



Exploration & Production

GENERAL SPECIFICATION

CORROSION

GS EP COR 201

Supply of sacrificial anodes

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1. Scope

The document defines the requirements regarding quality, inspection and guarantees to be met for the supply of sacrificial anodes for cathodic protection of offshore structures and/or containers.

The structures concerned are fixed structures (platforms, pipes, pile dolphins, landing stages, etc.), floating structures (buoys, barges, storage ships, etc.), and/or containers (tanks, vessels, exchangers).

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
ASTM D 1141	Specification for substitute ocean water
EN 10204	Metallic products - Types of inspection documents
ISO 8501-1	Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings

Professional Documents

Reference	Title
DNV-RP-B401	Cathodic Protection Design
NACE RP0387	Metallurgical and inspection requirements for cast galvanic anodes for offshore application
NACE TM0190	Impressed current test method for laboratory testing of aluminium anodes

Regulations

Reference	Title
Not applicable	



Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS EP COR 401	Installation of anodes on submerged pipelines

3. Sacrificial alloys

3.1 Chemical composition

The type of sacrificial alloy is specified in the Job Specification enclosed with the invitation to tender.

The sacrificial alloys that shall be used are as follows, the compositions are given in mass percentage and show the acceptable limits of alloying components and pollutions compared to the base metal:

3.1.1 Magnesium alloy

3.1.1.1 Type M1

Mn	Al	Zn	Fe	Cu	Si	Pb	Ni	Others
0.25 min	5-7	2-4	0.005 max	0.08 max	0.3 max	0.03 max	0.003 max	0.3 max

3.1.1.2 Type M2

Mn	Al	Zn	Fe	Cu	Si	Pb	Ni	Others
0.5-1.5	0.05 max	0.03 max	0.03 max	0.02 max	0.05 max	0.01 max	0.002 max	--

3.1.2 Zinc alloys

3.1.2.1 Type Z1

Al	Cd	Fe	Cu	Pb	Others
0.1-0.5	0.025-0.07	0.005 max	0.005 max	0.006 max	0.10 max

3.1.2.2 Type Z2

Al	Cd	Fe	Cu	Pb	Others
0.005 max	0.003 max	0.0014 max	--	--	--

3.1.3 Indium-activated aluminium alloys

Zn	In	Fe	Si	Cu	Others
2.5-6	0.015- 0.030	0.09 max	0.10 max	0.005 max	0.10 max

Any other type of alloy shall be subject to a concession request by the Supplier to the Owner for approval.

The Supplier shall give a precise indication of the nominal composition of its alloy.

The Supplier shall endeavor to guarantee the narrowest possible range, to ensure maximum uniformity of the chemical composition of the anode batch.

The Supplier shall also indicate the actual density of the alloy, which is used to calculate the anode mass required to determine the submerged weight of the pipelines and the weight of the structures.

3.2 Electrochemical properties

3.2.1 Minimum required

The tender shall indicate the electrochemical properties of the proposed sacrificial alloy in natural seawater at ambient temperature:

- Open circuit potential
- Close circuit potential
- Practical mass consumption (kg/A.an) or electrochemical capacity (A.h/kg).

The Supplier shall also indicate separately these characteristics in conditions as close as possible to those of the electrolyte in which the anodes are to operate (specified in the Job Specification).

At delivery, the electrochemical test certificates (§ 10.4) shall include the actual properties of the alloy and comply with the initially proposed values.



3.2.2 Testing

Two kinds of tests are required:

3.2.2.1 Alloy qualification

Electrochemical properties shall be measured using DNV long term “free running” tests as specified in [DNV-RP-B401](#) Annex C.

This test at ambient temperature shall last for a period of minimum 12 months in natural sea-water or, failing this, artificial sea-water according to [ASTM D 1141](#) (pH adjusted to 8.2 ± 0.1), with the electrolyte continuously replenished can be used.

This test shall be required for the qualification of the sacrificial alloy, in the frame of the technical audit and as a minimum every 5 years for each Supplier to guarantee the minimum requirements of the sacrificial alloy.

3.2.2.2 Quality control

The short duration electrochemical test method shall be used to test the alloy quality at the PQT (§ 5) and during the production. It shall be submitted to the Owner for approval.

These tests shall comply with the methods prescribed by [DNV-RP-B401](#) Annex B, or by [NACE TM0190](#).

Unless otherwise indicated in the Job Specification, the electrochemical property checks shall be performed on the following minimum basis:

- One test for an order concerning a net mass of alloy between 0 and 10 tons, two tests for 10 to 20 tons, and one additional test for every 20 tons
- For melts with a chemical composition very near the limits of the range specified by the stated nominal composition, one or more additional tests may be requested.

4. Core quality requirements

The steel used to manufacture anode cores or support fittings on the frame (gusset plates, reinforcing plates or collars) shall be of weldable quality ($C \leq 0.23\%$; $CE \leq 0.40\%$).

A surface preparation ensuring good bonding of the sacrificial alloy to the core shall be applied by the Supplier in accordance with the following rules:

- Grit blasting to Sa 2 1/2 according to [ISO 8501-1](#): this surface preparation is sufficient if the surface quality is kept in good condition until casting (cores stored maximum 24 hours in dry area)
- Aluminium spraying may be required for aluminium anodes if the surface condition obtained by blast cleaning is not guaranteed
- For zinc and magnesium anodes, hot dip galvanized or zinc electro-plated inserts may be required if the blast cleaning preparation is not satisfactory.

Any other surface preparation shall be subject to the prior written approval of the Owner.

5. Pre-qualification testing (PQT)

For specific orders where the global anodes quantity is over 10 tons or when the anode design is atypical or concerns bracelet anodes, a pre-qualification testing (PQT) shall be carried out at least two months prior to starting the anode production.

For lower anodes quantities, the PQT is optional, but it is Company's responsibility to decide if it will take place or not.

The objective of this PQT is to attend the manufacturing of anodes, to check they comply with the order requirements (dimensions, weight) and the physical quality (§ 7).

The PQT is also the opportunity to launch quality control testing (§ 3.2.2.2) to ensure the alloy meet the minimum electrochemical requirements.

The different stages of the anode manufacturing process shall be collected in an Inspection and Test Plan (ITP) to be discussed and clarified before conducting the PQT.

6. Massive anodes for fixed or floating structures and containers

6.1 Shape and dimensions

These are indicated in the Job Specification or, failing this, shall be proposed by the Supplier in the tender.

In all cases, the Supplier's tender shall give the exact values of the net weight, gross weight (including the core and attachment supports) and the dimensions of the anode.

The Supplier shall also supply a detailed drawing.

Unless otherwise stated in the Job Specification, the tolerances on weight and dimensions shall be as follows:

- Individual anodes of each type shall have a weight within $\pm 3\%$ of the nominal weight for anodes above 50 kg of weight. For anodes weighing less than 50 kg the tolerance shall be $\pm 5\%$.
- The total weight of the delivery should not be more than 2% above the nominal Contract weight. No negative tolerance is permitted on the total order.
- The anode mean length shall be $\pm 3\%$ of the nominal length or ± 15 cm whichever is the smaller.
- The anode mean width shall be $\pm 5\%$ of nominal mean width.
- The anode mean depth shall be $\pm 5\%$ of nominal mean depth.
- The diameter of cylindrical anodes shall be $\pm 5\%$ of nominal diameter.
- The maximum longitudinal bending between the middle and the anode ends shall be $\pm 1\%$ of the nominal length.

6.2 Slender anodes with stand-off supports

For slender anodes with stand-off supports, the core shall be cylindrical (tube or round) to avoid gas retention when casting.



The core dimensions shall be proportional to the mass of the sacrificial alloy and to the shaking conditions of the future environment.

Unless otherwise specified in the Job Specification, the choices available for these dimensions under normal operating conditions shall be as indicated in the table below:

Diameter of cylindrical cores			
Net mass M of anode (kg)	Inside containers	Structures in the Gulf of Guinea, Mediterranean Sea and Adriatic Sea	Structures in the North Sea
$M < 50$	round $\frac{1}{2}$ "	round $\frac{3}{4}$ "	round $\frac{3}{4}$ "
$50 \leq M < 75$	round $\frac{3}{4}$ "	round $\frac{3}{4}$ "	tube 2" sch 80
$75 \leq M < 150$	round $\frac{3}{4}$ "	tube 2" sch 80	tube 2½" sch 80
$150 \leq M < 200$	tube 2" sch 80	tube 2½" sch 80	tube 3" sch 80
$200 \leq M < 350$	tube 2" sch 80	tube 3" sch 80	tube 4" sch 80
$350 \leq M$	tube 2" sch 80	tube 4" sch 80	tube 4" sch 80

Unless covered by a concession arrangement, the core of slender anodes for offshore structures (especially jackets) shall terminate at both ends of the anodes and not at one side.

Stand-off supports shall be made either by core bending to ensure that the sacrificial metal is not loaded during the operation or by welding a cylindrical lug with an elbow added as shown in the drawing in Appendix 1.

The distance "l" between each end of the anode and the axis of the next support lug (see Appendix 1) shall be as short as possible, and shall not exceed the figures below, according to the core diameter.

Maximum anode/support distance "l"				
Core diameter	2"	2" and 2½"	3"	4"
l (mm) maximum	200	300	350	400

The distance "h" between the alloy and the leg on which the anode is located, should be usually from 300 to 500 mm, unless otherwise indicated in the Job Specification.

For offshore structures, doubler plates shall be welded to the structure before welding the anode support.

This system may be supplemented with a gusset plate reinforcement before welding the anode support.

The reinforcement shall be installed as shown in the drawing in Appendix 1 (section 2-2) herein, and the mechanical strength calculation enables the characteristics of the reinforcement plate (length L', thickness) and of the gusset plate (length l', height h', thickness) to be defined.

6.3 Flat or plated anodes

For flat anodes, cores shall be flat irons of which the number and dimensions (thickness, width) are adapted to the net mass of the sacrificial alloy.



Such cores shall terminate laterally to ensure mechanical fixing and electrical contact by welding to the structures.

For plated anodes, their core shall not be centered within their section and a minimum alloy thickness shall be left underneath: this thickness shall be 10% of the anode height or 5 mm minimum.

Their protruding core ends shall be located in the same plan as the side close to the structure surface.

None of the anode surfaces shall be painted, with the exception of flush-mounted anodes: their side in contact with the structure shall be given one coat of modified epoxy paint (100 μ m minimum).

7. Bracelet anodes for sea lines

7.1 Shape and dimensions

The shape, approximate dimensions and net mass of the anodes are indicated in the Job Specification.

In the tender, in addition to the information requested in section 3, the Supplier shall specify these dimensions and also indicate the gross and net mass of the anode.

Unless otherwise stated in the Job Specification, the tolerances on weight and dimensions shall be as follows:

- Individual anodes of each type shall have a weight within $\pm 3\%$ of the nominal weight for anodes above 50 kg of weight. For anodes weighing less than 50 kg the tolerance shall be $\pm 5\%$.
- The total weight of the delivery should not be more than 2% above the nominal Contract weight. No negative tolerance is permitted on the total order.
- The length of the anode casting shall be $\pm 3\%$ of nominal length or ± 25 mm, whichever is smaller.
- Anode internal diameter shall conform to the following dimensional tolerances:
 - $-0 + 4$ mm for pipeline diameters less or equal to 300 mm
 - $-0 + 6$ mm for pipeline diameters from 300 to 600 mm
 - $-0 + 1\%$ for pipeline diameters greater than or equal to 600 mm.
- The dimensional tolerances on the anode thickness shall be ± 3 mm.
- The tolerance on the position of the cores with respect to the position on the drawing approved by the Owner shall be ± 3 mm.

7.2 Bevel

For anodes to be installed on a non-concrete pipe, the tips of the half-anodes shall be bevelled to prevent jerks in the passage of tubes over the "stinger" rollers. The bevel slope shall be such that $65^\circ < \alpha < 75^\circ$.

For concreted pipes, no bevel is required but the anodes thickness shall be such that it is equivalent to the concrete thickness, or maximum 10 mm less.

7.3 Coating

None of the anodes surface shall be painted with the exception of the internal surface of anode bracelets, which shall be given one coat of modified epoxy paint (100 µm minimum).

For additional information on bracelet anodes, see [GS EP COR 401](#).

8. Physical quality

8.1 Sacrificial alloy/core interface

The sacrificial alloy shall exhibit good adhesion to the core to avoid any mechanical disbonding and ensure excellent electrical contact.

No cavities longer than 10 mm shall appear at this level, and for any divided section.

The sum of the lengths of the cavities shall not exceed 5% of the length of the alloy/core interface examined.

8.2 Cracks

The presence of cracks shall be minimized.

There shall be no cracks that could entail a loss of metal.

The tolerances for cracks are as follows:

Anode type	Position	Maximum number	Maximum width	Length
Slender anodes	Only transverse	≤ 2	≤ 1 mm	≤ 100 mm
Zinc bracelet anodes		≤ 1	≤ 0.5 mm	≤ 50 mm
Al bracelet anodes		≤ 2	≤ 1 mm	≤ 100 mm

The depth of the crack shall not exceed 10% of the sacrificial alloy thickness.

8.3 Surface defects

The surface of the anode shall be free of slag.

Each anode shall be cast in one step, i.e. it shall be free of intermediate solidification.

There must be no projecting metal potentially dangerous to users.

Cast shrinkage cavities should be avoided as much as possible, especially on the main surfaces. They may be tolerated up to a depth of 7 mm.

There shall be no more than two cast shrinkage cavities per anode.

Tapering adjacent to the core termination may be tolerated up to a maximum of 10% of the thickness or equivalent diameter of the anode, to a maximum of 10 mm.

8.4 Internal defects

- No section of the core shall contain more than 2% of cavities.
- No cavity shall have an area larger than 1 cm².

- No section of the anode shall contain more than 1% of non-metallic inclusions.
- The number and method of selection of anodes to be sectioned during a Contract should take account of anode design and number of anodes. The Owner reserves the right to cut up to 1% of the number of anodes produced, with a minimum of one anode per anode type. The anode shall be selected at random for sectioning.
- Typically, each anode shall be sectioned transversely by single cuts at 25%, 33% and 50% of nominal length, and once in the lengthwise direction for bracelet anodes. An adapted blade shall be available in the factory for anode cutting. Any other cutting location for a particular anode design shall be agreed by Owner.
- In case of failure to satisfy the acceptance criteria, a second anode shall be selected at random for sectioning. In case of failure to satisfy the acceptance criteria the whole anode batch shall be rejected.
- The cut faces, when examined visually without magnification, shall not have more than:
 - 1% of the sum of the surface area, nor more than 2% or any one surface as gas holes or porosity
 - 0.5% of the sum of the surface area nor more than 1% of any one surface as non-metallic inclusions
 - 5% of the tubular insert circumference containing voids adjacent to the insert in average on all sections, the maximum for any one section being 10% of the circumference or a maximum of 25 mm.
- For non tubular cores (e.g., channel or "T" section steel) where prevention of voids may be particularly difficult, the limits shall be specified and agreed upon prior to manufacture.

9. Checks to be performed by the Supplier

The Supplier shall perform the checks specified below and submit the results to the Owner on acceptance. It shall be compliant with [NACE RP0387](#).

Inspection shall be performed by the Manufacturer's Inspection Department in the presence of an Inspector approved by the Company.

Inspection results shall be written up in a report and jointly signed by the Manufacturer's Inspection Department Representative and the Inspector.

Inspection shall consist of:

- Size, weight, insert position and identification mark checks
- Examination of the spectro-analysis results and of the quality control tests results
- Examination of cut surfaces, voids, inclusions, insert adherence and position of insert
- Examination of the steel grade used for the inserts and fasteners
- Examination of anode surface condition after removal from the mould.

9.1 Alloy chemical composition

The composition of each melt of the alloy selected shall be checked systematically by the Supplier, who shall perform at least two analyses on each melt (at the beginning and the end).



A single analysis is permitted if the melt does not exceed 1,000 kg for zinc and 500 kg for aluminium and magnesium.

The Supplier shall perform these analyses using a method accurate enough for the results to be expressed to the same number of significant figures as those of the nominal composition of the alloy specified in chapter 3.1.

9.2 Electrochemical properties

As indicated in § 3.2.2.2, quality control tests shall be carried out to determine the closed-circuit potential and practical mass consumption or electrochemical capacity.

Samples shall be taken during casting (diameter 30 mm, length 150 mm) or preferably on anodes.

The results of these tests shall conform with the nominal values specified by the Supplier with the following tolerances:

- ± 25 mV for the closed-circuit potential. In addition; no test values more positive than the potential used in the design calculation shall be accepted
- + 5% for the guaranteed practical mass consumption. In addition, no test values of practical mass consumption higher than what is applied in the design calculation shall be accepted.

The Owner reserves the right to reject the batch of anodes if the results fail to meet the specifications. The Owner may also postpone acceptance of batches of anodes for which the results of these electrochemical tests are not submitted at the time of inspection..

10. Acceptance

10.1 Supplier's obligations

For orders of more than 4 tons of sacrificial metal cast, the Supplier shall provide the Owner with representative samples of each melt for check analysis.

For each melt, one sample 30 mm in diameter and 10 mm thick (approximately) shall be provided.

In case of disagreement about the composition of the samples, the samples concerned shall be sent to an outside laboratory under conditions to be determined by mutual agreement.

Every 10 t, the Supplier shall also provide the Owner with a sample 30 mm in diameter and 150 mm long for checking the electrochemical properties in an outside laboratory.

10.2 Marking of anodes

Each anode shall be marked with:

- The name of the Supplier
- The type of alloy
- An identification number corresponding to the melt number
- The serial No. in the casting.

Marking shall be carried out by cold-stamping on the upper third of one of the support tubes, on one of the lugs of the anode, or on the sacrificial alloy. Marking on the sacrificial alloy is tolerated, but is not the preferred method.

10.3 Factory acceptance of anodes

Inspection of the anodes by the Owner in the factory shall concern the following aspects in particular:

- Gross weight of the anodes
- Number and dimensions of the anodes
- Position of the insert
- Physical quality of the anodes (§ 8):
 - Anodes/core interface (§ 8.1)
 - Cracks (§ 8.2)
 - Surface defects (§ 8.3)
 - Internal defects (§ 8.4).
- Chemical compositions of the alloy (§ 9.1) and steel insert (§ 4)
- Results of quality control tests (electrochemical properties § 9.2)
- Marking (§ 10.2).

A minimum of 10% of the anodes ordered shall be inspected systematically. If no defect is found, acceptance shall be declared for the entire order. Otherwise, inspection shall continue.

10.4 Documents to be supplied

Supplier shall issue an inspection document according to [EN 10204](#), inspection certificate type 3.21.

Acceptance of the product shall only be declared on the basis of this certificate and if all the documents to be provided by the Supplier comply with this specification:

- A list of all melts numbered in chronological order and showing each anode with its serial No. and gross weight
- Analysis certificates
- Electrochemical test certificates giving the method, the results and the melt number or the serial No. in the casting operation
- Mill certificates of the steels used
- A certificate of conformity written by the Supplier which guarantees that the anodes comply the requirement of the order.

10.5 On-site acceptance of anodes

Potential and current measurements, supplemented with inspections and photographs, shall be performed by the Owner during the first year of operation. If it is proved that a certain number of anodes remain blocked and do not function, the warranty clause shall be applied.

Appendix 1 Slender anode with stand-off supports

