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# Standard
# Recommended Practice

# Metallurgical and Inspection Requirements for Cast Galvanic Anodes for Offshore Applications



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## Foreword

The purpose of this standard recommended practice is to set minimum physical quality and inspection standards for cast galvanic anodes for offshore applications. The objectives of this standard are (1) to standardize an industry-wide practice that can be used by consultants, manufacturers, and users to define the physical requirements of cast galvanic anodes; and (2) to be specific enough to assist the inspection authority in its task of confirming that cast galvanic anodes comply with the physical requirements.

This standard is complementary to NACE Standard RP0176, "Corrosion Control of Steel Fixed Offshore Platforms Associated with Petroleum Production,"[1] and with respect to its limited offshore content, the British Standards Institution (BSI)(1) 7361, Part 1.[2]

The manufacturer should have a documented quality plan for the manufacture and inspection of cast galvanic anodes. The content and development of the quality plan and associated documentation is outside the scope of this standard.

This standard was originally prepared in 1987 by NACE Task Group T-7L-5, a component of Unit Committee T-7L on Cathodic Protection, in association with a working group of the Corrosion Control Engineering Joint Venture (CCEJV), sponsored by NACE International and the Institute of Corrosion Science and Technology (ICorr).(2) This standard was reaffirmed in 1990 and revised in 1999, and is issued by NACE International under the auspices of Group Committee T-7 on Corrosion by Waters.

In NACE standards, the terms *shall*, *must*, *should*, and *may* are used in accordance with the definitions of these terms in the *NACE Publications Style Manual*, 3rd. ed., Paragraph 8.4.1.8. *Shall* and *must* are used to state mandatory requirements. *Should* is used to state that which is considered good and is recommended but is not absolutely mandatory. *May* is used to state that which is considered optional.

(1) British Standards Institution, 389 Chiswick High Road, London W4 4AL, United Kingdom.
(2) Institute of Corrosion Science and Technology (ICorr), P.O. Box 253, Leighton Buzzard, Bedfordshire LU7 7WB, United Kingdom.

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**Contents**

## Section 1: General

1.1 This standard defines minimum physical quality and inspection standards for cast galvanic anodes for offshore applications.

1.2 This standard is applicable to typical offshore platform anode configurations, and although some aspects of the standard may be relevant to all galvanic anodes, it is not intended to apply to bracelet, tank, pipeline, or extruded anodes, or generally to anodes below 50 kg (110 lb) net weight.

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

1.4 The manufacturer shall be responsible for meeting the quality levels specified in this standard. The user may determine the extent of inspection to be conducted to prove compliance with the quality specified.

## Section 2: Definitions

**Batch:** A group of anodes produced before, between, or after a significant interruption of the casting sequence of a heat of anodes.

**Cast Galvanic Anode:** A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

**Certificate of Conformity:** A written statement made by the representative (executive) of the manufacturer and endorsed by a representative of the user that the anodes listed comply with the requirements of the purchase order.

**Cold Lap:** Horizontal discontinuity caused by solidification of the meniscus of a partially cast anode as a result of interrupted flow of the molten metal, following which the solidified meniscus is covered with molten 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 an anode (hot cracking), during the contraction of an anode after solidification, or under externally applied loads. Hot cracking may be associated with the shrinkage depression that can occur in open-topped molds.

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

**Heat:** The product that is cast to a planned procedure in one melting operation in one furnace, without significant interruption. It is also called a melt and defines the molten metal and identifies the anodes cast from it.

**Insert:** The form over which the anode is cast and that is used to connect the anode to the structure requiring protection. It is sometimes referred to as a core.

**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:** Incompletely deoxidized steels. (See ASM[(3)] Handbook[3] for a comprehensive definition.)

**Rust Discoloration:** A brown bloom of iron oxide.

**Sample:** A representative specimen.

[(3)] ASM International (formerly American Society for Metals), 9639 Kinsman Rd., Materials Park, OH 44073.

**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 riser of the casting.

**Surface Lap:** A horizontal surface discontinuity on the top surface of a casting produced by molten metal solidification at the edge of a liquid metal meniscus and induced by an interruption in the flow of molten metal, e.g., during the topping up of a mold.

**Topping Up Metal:** The molten metal added to a casting's shrinkage depression to compensate for liquid metal contraction that occurs during solidification of a casting.

**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 anode 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.

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## Section 3: Physical Requirements of Cast Galvanic Anodes

3.1 Samples for Chemical Analysis and Performance Testing

3.1.1 Representative metal samples shall be taken for chemical analysis at the beginning and end of each heat, except for heats of less than 1,000 kg (2,200 lb), when only one sample shall be taken at the start of each heat. When specified, representative metal samples for performance testing shall be taken near the middle of a pour from a heat.

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

3.1.3 Performance testing on specified samples (Paragraph 3.1.1) shall be conducted in conformance with a standardized potential and capacity determination test, e.g., NACE Standard TM0190,[4] or user-approved equivalent, to prove compliance with agreed criteria.

3.2 Cast Galvanic Anode Identification

3.2.1 Each cast galvanic anode shall be marked with its unique heat and sequence number. For heat-treated anodes, a heat-treatment batch number shall also be provided on each anode.

3.3 Cast Galvanic Anode Weights

3.3.1 Individual cast galvanic anodes of each type and of nominal weights greater than 50 kg (110 lb) shall be within ±3% of the nominal weight or 2 kg (5 lb), whichever is greater.

3.3.2 To confirm compliance with Paragraph 3.3.1, all anodes of nominal weight greater than or equal to 140 kg (310 lb) shall be weighed. For lighter anodes, a minimum of 10% random selected anodes shall be weighed.

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

3.4 Cast Galvanic Anode Dimensions and Straightness

3.4.1 Dimensions shall conform to the following:

3.4.1.1 Cast galvanic anode mean length shall be within ±3% of the nominal length or ±25 mm (1.0 in.), whichever is smaller.

3.4.1.2 Cast galvanic anode mean width shall be ±5% of the nominal mean width.

3.4.1.3 Cast galvanic anode mean depth shall be ±10% of the nominal mean depth.

3.4.1.4 The diameter of cylindrical cast galvanic anodes shall be ±2.5% of the nominal diameter.

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

3.4.3 To confirm compliance with Paragraphs 3.4.1 and 3.4.2, a minimum of 10% of all anodes shall be dimensionally inspected.

3.5 Cast Galvanic Anode Insert Dimensions and Position

3.5.1 Any special provisions needed to make the anode 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 Cast galvanic anode insert location within the anodes shall not deviate from nominal position more than 5% of the nominal anode width and length and

10% of the nominal anode depth. For inserts intentionally close to a surface of the anode material, these designated tolerances may be inappropriate and should be subject to separate agreement.

3.5.3 Cast galvanic anode insert cross-section dimensions shall comply with the appropriate specification for the insert material used.

3.5.4 To confirm compliance with Paragraphs 3.5.1 through 3.5.3, a minimum of 10% of all anodes shall be dimensionally inspected. All dimensions identified by the user as critical shall be inspected for all anodes.

3.6 Cast Galvanic Anode Insert Materials

3.6.1 Cast galvanic anode inserts shall be fabricated from weldable structural steel plates or sections and/or from weldable steel pipe. When insert-to-structure weldability is an issue, special insert materials may be required and shall be specified by the user.

3.6.2 Rimming steels shall not be used.

3.6.3 The carbon equivalent of insert materials shall not exceed 0.41%. The carbon equivalent value ($C_{ev}$) shall be calculated using the formula shown in Equation (1):

$$C_{ev} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \qquad (1)$$

where each element is expressed in weight percent.

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

3.6.4.1 Pipe: API[4] 5L[5] grade B; ASTM[5] A 106[6] grade A or B; ASTM A 53[7] grade B.

3.6.4.2 Plate, bar sections: EN[6] 10025 grade S235 or S275[8]; ASTM A 36 grade A.[9]

3.6.5 For low-temperature applications (below 5°C [41°F]), consideration should be given to the notch toughness of the base material and to the toughness of the material welded to the parent structure.

3.7 Fabrication of Cast Galvanic Anode Inserts by Welding

3.7.1 All fabrication welding of steel cast galvanic anode inserts shall be in conformance with the relevant requirements of AWS[7] D1.1,[10] or both EN 10287[11] and EN 10288,[12] or user-approved equivalents. This compliance shall include qualification of welders, welding procedures, weld inspection, and other listed provisions of the relevant codes.

3.7.2 The level and type of further nondestructive testing inspection, if any, shall be by separate agreement.

3.8 Cast Galvanic Anode Insert Surface Preparation

3.8.1 For aluminum cast galvanic anodes, the steel fabrication to be inserted into the cast galvanic anode shall be prepared by a dry blast-cleaning process to a minimum quality complying with ISO[8] 8501-1[13] SA2½, NACE No. 2/SSPC[9]-SP 10,[14] or user-approved equivalent.

3.8.1.1 Before casting, rust discoloration and/or visible surface contamination shall not be permitted.

3.8.2 For zinc or magnesium anodes, the steel fabrication to be inserted into the cast galvanic anode shall be galvanized to ASTM A 123[15] or BS 729,[16] zinc electroplated to ASTM B 633[17] or BS 1706,[18] or blast cleaned in accordance with Paragraph 8.8.1, or user-approved equivalents.

3.8.2.1 Before casting, rust discoloration and/or visible surface contamination of the zinc-coated or blast-cleaned surface shall not be permitted.

3.9 Surface Irregularities on the Cast Galvanic Anode Casting[19]

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

3.9.2 A shrinkage depression that exposes insert steel shall not be accepted.

3.9.3 Casting surface irregularities shall be fully bonded to the bulk galvanic material.

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

3.9.5 Cold shuts or surface laps shall not exceed a depth of 10 mm (0.4 in.).

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(4) American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005.
(5) American Society for Testing and Materials (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.
(6) European Committee for Standardization (EN), rue de Stassart 36, B-1050 Brussels, Belgium.
(7) American Welding Society (AWS), P.O. Box 251040, Miami, FL 33126.
(8) International Organization for Standardization (ISO), 1 rue de Varembe, Case Postale 56, CH-1121 Geneva 20, Switzerland.
(9) Steel Structures Painting Council (SSPC), 40 24th St., Pittsburgh PA 15222.

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

3.9.7 Except as identified in Paragraph 3.9.6, peening of cracks or other mechanical treatments to conceal casting defects shall not be accepted.

3.9.8 All cast galvanic anodes of each type shall be inspected visually to confirm compliance with Paragraphs 3.9.1 through 3.9.7.

3.10 Cracks in Cast Galvanic Anode Material

3.10.1 With the exceptions stated in Paragraphs 3.10.2 through 3.10.4, anode cracks shall not be cause for anode rejection due to the fact that, even with good foundry practice, particular compositions of cast galvanic anode alloys (notably aluminum-based) suffer a degree of cracking that does not affect performance.[20]

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

3.10.3 Within the section of cast galvanic anode 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 if there are no more than 10 cracks per anode. Small dense cracks shall be considered one crack. Cracks of 0.5 mm (0.02 in.) width or less shall not be included in the crack count. Full circumferential cracks shall not be permitted.

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

3.10.5 All cast galvanic anodes shall be inspected to confirm compliance with Paragraphs 3.10.2 through 3.10.4.

3.11 Cast Galvanic Anode Sections and Internal Defects

3.11.1 The number and method of selection of cast galvanic anodes to be sectioned for detection of internal defects shall be at the specific request of the user, including progressive examination requirements.

3.11.2 Cast galvanic 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 of the cast galvanic anodes, when examined visually without magnification, shall not have more than:

3.11.3.1 Two percent of the sum of the surface area or more than 5% of any one surface as gas holes or porosity.

3.11.3.2 One percent of the sum of the surface area or more than 2% of any one surface as nonmetallic inclusions.

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

3.11.3.4 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 on prior to manufacture.

3.12 Heat Treatment

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

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

3.13 Packing and Shipment

3.13.1 Cast galvanic anodes shall be bundled, strapped, placed on pallets, or individually loaded by an agreed procedure to facilitate unloading and minimize damage to anodes and 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 standard when 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 this standard.

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 cast galvanic anodes, and all anodes not complying with this standard may be rejected.

## Section 4: Manufacturer Documentation

4.1 General

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

4.2 Retained Documentation

4.2.1 Retained documentation shall be available for inspection by the user at the manufacturing plant during the contract period and, subject to reasonable notice, for a period of two years thereafter.

4.2.2 Analysis results produced in accordance with Paragraphs 3.1.2 and 3.1.3 shall be referenced to individual heat numbers and shall form part of the retained documentation.

4.2.3 Individual and total anode contract weights taken in accordance with Paragraph 3.3 shall form part of the retained documentation.

4.2.4 Heat-treatment records (when required) in accordance with Paragraph 3.12.1 shall be referenced to individual batch numbers and shall form part of the retained documentation.

4.2.5 Any electrochemical performance tests[4] (not specified in this standard) undertaken by the manufacturer 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 manufacturer certifying that the cast galvanic anodes comply in all respects with this standard and the purchase order.

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

## References

1. NACE Standard RP0176 (latest revision), “Corrosion Control of Steel Fixed Offshore Platforms Associated with Petroleum Production” (Houston, TX: NACE International).

2. BS 7361 Part 1 (latest revision), “Cathodic Protection” (London, England: BSI).

3. ASM Handbook (latest revision) (Materials Park, OH: ASM International).

4. NACE Standard TM0190 (latest revision), “Impressed Current Test Method for Laboratory Testing of Aluminum Anodes” (Houston, TX: NACE).

5. API Spec 5L (latest revision), “Specification for Line Pipe” (Washington, DC: API).

6. ASTM A 106 (latest revision), “Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service” (West Conshohocken, PA: ASTM).

7. ASTM A 53 (latest revision), “Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless” (West Conshohocken, PA: ASTM).

8. EN 10025 (latest revision), “Hot rolled products of non-alloy structural steels, Technical delivery conditions” (Brussels, Belgium: EN).

9. ASTM A 36 (latest revision), “Standard Specification for Carbon Structural Steel” (West Conshohocken, PA: ASTM).

10. AWS D 1.1 (latest revision), “Structural Welding Code - Steel” (Miami, FL: AWS).

11. EN 10287 (latest revision), “Approval testing of welders” (Brussels, Belgium: EN).

12. EN 10288 (latest revision), “Specification and approval of welding procedures for metallic materials” (Brussels, Belgium: EN).

13. ISO 8501-1 (latest revision), “Visual Assessment of Surface Cleanliness” (Geneva, Switzerland: ISO).

14. NACE No. 2/SSPC-SP 10 (latest revision), “Near-White Metal Blast Cleaning” (Houston, TX USA: NACE, and Pittsburgh, PA: SSPC).

15. ASTM A 123 (latest revision), “Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products” (West Conshohocken, PA: ASTM).

16. BS 729 (latest revision), “Hot Dip Galvanized Coatings on Iron and Steel Articles” (London, England: BSI).

17. ASTM B 633 (latest revision), “Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel” (West Conshohocken, PA: ASTM).

18. BS 1706 (latest revision), “Electroplated Coatings of Cadmium and Zinc on Iron and Steel” (London, England: BSI).

19. D.L. Johnson, “Anode Foundry Production Anomalies,” CORROSION/97, paper no. 468 (Houston, TX: NACE, 1997).

20. P.A. Warnock, “Offshore Sacrificial Anode Design - A Producers View of Limiting Factors for Success,” CORROSION/95, paper no. 305 (Houston, TX: NACE, 1995).