[Cathodic Protection](#)", from Luciano Lazarri and Pietro Peddeferri.

In any case, the method shall be conservative and demonstrate that potential criterion is achieved at the most remote location from anodes for the highest current demand (generally at the end of life).

The same approach shall be used to check the distance between connections when a small diameter piggy back pipeline is protected with bracelet anode installed on a larger pipeline.

Apart from the anodes distributed along the sealine, supplementary anodes shall be installed at specific locations in order to compensate for possible interferences (risers, spool pieces, branch connections, crossing of sealines, etc).

Insulating half-shells (composite SVR or equivalent material) may be installed between the anodes and the sealine in order to limit the temperature of the anode. The thickness of such half shells (generally 10 mm) shall be defined by Contractor who shall take into account the reduction of anode electrochemical efficiency.



Note: An alternative solution to avoid high temperature at the anodes in shallow waters is to install the anodes away from the sealine and to use a cable connection. Such specific design shall be approved by Company.

Cathodic protection of SCRs is ensured by anodes located only at the sea bottom. Modeling of the CP system shall be carried out, demonstrating that an adequate potential level will be reached at each location during the whole design lifetime, using software approved by Company (e.g. PROCOR, BEASY, or equivalent).

For areas where it is difficult for the cathodic protection current to reach the sealine (e.g. underneath vortex breakers), Thermal Sprayed Aluminium coating shall be used.

Anodes shall be installed according to Company General Specification **GS EP COR 401**.

7. Verification of protection

Verification of the cathodic protection system after installation of the sealine shall be performed according to the recommendations of **GS EP COR 502**.

The chosen verification procedure shall be described and approved by Company.

8. Technical file

The detailed technical study shall be approved by Company.

It shall at least contain:

- Hypotheses considered for the calculation
- Chosen anode material
- Anode bracelet dimensions
- Detailed calculations verifying that the protection is ensured for the design life of the sealine.