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Galvanic anodes for cathodic protection in seawater and saline sediments

Anodes galvaniques pour la protection cathodique dans l'eau de mer et les sédiments salins

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Contents

Foreword

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This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 219, *Cathodic protection*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This standard defines the minimum requirements for the galvanic anode quality levels and verification procedures.

The anticipated performance of the cast galvanic anodes for use in seawater and saline mud or sediment is determined by their composition, anode dimensions and the quality of their manufacture.

In addition, the document provides guidance and recommendations related to the environmental impact.

Galvanic anodes for cathodic protection in seawater and saline sediments

1 Scope

This document defines requirements and gives recommendations for the chemical composition, electrochemical properties, physical tolerances and test and inspection procedures for cast galvanic anodes of aluminium, magnesium and zinc-based alloys for cathodic protection in seawater, saline sediment and brackish water.

Information on salinity ranges can be found in Annex A.

The requirements and recommendations of this document can be applied to any available anode shape for cast anodes, e.g. trapezoid, circular, half-spherical cross sections, bracelet type.

Whilst other metals, such as soft iron, can be used as galvanic anode material to protect more noble metals than iron and steel, these are not covered in this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 630 (all parts), *Structural steels*

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

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*

ISO 9606-1, *Qualification testing of welders — Fusion welding — Part 1: Steels*

EN 10025, *Hot rolled products of structural steels (all parts)*

ISO 10474:2013, *Steel and steel products — Inspection documents*

ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 15609-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
anode consumption rate
mass consumption rate
amount of anode material consumed for a current output of one ampere during one year

Note 1 to entry: The anode consumption rate is expressed in kilograms per amp year [kg/(A·y)].

3.2
batch
group of anodes all produced from a single furnace cast

Note 1 to entry: Multiple batches of different anodes can be produced from a single cast.

3.3
bracelet anode
anode shaped as half-shells (annular castings) to be positioned on tubular items

Note 1 to entry: Two half-shell castings fit together to become a bracelet anode. These are typically used for submarine pipelines and occasionally used for marine structure tubulars.

Note 2 to entry: Bracelet anodes can be fabricated as half or part shell castings with the structural core within the casting, or as cast segments with only the supporting core within the casting and the structural steel elements external to the castings. Segmental bracelets comprise individual castings attached to external steel bands to fit around the pipeline or tubular structure.

3.4
cast
charge
heat
single furnace load with a unique, analysed chemical composition from which anodes are produced

3.5
closed circuit potential
potential of an electrode measured with respect to a reference electrode or another electrode when a current is flowing in the circuit

3.6
cold shut
surface discontinuity in the cast anode alloy caused by solidification of a portion of a meniscus during the progressive filling of a mould, which is later covered with more solidifying metals as the molten metal level rises

Note 1 to entry: Cold shuts often occur remote from the point of pour.

3.7
crack
imperfection produced by a local rupture in the solid state, which can arise from the effect of cooling or stresses

3.8
driving voltage
voltage between the galvanic anode to electrolyte potential and the structure to electrolyte potential

Note 1 to entry: For design purposes, the driving voltage refers to the difference between the closed-circuit potential of the anode and the design protective potential of the structure. This value is used to determine the maximum available anode current for a given circuit resistance.

3.9
electrochemical capacity
total amount of electric charge that is produced when a fixed mass of anode alloy is consumed electrochemically

Note 1 to entry: Electrochemical capacity is expressed in ampere hours per kg (A·h/kg).

Note 2 to entry: This represents the practical amount of charge per unit mass available, which is less than the theoretical, Faradaic value.

Note 3 to entry: An alternative, not preferred, term is alloy capacity.

Note 4 to entry: Electrochemical capacity is not a material constant but can vary with electrolyte conditions.

3.10
electrochemical property
property of potential and electrochemical capacity that characterises a galvanic alloy and can be assessed by quantitative tests

3.11
flush mounted anode
anode fitted to a structure with one face in contact with or very close to the structure

3.12
free-running test
electrochemical test where potential and current are not controlled

3.13
gas hole
blow hole, channel or porosity produced by gas evolution during solidification or entrapped air

Note 1 to entry: Gas holes can indicate:

— contamination of the mould or core prior to casting;

— poor mould or insert design;

— casting process permitting entrapped air during the pour.

3.14
gross mass
mass of a cast anode, including the mass of the steel core and any integral attachments on completion of casting

3.15
insert
core
structural item over which the anode is cast and which supports the alloy and can be used to connect the anode to the structure requiring protection

Note 1 to entry: The insert (core) is generally made of steel. Its design helps determine the utilization factor of the anodes.

3.16
ladle sample
specimen taken from the molten metal

3.17
net mass
mass of cast anode, excluding the mass of the steel core and any integral attachments on completion of casting

Note 1 to entry: Net mass represents the mass of the galvanic alloy material and is used in cathodic protection design.

3.18
nominal value
designated or intended value

Note 1 to entry: Examples of nominal values are length, width and mass.

3.19
non-metallic inclusions
particles of oxides and other refractory materials entrapped in liquid metal during the melting or casting sequences

3.20
pitting
localised corrosion resulting in cavities extending from the surface into the metal

3.21
polarization
change in the potential of an electrode as a result of current flow to or from that electrode

3.22
shrinkage depressions
natural concave surfaces which can be produced when liquid metal is allowed to solidify in a mould without the provision of extra liquid metal to compensate for the reduction in volume that occurs during the liquid and liquid–solid (solidification) contractions on cooling the liquid-solid transformation

3.23
stand-off anode
anode which is offset a certain distance from the object on which it is positioned

3.24
surface morphology
description of the features or structure of the anode surface

3.25
undercutting
formation of subsurface cavities which can be caused by pitting corrosion or inter-granular corrosion

3.26
utilization factor
fraction of the galvanic alloy mass in an anode which can be used for cathodic protection current before the galvanic material is no longer supported by the core or the anode can no longer deliver the minimum required current

Note 1 to entry: Utilization factor is generally expressed numerically (e.g. 0,80) and is dependent on the detailed anode design and location of the insert.

Note 2 to entry: Utilization factor is critical in the determination of anode mass requirements for a cathodic protection design.

3.27
void
lack of bond between the steel core and the cast alloy of an anode that can be formed by movement of the anode core in the mould as the alloy solidifies

4 Symbols and abbreviations

4.1 Symbols

y	year
E	anode consumption rate, kg/(A·y)
Q	electrochemical capacity of the alloy, A·h/kg
CE	carbon equivalent

4.2 Abbreviations

CP	cathodic protection
EPD	environmental product declaration
ITP	inspection and test plan
LCA	life cycle assessment
QC	quality control

5 Competence of personnel

It is the responsibility of personnel performing the design of the anode and the anode core to ensure that the anode, including its core, is suitable to deliver the utilization factor, see Clause 7. Those responsible for the core design shall have the appropriate level of competence for the tasks undertaken. Those responsible for all other aspects of the anode manufacture, inspection and testing shall also have the appropriate level of competence for the tasks undertaken. These should be the subject of the necessary training, assessment and documentation by the anode manufacturer to ensure that the requirements of this document are met.

NOTE Competence of CP personnel to the appropriate level for tasks undertaken can be demonstrated by certification in accordance with ISO 15257 or by another equivalent prequalification procedure.

6 Galvanic anode materials and their properties

6.1 General

In this document, alloys used for galvanic anodes in seawater or saline sediment shall be based on aluminium (Al), magnesium (Mg) or zinc (Zn). The performance, and therefore the suitability of a particular alloy for a specific application, depends on the composition and characteristics of both the anode alloy, the electrolyte and operation conditions of the polarized anode.

The performance of an anode alloy will vary in different environmental conditions. The performance data shall include the electrochemical capacity in ampere-hours per kilogram (A·h /kg), and the closed-circuit anode to electrolyte potential of a working anode measured against a calibrated standard reference electrode (see 6.3 and Annex D).

Each anode shall be uniquely marked by hard stamping with the cast number during production. Other markings can be added by agreement between purchaser and manufacturer and may include for example, a manufacturer identification, an alloy designation, anode mass and a sequential production number within the cast. Marking should be by hard stamping on the anode surface located where it is visible when the anodes are stacked or palleted for storage or delivery.

6.2 Anode alloy composition

The performance of an alloy is dependent on the specific alloy composition. Variations in composition from established specifications can result in variations in activation, resistance to passivation, electrochemical capacity and corrosion surface morphology. Some elements are known to have a detrimental effect on anode performance and their content is normally subject to strict control.

The most common galvanic anode generic compositions for aluminium, magnesium and zinc-based anode alloys are given in Annex C.

Strict control of the alloy chemical composition, both alloying elements and impurities, is essential and shall be carried out on each cast.

A minimum of two samples from each cast (ladle sample) shall be taken for chemical analysis. The samples shall be taken in the beginning and at the end of casting from the pouring stream. The sample shall be taken at the beginning of the first cast and at the end of the second cast, then in the beginning of the third cast and so on. The samples shall be analysed to verify the required chemical composition. All samples shall be identified with the cast number. All anodes from that particular cast shall be similarly identified with the cast number (see 6.1).

The samples shall be analysed to prove conformity with the agreed chemical composition limits of the alloy being produced. Additional sample(s) may be taken and stored for future determination of chemical composition.

NOTE Spark emission spectrometry is an appropriate method of analysis in a production environment but requires regular calibration against known and certified reference alloy samples.

Where a small holding furnace is used to continue topping up the cooling and solidifying anode after pouring from the main furnace has ceased, the holding furnace shall be supplied from the same cast as in the main furnace. A sample should be taken from the holding furnace for chemical analysis to ensure that the composition remains within limits.

The chemical composition of all samples analysed shall be documented. Anodes from casts which do not meet the required chemical composition shall be rejected.

6.3 Electrochemical properties

Cathodic protection (CP) is electrochemical in nature. The anode material's electrochemical properties are primary factors in cathodic protection design and therefore shall be documented.

These properties are:

— closed circuit potential;

— practical electrochemical capacity.

These properties can vary with electrolyte conditions. They can also vary over time, even when exposed to constant conditions. This is due to the corrosion products and layers of marine growth that form on the anode surface as well as variations in current demand. Caution should be exercised when considering these parameters for CP-specific design purposes (see 6.4.2).

NOTE 1 ISO 15589-2 and References [11] and [12] give further information on the impact of capacity variations of temperature and environment on cathodic protection design for pipelines.

NOTE 2 Due to self-corrosion, all anode materials have a practical electrochemical capacity lower than the capacity calculated by considering the theoretical electrical equivalence determined by Faraday's Law (i.e. some of the anode mass is consumed through self-corrosion, not current supply, and is not available for cathodic protection). The practical electrochemical capacity is used in cathodic protection design.

6.4 Electrochemical testing

6.4.1 General

There are two principal reasons for carrying out electrochemical tests: to determine alloy electrochemical performance and to conduct production quality control. Testing can also be carried out for research purposes, but such tests are generally customised and not considered in this document.

The principal methods of electrochemical testing are described in Annex D.

6.4.2 Performance testing

To determine alloy performance, there is no substitute for prolonged field testing of alloys in practical situations. Experience with different anode applications can be drawn upon, where possible.