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National Association of Corrosion Engineers

Standard Recommended Practice

Metallurgical and Inspection Requirements for Cast Sacrificial Anodes for Offshore Applications

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Standard
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Foreword

The purpose of this standard recommended practice is to set minimum physical quality and inspection standards for cast sacrificial anodes for offshore applications. This recommended practice is applicable to typical offshore platform anode configurations, and although some aspects of the standard may be relevant to all sacrificial anodes, it is not intended to apply to bracelet, hull, tank, pipeline, or extruded anodes, nor generally to anodes below 50 kg net weight.

This recommended practice was prepared by NACE Task Group T-7L-5 in association with a Working Group of the Corrosion Control Engineering Joint Venture (CCEJV), sponsored by the National Association of Corrosion Engineers and the Institution of Corrosion Science and Technology.[1] Task Group T-7L-5 is a component of Unit Committee T-7L on Cathodic Protection in Natural Waters; which issues this standard under the auspices of Group Committee T-7 on Corrosion by Waters. This standard was reaffirmed without revisions in April 1990.

This recommended practice is complementary to NACE Standard RP0176 (latest revision): Control of Corrosion on Steel, Fixed Offshore Platforms Associated with Petroleum Production (latest revision), and with respect to its limited offshore content, the British Standards Institution Code of Practice CP 1021-1973.[2]

This recommended practice does not address electrochemical or other anode performance test procedures. Another NACE Task Group (T-7L-2 on Aluminum Anode Quality Control) correlated a standardized, short-term potential and capacity determination test procedure for quality control purposes in international laboratories.[3] Another CCEJV/NACE Task Group is addressing long-term laboratory test procedures for performance characterization.

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(1)Institution of Corrosion Science and Tech., Birmingham, England.
(2)British Standards Institution, London, England.
(3)NACE Standard TM0190-90, "Impressed Current Test Method for Laboratory Testing of Aluminum Anodes." Houston, TX: NACE, 1990.

Section 1: General

1.1 This recommended practice defines minimum physical quality and inspection standards for cast sacrificial anodes for offshore applications.

1.2 The objectives of this recommended practice are: (1) to standardize an industry-wide practice that can be used by consultants, manufacturers, and users to define the physical requirements of anodes; and (2) to be specific enough to assist the inspection authority in their task of confirming that anodes comply with the physical requirements.

1.3 This recommended practice is applicable to the majority of anodes used on fixed offshore structures, i.e., cast anodes with circular or trapezoidal cross sections, with length substantially greater than width, and generally of a "stand-off" configuration (having extensions to the steel insert to achieve stand-off).

1.4 This recommended practice does not select particular anode alloy compositions or define short- or long-term performance tests.

1.5 This recommended practice does not specify particular anode or anode insert designs. An experienced corrosion specialist should be responsible for anode and anode insert design. Particular attention should be addressed to NACE Standard RP0176 (latest revision).

1.6 The manufacturer is responsible for meeting the quality levels specified in the recommended practice. The purchaser shall determine the extent of inspection to be conducted by the purchasing organization to prove compliance with the quality specified.

Section 2: Definitions

Cast Sacrificial Anode: The negative (reactive) component of a galvanic cell, designed to oxidize sacrificially and produce direct electrical current to protect a more electropositive (noble) metal operating in the same electrolyte and produced to a desired shape by the solidification of a molten alloy in a mold or die.

Certificate of Conformity: A statement made by the producer's representative (executive) and endorsed by a representative of the customer that the anodes listed comply with the requirements of the order.

Cold Lap: Horizontal discontinuity caused by solidification of the meniscus of a partially cast anode as a result of interrupted flow of the casting stream. The solidified meniscus is covered with metal when the flow resumes. Cold laps can occur along the length of an anode.

Cold Shut: Horizontal surface discontinuity caused by solidification of a portion of a meniscus during the progressive filling of a mold, which is later covered with more solidifying metal as the molten metal level rises. Cold shuts generally occur at corners remote from the point of pour.

Cracking: Fracture of metal along an irregular path producing a discontinuity similar to a ragged edge. It can occur during the solidification of the anode (hot cracking), during the contraction of the anode after solidification, or under externally applied loads. Hot cracking may be associated with the shrinkage depression that can occur in open-topped molds.

Dulling of Steel: Deterioration in appearance of shot-blasted inserts because of oxidation that causes darkening of the surface but not rust discoloration (see Rust Discoloration).

Dulling of Zinc: Deterioration in appearance of zinc-coated inserts because of oxidation that produces a white bloom of zinc oxide.

Electrochemical Properties: Those properties of potential and current capacity that characterize a sacrificial anode and can be assessed by quantitative tests.

Gas Holes: The evidence of bubbles within the solidifying metal. The holes can indicate that moisture was on the mold or insert prior to casting, or that the liquid metal contained a high level of hydrogen that had been thrown out of solution to form bubbles during the cooling of the metal.

Heat: Also called a "melt" or "cast," it is the unit that defines molten metal and identifies the anodes cast from it. A heat is the product that is cast to a planned procedure in one melting operation in one furnace, without significant interruption. If the casting sequence is interrupted, the anodes produced before, between, and after the interruptions constitute "batches."

Inserts: The form over which the anode is cast and which is used to connect the anode to the structure requiring protection. These are sometimes referred to as "cores."

Low Carbon Steels: Steels having less than 0.30% carbon and no intentional alloying additions.

Nonmetallic Inclusions: Particles of oxides and other refractory materials entrapped in liquid metal during the melting or casting sequences.

Porosity: Generally distributed fine holes caused by gas bubbles, shrinkage (formed by the starvation of eutectic material within the dendrite arms during "unfed" solidification), or a combination of the two mechanisms when hydrogen in solution diffuses into the lower pressure shrinkage voids.

Protrusion: Extraneous material on the anode surface. It may interfere with the anode-to-structure fit, appear unattractive, and be a safety hazard if there are sharp edges. Protrusions can be formed by careless filling of the mold or the flash from imperfect fitting of mold sections.

Rimming (Rimmed) Steels: An incompletely deoxidized steel. (See ASM Metals Handbook, 7th Edition for exhaustive definition.)

Rust Discoloration: A brown bloom of iron oxide.

Sample: A representative specimen.

Shrinkage Depression: The natural concave surface produced when liquid metal is allowed to solidify in a container without the provision of extra liquid metal to compensate for the reduction in volume that occurs during the liquid-solid transformation. The term also applies to the concave surface produced when liquid metal is solidified in a closed mold in such a manner that the area is not "fed" by the liquid metal provided by the casting's riser.

Tap Sample: A specimen taken from a molten metal stream. Such samples may be taken at the commencement of pouring and then at regular intervals until a final sample is taken at the end of the pour.

Voids Adjacent to Insert: Visible spaces between anode and insert materials. These can be caused by surface evaporation of moisture from the insert, contraction of the insert, or movement of the insert during casting caused by uneven heating and expansion that distorts the insert and prevents it from returning to its original, desired position within the anode.

Section 3: Physical Requirements of Anodes

3.1 Samples for Chemical Analysis

3.1.1 Representative metal samples shall be taken at the beginning and end of each heat, except for heats of less than 1000 kg (2205 lbs), when only one sample shall be taken at the start of each heat.

3.1.2 The samples shall be analyzed to prove compliance with the chemical composition limits of the alloy being produced.

3.2 Anode Identification

3.2.1 Each anode shall be marked with its unique heat number. For heat treated anodes, a heat treatment batch number shall be provided on each anode.

3.3 Anode Weights

3.3.1 Individual anodes of each type and of nominal weights greater than 50 kg (110 lbs) shall be within ±3% of the nominal weight.

3.3.2 An agreed sample of anodes of each type shall be weighed, either individually or in small batches, to confirm general compliance with Paragraph 3.3.1.

3.3.3 The total contract weight shall be no more than 2% above and not below the nominal contract weight.

3.4 Anode Dimensions and Straightness

3.4.1 Dimensions shall conform to the following:

3.4.1.1 Anode mean length shall be ±3% of nominal length or ±25 mm (0.98 in.), whichever is smaller.

3.4.1.2 Anode mean width shall be ±5% of nominal mean width.

3.4.1.3 Anode mean depth shall be ±10% of nominal mean depth.

3.4.1.4 The diameter of cylindrical anodes shall be ±7.5% of nominal diameter.

3.4.2 The straightness of the anode shall not deviate more than 2% of the anode nominal length from the longitudinal axis of the anode.

3.4.3 For all anodes, the anode and anode insert dimensions shall be suitable for the proposed fitting requirements. (In the case of flush mounting anodes, the fit-up may dictate more stringent requirements than detailed in Paragraphs 3.4.1 and 3.4.2, and these shoud be subject to separate agreement.)

3.4.4 An agreed sample of all anodes of each type shall be measured to prove compliance with Paragraphs 3.4.1 and 3.4.2.

3.5 Insert Dimensions and Position

3.5.1 Any special provisions needed to make the insert a suitable means of attachment shall predominate in the requirements of Paragraphs 3.4, 3.5, 3.6, and 3.7.

3.5.2 Anode insert location within the anodes shall be within ±5% of the nominal position in anode width and length and within 10% of the nominal position in anode depth. For inserts intentionally close to a surface of the anodic material, these designated tolerances may be inappropriate and should be subject to separate agreement.

3.5.3 Anode insert cross section dimensions shall comply with the appropriate specification for the insert material used.

3.5.4 Anode insert protrusions, fixing centers, and any other critical dimensions specified in the contract in pursuance of Paragraph 3.5.1 shall be measured on an agreed sample of all anodes of each type.

3.6 Insert Materials

3.6.1 Inserts shall be fabricated from weldable structural steel plates or sections and/or from weldable steel pipe.

3.6.2 Rimming steels shall not be used.

3.6.3 The carbon equivalent of insert materials shall not exceed 0.45%. The carbon equivalent value (C_{ev}) shall be calculated with the following formula:

$$C_{ev} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

where each element is expressed in weight percent (BS 4360: 1986 Appendix B).

3.6.4 Subject to meeting the requirements of 3.6.2 and 3.6.3, the following example specifications of steel types are acceptable:[4]

3.6.4.1 Pipe: API 5L Grade B, ASTM A-106 Grade A or B BS3602-HFS27, ASTM A53 Grade B

3.6.4.2 Plate, bar sections: BS 4360 Grade 40A or 43A ASTM A283 Grade C

3.6.5 For low temperature applications, consideration shall be given to the notch toughness of the material; in particular, to the toughness of the material to be welded to the parent structure.

3.7 Fabrication of Inserts by Welding

3.7.1 All fabrication welding of steel inserts shall be in accordance with the relevant requirements of the American Welding Society AWS D1.1 Structural Steel Welding Code, latest edition, or approved equivalent.

3.7.2 Qualification of welders and of welding procedures shall be in accordance with the requirements of AWS D1.1, latest edition, or approved equivalent. Welding procedures that meet the relevant provisions of AWS D1.1 shall be rated as prequalified and therefore exempt from test or qualifications.

3.7.3 All welds shall be visually inspected.

3.7.3.1 The level and type of other nondestructive testing inspection, if any, shall be by agreement.

3.8 Insert Surface Preparation

3.8.1 For aluminum anodes, the steel fabrication to be inserted into the cast anode shall be prepared by a dry blast cleaning process to a minimum quality complying with SIS 05 5900 - 1967 Sa 2 1/2 or equivalent, e.g., NACE Standard TM0170-70 or TM0175-75, No. 2, near white finish.

3.8.2 At the time the aluminum anodes are cast, "dulling" of the blast cleaned surface of the insert shall be permitted. Rust discoloration and/or visible surface contamination shall not be permitted.

3.8.3 For zinc anodes, the steel fabrication to be inserted into the cast anode shall be prepared by dry blast cleaning to SIS 05 5900 1967 Sa 2 1/2, galvanizing to BS 729, or zinc electroplating to BS 1706, or equivalents.

3.8.4 At the time the zinc anode is cast, "dulling" of blast cleaned or zinc coated steel insert surfaces shall be permitted. Rust discoloration and/or visible surface contamination of the blast cleaned or zinc coated surface shall not be permitted.

3.9 Surface Irregularities on the Anode Casting

3.9.1 Shrinkage depressions shall not exceed 10% of the nominal depth of the anode as measured from the uppermost corner to the bottom of the depression.

3.9.2 Casting surface irregularities shall be fully bonded to the bulk anodic material.

3.9.3 Not more than 1% of the total surface of the anode casting shall be contaminated with nonmetallic inclusions visible to the naked eye.

3.9.4 Cold shuts or surface laps shall not exceed a depth of 10 mm or extend over a total length of more than 3 times the width of the anode.

3.9.5 All protrusions detrimental to the safety of personnel during handling shall be removed.

3.9.6 Reduction in cross section of anodic material adjacent to the emergence of inserts shall not exceed 10% of the nominal anode cross section.

3.9.7 An agreed sample of all anodes of each type shall be inspected visually to confirm compliance with Paragraphs 3.9.1 and 3.9.6.

3.10 Cracks in Cast Anodic Material

3.10.1 Even with good foundry practice, particular compositions of anode alloy (notably aluminum based) suffer a degree of cracking.

3.10.2 Longitudinal cracks are not permitted except in the final "topping-up" metal.

3.10.3 Within the section of sacrificial anodic material wholly supported by the insert, transverse cracks of unlimited length and depth are permitted if width does not exceed 5 mm (0.2 in.) and there are no more than 10 cracks per anode. Full circumferential cracks shall not be permitted. Small dense cracks shall be considered one crack. Cracks of 0.5 mm (0.02 in.) width or less shall be ignored. However, when operating in compliance with this standard, the sacrificial material shall not be considered a structural member of the anode.

3.10.4 For sections of anodic material not wholly supported by the anode insert, no visible cracks shall be permitted.

3.10.5 An agreed sample of all anodes shall be inspected to confirm compliance with Paragraphs 3.10.2, 3.10.3, and 3.10.4.

3.11 Anode Sections and Internal Defects

3.11.1 The number and method of selection of anodes to be sectioned during a contract should take account of anode design and number of anodes. Details shall be agreed upon prior to manufacture.

[4]All references are listed at end of document.

3.11.2 Typically, anodes shall be sectioned transversely by single cuts at 25%, 33%, and 50% of nominal length, or at such other agreed locations for a particular anode design.

3.11.3 The cut faces, when examined visually without magnification, shall not have more than:

3.11.3.1 2% of the sum of the surface area, nor more than 5% of any one surface as gas holes or porosity

3.11.3.2 1% of the sum of the surface area nor more than 2% of any one surface as nonmetallic inclusions

3.11.3.3 10% of the tubular insert circumference containing voids adjacent to the insert as an average of all sections, the maximum for any one section being 20% of the circumference.

3.11.4 For nontubular 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.

3.12 Heat Treatment

3.12.1 For anodic alloys where post-casting heat treatment forms part of the specification for the material manufacture, the heat treatment history of each batch of anodes, i.e., each heat treatment furnace charge, shall be recorded.

3.12.2 The temperature of the furnace and of a representative anode in each charge shall be recorded continuously throughout the heat treatment.

3.13 Packing and Shipment

3.13.1 Anodes shall be bundled, strapped, placed on pallets, or individually loaded by an agreed procedure to facilitate unloading and minimize damage to anodes and their inserts between the manufacturing plant and the installation site.

3.14 Repeat Measurement, Tests, Inspections, and Rejections

3.14.1 In any instance in this recommended practice where the sample fails to meet the specified requirement, the manufacturer shall have the right to double the size of the sample to indicate general compliance with the recommended practice.

3.14.2 If under Paragraph 3.14.1 the larger sample size results in more failures, the sample may be increased to include all of the anodes, and all anodes not complying with the recommended practice may be rejected.

Section 4: Documentation of Inspection

4.1 General

4.1.1 Documentation shall be considered in two parts: (1) the retained documentation collected by the vendor during the normal quality control procedures and which shall be maintained by the vendor and made available for viewing or copying on request from the purchaser, and (2) the documentation that shall be provided to the purchaser by the vendor.

4.2 Retained Documentation

4.2.1 Retained documentation shall be available for the purchaser's inspection at the vendor's plant during the contract period and, subject to reasonable notice, for a period of 2 years thereafter.

4.2.2 Analysis results produced from Paragraphs 3.1.1 and 3.1.2 shall be referenced to individual heat numbers and shall form part of the retained documentation.

4.2.3 Heat treatment records (where required) from 3.12.1 shall be referenced to individual batch numbers and shall form part of the retained documentation.

4.2.4 Any electrochemical performance tests (not specified in this recommended practice) undertaken by the vendor shall be referenced to individual heat numbers (and batch numbers, if applicable) and shall form part of the retained documentation.

4.3 Supplied Documentation

4.3.1 A certificate of conformity shall be supplied by the vendor certifying that the anodes comply in all respects with the recommended practice and the purchase order.

4.3.2 Shipping documentation shall be provided to give evidence of compliance with Paragraph 3.13.1.

Reference Codes and Standards

API Specification 5L Grade B, American Petroleum Institute, Washington, DC.

ASM Metals Handbook, 7th Edition, American Society for Metals, Metals Park, OH 44073.

ASTM Specification A106 Grade A or B, ASTM, Philadelphia, Pennsylvania.

ASTM Specification A-283 Grade C, ASTM, Philadelphia, Pennsylvania.

ASTM Specification A53, Grade B, ASTM, Philadelphia, Pennsylvania.

American Welding Society Standard, D 1.1: Structural Steel Welding Code, Miami, Florida.

BS 729: Hot Dip Galvanized Coatings on Iron and Steel Articles, British Standards Institution (BSI), London.

BS 1706: Electroplated Coatings of Cadmium and Zinc on Iron and Steel, British Standards Institution (BSI), London.

BS 3602 Grade HFS 23 or 27, British Standards Institution (BSI), London. BS 4360 Grade 40A or 43A, British Standards Institution (BSI), London.

NACE RP0176-83: Recommended Practice: Corrosion Control on Steel, Fixed Offshore Platforms Associated with Petroleum Production, National Association of Corrosion Engineers, Houston, Texas.

NACE TM0170-70, Visual Standard for Surfaces of New Steel Air-Blast Cleaned with Sand Abrasive, National Association of Corrosion Engineers, Houston, Texas.

NACE TM0175-75, Visual Standard for Surfaces of New Steel Centrifugally-Blast Cleaned with Steel Grit and Shot, National Association of Corrosion Engineers, Houston, Texas.

Swedish Standard SIS 05 5900-1967: Pictorial Surface Preparation Standards for Painting Steel Surfaces, Swedish Standards Institution, Stockholm.