

## TECHNICAL SPECIFICATION

# **Manufacture, Testing and Inspection of Sacrificial Anodes for Deepwater Project Structures and Pipelines, Including Qualification of Manufacturers/Suppliers and Manufacturing Facilities (Based on NACE RP0387, RP0492 and TM0190)**

DEP 37.81.20.31-EPP

February 2006

## DESIGN AND ENGINEERING PRACTICE



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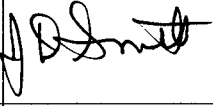

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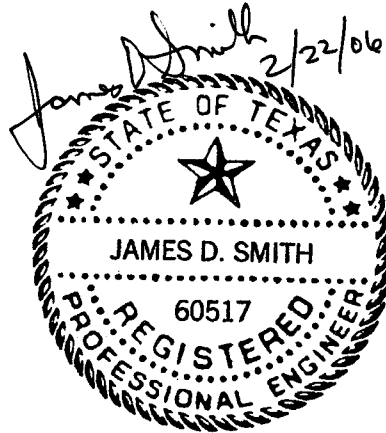
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DOCUMENT CONTROL

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## 1. INTRODUCTION

### 1.1 SCOPE

This DEP specifies minimum requirements for manufacture, testing, and inspection of sacrificial anodes for deepwater project structures and pipelines. Also included are requirements for prequalification of sacrificial anode manufacturers/suppliers and manufacturing facilities. Typical applications of sacrificial anodes covered by this DEP as applied to deepwater projects are: structures, pipelines, top-tensioned and steel catenary risers, flowline jumpers, sleds, piles, tendons, subsea trees and manifolds, umbilical terminations, hull external surfaces and appurtenances, hull ballast tanks, and mooring equipment. This DEP is based on NACE RP0387, RP0492 and TM0190.

This DEP is a revision and combination of SIEP Supplement 5 Rev 3 dated September 2000, SIEP Supplement 9 Rev 2 dated July 1992, SIEP Supplement 21 dated September 1990, SIEP Supplement 39 Rev 0 dated September 1999 and EPP-PS-204 Rev 1 dated January 2004; see (1.6) for a summary of the main changes.

### 1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This DEP is intended for use in procurement and manufacture of sacrificial anodes for deepwater projects such as structures, pipelines, top-tensioned and steel catenary risers, flowline jumpers, sleds, piles, tendons, subsea trees and manifolds, umbilical terminations, hull external surfaces and appurtenances, hull ballast tanks, and mooring equipment.

When DEPs are applied, a Management of Change (MOC) process should be implemented. This is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

### 1.3 GENERAL DEFINITIONS

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies coating materials, equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

#### 1.4 SPECIFIC DEFINITIONS

<b>QP</b>	Quality Plan. Reference ISO 9000 Paragraphs 2.7.2.b and 3.7.5. Shall include inspection and test requirements and provide columns or spaces for the Principal and Contractor, if applicable, to indicate 3rd-party inspector inspection activities, e.g. monitor, witness, hold points, etc. for the operations to be undertaken. It is required that the QP be approved by the Principal and Contractor, if applicable.
<b>MPS</b>	Manufacturing Procedure Specification. Reference ISO 9000 Paragraphs 2.7.2.c, 2.7.2.e, 3.4.5 and 3.7.3. The MPS shall clearly define the sequence of operations and process controls to be implemented at each manufacturing step as well as specifically annotate any procedures, processing parameters, or requirements that deviate from this DEP. It is required that the MPS be approved by the Principal and Contractor, if applicable.
<b>AFC drawings</b>	Approved for Construction drawings.
<b>MAST</b>	Mean anticipated service temperature.
<b>OES</b>	Optical emission spectroscopy.
<b>AA</b>	Atomic absorption.
<b>ICP</b>	Inductively coupled plasma.
<b>DCP</b>	Direct-current plasma.
<b>SCE</b>	Saturated calomel electrode.
<b>LUGGIN PROBE</b>	Also known as a Luggin-Haber capillary. A device used in measuring the potential of an electrode with a significant current density imposed on its surface. The probe minimizes the IR drop that would otherwise be included in the measurement and without significantly disturbing the current distribution on the specimen. Available as a purchase item from scientific equipment companies specializing in the design and manufacture of electrochemical instrumentation.
<b>DFT</b>	Dry film thickness.
<b>AWG</b>	American wire gauge.
<b>HMWPE</b>	High molecular weight polyethylene.

#### 1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in parentheses. Other documents referenced by this DEP are listed in (8.).

1.6 SUMMARY OF MAIN CHANGES

This DEP is a revision and combination of SIEP Supplement 5 Rev 3 dated September 2000, SIEP Supplement 9 Rev 2 dated July 1992, SIEP Supplement 21 dated September 1990, SIEP Supplement 39 Rev 0 dated September 1999 and EPP-PS-204 Rev 1 dated January 2004. The following are the main, non-editorial changes.

Old section	New section	Change
		Due to massive reformatting required to combine and convert SIEP Supplement 5 Rev 3 dated September 2000, SIEP Supplement 9 Rev 2 dated July 1992, SIEP Supplement 21 dated September 1990, SIEP Supplement 39 Rev 0 dated September 1999 and EPP-PS-204 Rev 1 dated January 2004 into the DEP format as well as bring them up to date with changes to requirements and referenced documents, the entire document should be considered as "changed". Hence, no effort is made in this section to identify the main, non-editorial changes.

1.7 COMMENTS ON THIS DEP

Comments on this DEP may be sent to J.D. Smith at [james.smith@shell.com](mailto:james.smith@shell.com) or to M.W. Walsh at [mike.walsh@shell.com](mailto:mike.walsh@shell.com).

## **2. GENERAL**

### **2.1 QUALITY REQUIREMENTS, QP AND MPS**

The anode Manufacturer/Supplier shall implement an ISO 9001 Quality Management System or equivalent as approved by the Principal and Contractor, if applicable. A QP and an MPS shall be specifically developed for each order and shall be approved by the Principal and Contractor, if applicable prior to commencement of manufacturing operations.

### **2.2 CONTRACTOR PROCUREMENT SPECIFICATION AND APPROVAL BY THE PRINCIPAL AND CONTRACTOR, IF APPLICABLE, OF THE ANODE MANUFACTURER/SUPPLIER AND MANUFACTURING FACILITIES**

This DEP may be used directly for procurement or, at the Contractor's option, the Contractor may prepare a detailed Procurement Specification which is compatible with the Contractor's document format and quality system. As a minimum, the Contractor's Procurement Specification shall incorporate all requirements contained herein and shall require approval by the Principal. The anode Manufacturer/Supplier and manufacturing facilities, as identified in the MPS, shall require approval by the Principal and Contractor, if applicable.

### **2.3 MEAN ANTICIPATED SERVICE TEMPERATURE (MAST)**

The default value for the mean MAST shall be 4.4°C (40°F) unless otherwise specified in project documents or on AFC drawings.

### **2.4 ADDITIONAL REQUIREMENTS**

Anode alloy type, configuration, i.e. flush-mount (Appendix 1), stand off (Appendix 2) or bracelet (Appendix 3), dimensions, net alloy and gross anode weight and any other requirements not covered specifically by this DEP will be addressed in project documents or on AFC drawings and subsequently included in the anode procurement documents. If such additional requirements are specified, they shall be included in the MPS.

### **2.5 UNDERLYING INDUSTRY SPECIFICATION**

Anodes shall be manufactured and tested in accordance with NACE RP0387 or NACE RP0492, as applicable, and NACE TM0170. Modifications, specific deletions or identifications of non-applicable parts, and additional requirements to NACE RP0387, RP0492 and TM0190 are given herein. Some statements and/or required values in NACE RP0387, RP0492 and TM0190 are repeated in this DEP for clarity or special emphasis; however, unless specifically deleted/waived by this DEP, all provisions of NACE RP0387 or NACE RP0492, as applicable, and NACE TM0170 shall apply. Alternative underlying industry specifications may be approved by Principal and Contractor, if applicable, on a case-by-case basis. In cases where there are conflicting requirements between this DEP and referenced industry specifications, the requirements of this DEP shall supersede. The underlying industry specification(s) shall be identified in the MPS.

2.6 ANODE MANUFACTURER/SUPPLIER AND ANODE MANUFACTURING FACILITIES  
PREQUALIFICATION

Unless otherwise specified in project documents or on AFC drawings, the anode Manufacturer/Supplier and manufacturing facilities shall successfully complete a prequalification process in accordance with (Appendix 5) and obtain approval from the Principal and Contractor, if applicable, prior to full-scale anode production commencement for an actual order.

Additionally, unless otherwise specified in project documents or on AFC drawings, the anode Manufacturer/Supplier shall produce a test anode for approval by the Principal and Contractor, if applicable, prior to commencement of full production when the casting is to take place using a new mold design or size. The test anode shall be manufactured utilizing the same anode alloy type, manufacturing process, molds, furnaces, etc. as to be used for production anodes. The anode Manufacturer/Supplier shall verify the dimension and weight requirements of the anode produced from the the new mold design or size. Additionally, the test anode shall be sectioned and examined for internal defects in compliance with NACE RP0387 Para. 3.11 or NACE RP0492 Para. 3.11, as applicable. Approval by the Principal and Contractor, if applicable, shall then be obtained prior to commencement of full production.

2.7 TRACEABILITY

Traceability of each anode and piece of anode core material shall be maintained with respect to heat number and Manufacturer/Supplier. Failure to provide verification of anode or core material traceability shall result in anode rejection.

2.8 INFORMATION TO BE CONVEYED TO ANODE MANUFACTURER/SUPPLIER

(Table 1) provides a summary of information to be conveyed to the anode Manufacturer/Supplier in the anode procurement documents in order for the anode Manufacturer/Supplier to be able to properly supply product in compliance with this DEP.

2.9 SUMMARY OF DOCUMENT SUBMITTALS REQUIRING APPROVAL BY THE PRINCIPAL AND CONTRACTOR, IF APPLICABLE

Various documents are identified by this DEP as requiring submittal to the Principal and Contractor, if applicable, for approval. Documents shall be submitted to the Principal and Contractor, if applicable, in a timely manner as specified in project documents, or otherwise by Principal or Contractor, as applicable, in order to allow for the formal review and approval process. (Table 2) provides a summary of required document submittals.

2.10 PREPRODUCTION MEETING

If required by the Principal or Contractor, as applicable, a preproduction meeting shall be held at the anode Manufacturer/Supplier's manufacturing facility prior to commencement of manufacture in order to discuss and assure common understanding of the QP and MPS in relation to the order. This preproduction meeting, when required, shall be a designated Hold Point in the QP.

2.11 POST-JOB PRODUCTION HISTOGRAMS

If required by the Principal or Contractor, as applicable, a summary report of results containing histograms of chemical, electrochemical and dimensional properties measured and recorded, as required in the QP and MPS, shall be supplied by the anode Manufacturer/Supplier at the completion of the order.

### **3. ANODE CHEMICAL PROPERTIES AND TESTING**

#### **3.1 ANODE CHEMICAL COMPOSITION**

The anode alloy shall be Aluminum-Zinc-Indium (Al-Zn-In) or Zinc (Zn) as specified in project documents or on AFC drawings. Alloy chemistry shall conform to those listed below (Table 3a or 3b). The specified composition shall be documented in the MPS.

#### **3.2 CHEMICAL ANALYSIS METHODS**

Chemical analyses shall be determined by OES, AA, ICP, DCP or other techniques as approved by the Principal and Contractor, if applicable, that have been calibrated against traceable standards. The specific chemical analysis technique to be utilized shall be documented in the MPS. A written procedure for conducting chemical analysis shall be referenced in the MPS and shall be approved by the Principal and Contractor, if applicable.

#### **3.3 COMPANY SUPPLIED CHEMICAL ANALYSIS CONTROL STANDARDS**

The anode Manufacturer/Supplier shall analyze the chemical composition of a chemical analysis control standard supplied by the Principal for the purpose of confirming chemical analysis quality control prior to conducting the chemical analysis for each heat of anode alloy. Analytical procedures and standards identical to those used on production anodes shall be utilized in the chemical analysis of this standard and the results reported on the applicable anode alloy data sheet. Necessary adjustments to the chemical analysis equipment or technique shall be made in order to achieve results on the standard within the tolerances given in (Table 4).

#### **3.4 RAW (BULK) ALUMINUM AND ZINC MILL CERTIFICATES**

Raw (bulk) aluminum and zinc alloy mill certificates shall be available for inspection in order to verify aluminum and zinc alloy purity. Requirements for (bulk) aluminum and zinc alloy purity shall be documented in the MPS. Contaminant levels in raw (bulk) aluminum and zinc shall not exceed the allowable levels given in (Table 3a or 3b), as applicable, for the anode alloy.

#### **3.5 FREQUENCY OF CHEMICAL ANALYSIS**

Chemical analysis shall be performed on three representative samples of each production heat. Samples for analysis shall be collected pre-pour, mid-pour and at end of pour for each heat. Alternative chemical analysis sampling plans for small heats may be approved by the Principal and Contractor, if applicable, as detailed in the MPS. The sampling plan shall be described and a written sampling procedure shall be referenced in the MPS. For each of the three chemical analyses, concentration of each element shall be within the applicable range given in (Table 3a or 3b), as applicable. An acceptable pre-pour analysis shall be obtained prior to casting anodes from each heat.

If any elemental concentration of a given heat fails to meet the requirements for the mid-pour or end of pour analyses, retests may be conducted on two additional representative samples cut from production anodes cast after the mid-pour analysis of the same heat. Anodes to be sampled shall be approved by the 3<sup>rd</sup>-party inspector if 3<sup>rd</sup>-party inspection has been required by the Principal or Contractor, if applicable. If both of the retests meet the criteria, all anodes of the heat shall be deemed acceptable. If either of the retests fails to meet the criteria, all anodes of the heat shall be rejected.

3.6 CHEMICAL ANALYSIS DOCUMENTATION

Results of the pre-pour "standardization" on the chemical analysis standard supplied by the Principal and the three chemical analyses conducted by the anode Manufacturer/Supplier for each heat shall be provided on the applicable Anode Alloy Data Sheet attached to this DEP, or equivalent as approved by the Principal and Contractor, if applicable, for each heat along with a statement describing the analysis technique (i.e. OES, AA, etc.). Each chemical analysis result shall be identified as to whether it was taken pre-pour, mid-pour, or end-of-pour.

#### 4. ANODE ELECTROCHEMICAL PROPERTIES AND TESTING

##### 4.1 ELECTROCHEMICAL TEST METHOD (NACE TM0190)

Electrochemical laboratory tests to evaluate anode potential and current capacity shall be conducted on at least one anode specimen cast after the mid-point pouring of each heat in accordance with NACE TM0190 unless specific deviations or modifications are prescribed in this DEP. Some statements or issues raised in NACE TM0190 are repeated or clarified herein for clarity or special emphasis.

##### 4.1.1 SAMPLES

NACE TM0190 Section 5 shall be replaced with the following.

The electrochemical property tests shall be performed on a representative sample of each production heat of anode alloy, unless otherwise approved by the Principal and Contractor, if applicable, as detailed in the MPS. The test sample shall be cut from a full size anode or anode segment (i.e. not a separately cast "pencil" or "mushroom" type specimen as is typically used by anode foundries), which was cast after the mid-point pouring of each heat in such a way as to leave a portion of as-cast surface for electrochemical testing. Prior to testing, the specimen shall have received identical treatments as given to the production anodes, except for a gentle water and/or acetone wash. Contrary to NACE TM0190 Section 5, sample surfaces to be electrochemically tested shall be as-cast and shall not be machined, shall not be dipped in the anode precleaning solution and shall not be dipped in the concentrated nitric acid solution. The test shall be performed on as-cast surfaces only, with a minimum exposed surface area of 2580-3226 mm<sup>2</sup> (4.0-5.0 in<sup>2</sup>). All saw cut surfaces shall be masked off with a suitable dielectric material as approved by the Principal and Contractor, if applicable, such that they do not influence test results and only as-cast surfaces are exposed to the test environment. Micro Products (Tobler Division) - Micro Super XP-2000 Stop-Off Lacquer is approved by the Principal for this purpose. Finally, in order to reduce error in electrochemical capacity measurement, overall sample weight shall be ≤ 150 g (5.3 Oz). Electrochemical test sample configuration and dimensions shall be approved by the Principal and Contractor, if applicable, as described in the MPS.

Note: Micro Super XP-2000 Stop-Off Lacquer is available from Tolber Chemical, 220 West 5th St., Hope, AK, 71801, USA [www.tolber.com](http://www.tolber.com)

##### 4.1.2 CURRENT DENSITY

Electrochemical tests shall be performed using a continuous anodic current density of 6.2 A/m<sup>2</sup> (4.0 mA/in<sup>2</sup>) based on the exposed as-cast sample surface area in accordance with NACE TM0190. Current shall be held constant throughout the test period using a constant-current DC power supply.

##### 4.1.3 SOLUTION

Electrochemical tests shall be conducted in either a non-agitated or gently flowing synthetic seawater test solution conforming to NACE TM0190 Para. 4.2. The test solution shall be exposed to air and, in contrast to NACE TM0190 Para. 2.2, maintained at MAST ± 3C° (MAST ± 5F°) for the duration of the test. Test solution pH and temperature shall be measured and recorded each day of the test (except weekends and holidays) and reported on the applicable Anode Alloy Data Sheet. The test solution shall be changed if pH becomes more acidic than pH 5 or more basic than pH 9, or after 7 days, whichever comes first. Changes to the test solution (date and time) shall be annotated in the applicable Anode Alloy Data Sheet.

##### 4.1.4 DURATION

The duration of the electrochemical tests shall be a minimum of 14 days (336 hours) in accordance with NACE TM0190.

#### 4.1.5 PROCEDURE

A written electrochemical test procedure describing the specific test set-up, method of making the required measurements, and sample cleaning methods shall be referenced by the MPS and shall be approved by the Principal and Contractor, if applicable.

#### 4.2 CLOSED CIRCUIT POTENTIAL TESTS

4.2.1 Closed Circuit potential measurements shall be determined on the test sample described in (4.1.1).

4.2.2 For the duration of the electrochemical test, potential measurements (to the nearest mV) shall be taken and recorded a minimum of twice daily each day of the test (except weekends and holidays). At least two of each day's potential measurements shall be a minimum of 6 hours apart. Should the 14th day fall on a weekend or holiday the test duration shall be extended to include two readings (a minimum of 6 hours apart) on the next workday.

4.2.3 Potential measurements shall be performed using a high impedance voltmeter (greater than 1 MΩ) and laboratory grade SCE working reference electrodes maintained at 24°C ± 3°C (75°F ± 5°F). A laboratory grade SCE "master" reference electrode shall be utilized to ensure accuracy of "working" electrodes. A "master" to "working" (cell to cell) electrode reading shall be taken and recorded at least twice each week for each "working" electrode and reported in the certification documents. If the "master" to "working" electrode reading exceeds ± 5 mV, the defective "working" electrode shall be replaced. "Working" electrode replacement shall be annotated (date and time) in the certification documents. If after replacement of the "working" electrode the difference still exceeds 5mV, it shall be investigated whether the replacement "working" electrode is truly deficient or whether the "master" electrode has become deficient. All potential measurements shall be performed with the reference electrode connected to the common (or negative) meter terminal.

4.2.4 Potential measurements shall be determined without disturbing the anode surface film. Each potential measurement shall be determined individually using a reference half-cell directly or a Luggin probe, following the method below:

Potential measurements recorded shall be representative of the average surface potential of the exposed surface. The reference half-cell or Luggin probe shall be held a distance of 12.7-19.1 mm (0.5-0.75 in) from the sample surface. Measurements should be made so that the exposed surface is covered in 645-1290 mm<sup>2</sup> (1-2 in<sup>2</sup>) sections. In no case are active pits to be probed closely and the results included in the recorded average potential. Fixed reference half-cell electrodes are encouraged in order to eliminate data scatter associated with operator manipulation of the reference half-cell tip or Luggin capillary tip.

#### 4.2.5 CLOSED CIRCUIT POTENTIAL TEST – ACCEPTANCE CRITERIA

##### 4.2.5.1 AL-ZN-IN ANODES

Closed circuit potential test acceptance values for Al-Zn-In anode alloys are given in (Table 5a).

##### 4.2.5.2 ZN ANODES

Closed circuit potential test acceptance values for Zn anode alloys are given in (Table 5b).

- 4.2.6 Results of all (i.e. two daily measurements each day of the test) closed-circuit potential measurements and checks against the stated acceptance criteria shall be documented on the applicable Anode Alloy Data Sheet for each heat.
- 4.3 CURRENT CAPACITY TEST
- 4.3.1 Current capacity shall be determined on the test sample described in (4.1.1) during the electrochemical test.
- 4.3.2 Current Capacity tests shall be conducted using the weight-loss method. These weight-loss measurements shall be determined with an analytical balance having a resolution of 0.0001 g (0.1 mg) or better.
- 4.3.3 Initial weight, current passed, test duration and final weight of each test sample shall be measured and reported in the certification documentation.
- 4.3.3 Samples shall be cleaned and dried before post-test values are determined. Contrary to NACE TM0190 Paragraph 7.11, samples shall not be immersed in the anode post-cleaning solution. All corrosion product shall be removed by bristle brushing under running water. Dried samples shall be viewed under low power magnification (10X) to verify complete removal of corrosion products. Additional cleaning shall be conducted until complete removal of corrosion products is observed. A more aggressive cleaning technique, e.g. water blasting at approximately 69 bar (1000 psi), may be used with prior approval by the Principal and Contractor, if applicable. Samples shall be weighed within 2 hours of cleaning.
- 4.3.4 An electronic or copper coulometer shall be used to determine cumulative current. An electro-mechanical device or data-logging device may be used with prior approval by the Principal and Contractor, if applicable. Calibration documentation shall be supplied in the certification documents.
- 4.3.5 Weight-loss current capacity shall be calculated in accordance with NACE TM0190 Para. 8.1 and reported for each heat.
- 4.3.6 CURRENT CAPACITY TEST – ACCEPTANCE CRITERIA  
The weight-loss current capacity of each heat shall be as given in (Table 6).
- 4.3.7 Results of the current capacity test and checks against the stated acceptance criteria shall be documented on the applicable Anode Alloy Data Sheet for each heat.
- 4.4 RETESTS  
If a given heat fails any of the electrochemical test criteria set forth in (4.2) or (4.3), retests may be conducted on two additional representative samples cut from randomly selected production anodes of that heat. At least one of the samples shall be taken from a production anode cast after the mid-pour of the heat. Anodes to be sampled shall be approved by the 3<sup>rd</sup>-party inspector if 3<sup>rd</sup>-party inspection has been required by the Principal or Contractor, if applicable. If both of the retests meet all of the criteria, all anodes of the heat shall be deemed acceptable. If either of the retests fails to meet the criteria, all anodes of the heat shall be rejected. The production anode components used for the retests shall not be considered part of the materials ordered.

**5. "OFF-THE-SHELF" ANODES**

If the anode Manufacturer/Supplier wishes to qualify "off-the-shelf anodes", then all of the tests required by (3.) and (4.) shall be conducted on samples cut from three representative production anodes from the heat to be qualified. Anodes to be sampled shall be randomly selected and shall be approved by the 3<sup>rd</sup>-party inspector if 3<sup>rd</sup>-party inspection has been required by the Principal or Contractor, if applicable. If all test results meet the criteria specified in (3.) and (4.) then the remaining anodes from the heat will also be considered to be qualified.

**6. ACCEPTANCE**

Data shall be reported on a data sheet of a form approved by the Principal and Contractor, if applicable. The appropriate anode core steel mill certificate(s) that corresponds with the anode heat produced shall be attached to the data sheet. The anode Manufacturer/Supplier shall verify the information contained on the data sheet by signing and dating. If 3<sup>rd</sup>-party inspection has been required by the Principal or Contractor, if applicable, then the 3<sup>rd</sup>-party inspector shall also sign and date the data sheet following evaluation and approval, prior to shipment of any anode. The data sheet shall be included in the certification documents supplied to the Principal and Contractor, if applicable.

**7. ANODE SPECIMENS FOR TESTING BY THE PRINCIPAL OR 3<sup>RD</sup>-PARTY LABORATORY**

The anode Manufacturer/Supplier shall retain a specimen of anode cut or machined from the same anode selected for electrochemical testing by the anode Manufacturer/Supplier from each heat for possible testing by the Principal or a 3<sup>rd</sup>-party laboratory. The specimen shall be held by the anode Manufacturer/Supplier for a period of two (2) years. The Principal or Contractor, if applicable, may request the specimen at anytime during the two (2) year period. Following the two (2) year period the anode Manufacturer/Supplier shall seek instruction from the Principal and Contractor, if applicable, in writing prior to disposal of the specimen. Failure of Principal and Contractor, if applicable, to respond within 30 days shall be interpreted by the anode Manufacturer/Supplier as approval to dispose of the specimen.

The specimen shall have the anode manufacturer's name, trademark or symbol and heat number clearly stamped on the cut or machined surface. Care shall be exercised to prevent cold working or other damage to the cast surfaces of the specimen. Specimens and copies of all certification documents shall be delivered to the Principal and Contractor, if applicable.

The specimen surface areas shall be a minimum of 3226 mm<sup>2</sup> (5 in<sup>2</sup>) of as-cast surface for flush-mount and stand-off anodes unless otherwise stated by the Principal and Contractor, if applicable.

Bracelet anode specimens shall be a minimum of 152.4 mm (6 in) wide by 152.4 mm (6 in) long (of as-cast surface) by designated anode thickness.

## 8. REFERENCES

In this DEP, reference is made to the following publications:

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
  2. The DEPs and most referenced external standards are available to Shell staff on the SWW (Shell Wide Web) at <http://sww05.europe.shell.com/standards/>.

### ASTM STANDARDS

Standard Practice for the Preparation of Substitute Ocean Water	ASTM D1141
Standard Specification for Cast and Wrought Galvanic Zinc Anodes	ASTM B418
Standard Specification for Carbon Structural Steel	ASTM A36
Standard Specification for Structural Steel for Ships	ASTM A131
Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products	ASTM A123
Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)	ASTM A385
Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service	ASTM A106
Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless	ASTM A53
Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes	ASTM A500
Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates	ASTM A283
Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel	ASTM A510

*Issued by:*

*American Society for Testing and Materials (ASTM International)  
100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 USA*

### API STANDARDS

Specification for Line Pipe	API SPEC 5L
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*Issued by:*

*American Petroleum Institute, Order Desk, 1220 L Street, N.W.,  
Washington, DC 20005-4070*

## ISO STANDARDS

Quality management systems – Fundamentals and vocabulary	ISO 9000
Quality management systems – Requirements	ISO 9001
Steel and steel products - Inspection documents	ISO 10474
Structural Steels - Plates, Wide Flats, Bars, Sections and Profiles	ISO 630
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 8501-1
Hot Dip Galvanized Coatings on Fabricated Iron and Steel Articles - Specifications and Test Method	ISO 1461
Metallic Coatings - Electroplated Coatings of Zinc on Iron or Steel	ISO 2081
Petroleum and Natural Gas Industries - Steel Pipe for Pipelines - Technical Delivery Conditions - Part 1: Pipes of Requirement Class A	ISO 3183-1
Petroleum and Natural Gas Industries - Steel Pipe for Pipelines - Technical Delivery Conditions - Part 2: Pipes of Requirements Class B	ISO 3183-2
Petroleum and Natural Gas Industries - Steel Pipe for Pipelines - Technical Delivery Conditions - Part 3: Pipes of Requirements Class C	ISO 3183-3
Hot Finished Structural Hollow Sections of Non-Alloy and Fine Grain Structural Steels Part 1: Technical Delivery Requirements	EN 10210-1
Non-alloy steel wire rod for conversion to wire Part 2: Specific requirements for general purpose wire rod	ISO 16120-2
Non-alloy steel wire rod for conversion to wire Part 4: Specific requirements for wire rod for special applications	ISO 16120-4

*Issued by:*

*International Organization for Standardization  
Case postale 56, 1211 Geneva 20, Switzerland*

## EUROPEAN STANDARDS

Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels	EN 10025-2
Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels	EN 10025-3
Hot rolled products of structural steels - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels	EN 10025-4

*Issued by:*

*European Committee for Standardization, Management Centre:  
rue de Stassart, 36 B-1050 Brussels*

**JAPANESE INDUSTRIAL STANDARDS**

Rolled steels for welded structure

G 3106

*Issued by:*

*Japanese Standards Association, 4-1-24, Akasaka, Minato-ku,  
Tokyo, 107-8440 Japan*

**NACE INTERNATIONAL STANDARDS**

Impressed Current Laboratory Testing of Aluminum  
Alloy Anodes

TM0190-98

Metallurgical and Inspection Requirements for Cast  
Sacrificial Anodes for Offshore Applications

RP0387-99

Metallurgical and Inspection Requirements for  
Offshore Pipeline Bracelet Anodes

RP0492-99

*Issued by:*

*NACE International, P.O. Box 218340, Houston, TX 77218-8340*

**Table 1 Information to be conveyed to anode Manufacturer/Supplier**

MAST, if different than default of 4.4°C (40°F)
Anode alloy type
Anode configuration type, i.e. flush-mount, stand-off, bracelet
Anode dimensions or AFC drawing
Anode net alloy and gross anode weight
3 <sup>rd</sup> -party inspection requirements
If, for bracelet anodes, bonding cables are required and whether they shall be attached to the anode core by the anode Manufacturer/Supplier
Any other requirements not covered specifically by this DEP

**Table 2 Document submittals requiring approval by the Principal and Contractor, if applicable**

	Required Timing of Document Submittal <sup>(1)</sup>
Anode Manufacturer/Supplier's Quality Plan (QP)	
Anode Manufacturer/Supplier's Manufacturing Procedure Specification (MPS)	
Contractor's procurement specification, if applicable	
Anode drawing (unless AFC Drawing supplied by Principal or Contractor, if applicable, is to be used)	
Core welding procedure specifications (WPS's)	
Written procedure for conducting chemical analysis	
Electrochemical test sample configuration (drawing) and dimensions	
Electrochemical test procedure describing the specific test set-up, method of making the required measurements, and sample cleaning methods	
Data sheet form	
Written dimensional inspection plan	
Written procedure for the determination of anode-to-core electrical resistance	
Written procedure for the surface preparation and painting process, including repairs (for flush-mount and bracelet anodes only)	
Written bonding cable attachment procedure, if applicable	

Note: There is a basic requirement that these documents all be approved by the Principal and Contractor, if applicable, prior to the commencement of anode manufacture; however, the responsible Principal or Contractor, if applicable, project staff will fill in this column with the precise requirements, e.g. 2 weeks after contract award, etc. that are deemed necessary to meet project schedule.

**Table 3a Al-Zn-In Anode Chemical Composition**

<b>Aluminum-Zinc-Indium (Al-Zn-In) Alloy</b>		
<b>Element</b>	<b>Minimum (wt %)</b>	<b>Maximum (wt %)</b>
Iron (Fe)		0.060
Zinc (Zn)	4.75	5.75
Copper (Cu)		0.0030
Silicon (Si)	0.08	0.12
Indium (In)	0.016	0.020
Cadmium (Cd)		0.0020
Others, Each		0.020
Others, Total		0.050
Aluminum	93.99	95.15

**Table 3b Zn Anode Chemical Composition (Conforms to ASTM B 418 Type 1)**

<b>Zinc (Zn) Alloy</b>		
<b>Element</b>	<b>Minimum (wt %)</b>	<b>Maximum (wt %)</b>
Aluminum (Al)	0.1	0.5
Cadmium (Cd)	0.025	0.07
Iron (Fe)		0.005
Lead (Pb)		0.006
Copper (Cu)		0.005
Others, Total		0.10
Zinc (Zn)	99.31	99.88

**Table 4 Control Sample Tolerances**

Element	Si	Fe	Cu	Zn	Cd	In
Acceptance Limit $\pm$ (wt%)	0.003	0.003	0.0004	0.10	0.0003	0.002

**Table 5a Acceptance Criteria for Al-Zn-In Anodes**

<b>Period (Days)</b>	<b>Potential Criteria (Average Daily)</b>
2 <sup>nd</sup> thru last	Equal to or more negative than -1070 mV <sup>(1)</sup>
3 <sup>rd</sup> thru last	Equal to or more negative than -1030 mV <sup>(1)</sup>
10 <sup>th</sup> thru last	Positive shift less than 5 mV/day. Average potential ≤ 15 mV more positive than average potential value of 6 <sup>th</sup> thru 11 <sup>th</sup> days.

Note 1 Potential measured vs. SCE maintained at 24°C ± 3C° (75°F ± 5F°)

**Table 5b Acceptance Criteria for Zn Anodes**

<b>Period (Days)</b>	<b>Potential Criteria (Average Daily)</b>
2 <sup>nd</sup> thru last	Equal to or more negative than -1020 mV <sup>(1)</sup>
3 <sup>rd</sup> thru last	Equal to or more negative than -1010 mV <sup>(1)</sup>
10 <sup>th</sup> thru last	Positive shift less than 5 mV/day. Average potential ≤ 15 mV more positive than average potential value of 6 <sup>th</sup> thru 11 <sup>th</sup> days.

Note 1 Potential measured vs. SCE maintained at 24°C ± 3C° (75°F ± 5F°)

**Table 6      Acceptance Criteria for Weight-Loss Current Capacity Test**

<b>Type</b>	<b>Current Capacity</b>
Al-Zn-In	$\geq 2425$ A·hr/kg (1100 A·hr/lb)
Zn	$\geq 760$ A·hr/kg (345 A·hr/lb)

## APPENDIX 1 FLUSH MOUNTED ANODES

### A1.1 INTRODUCTION

This Appendix defines the minimum requirements specific to flush-mounted anodes in addition to (1.) thru (7.) of this DEP. Typical uses for these anodes would be on offshore structures, floating structure hulls, ballast tanks, mooring system wire-rope sockets and connecting hardware, and subsea equipment. Flush-mounted anodes shall be manufactured and inspected in accordance with NACE RP0387 unless specific deviations or modifications are prescribed in this appendix. Some statements or issues raised in NACE RP0387 are repeated or clarified herein for clarity or special emphasis.

### A1.2 ANODE CORES

#### A1.2.1 Core Material Specification

NACE RP0387 Para. 3.6.4 shall be replaced by the following.

Unless otherwise specified in project documents or on AFC drawings, anode core materials shall be weldable structural steel in compliance with one of the following, or equivalent, as approved by the Principal and Contractor, if applicable:

ASTM A36

ASTM A131 Grades A, B, CS, D, DS, E

JIS G 3106 Grade SM400

EN 10025-2 Grades E295, S275

EN 10025-3 Grade S275

EN 10025-4 Grade S275

ISO 630 Grades E 275

Compliance with the following may be substituted for NACE RP0387 Para. 3.6.3 if desired by the anode Manufacturer/Supplier or if specified in project documents or on AFC drawings.

Anode core materials shall have a  $P_{cm} \leq 0.23$  where:

$$P_{cm} = C + (Si/30) + [(Mn + Cu + Cr)/20] + (Ni/60) + (Mo/15) + (V/10) + (5B)$$

Note: All elements in wt.%

The following values shall be assumed for any of the elements in the  $P_{cm}$  formula that have not been reported on the mill certificate:

$$Si = 0.35, Mn = 1.2, Cu = 0.25, Cr = 0.10, Ni = 0.10, Mo = 0.05, V = 0.08, B = 0.0005$$

#### A1.2.2 Core Material Mill Certificate

The core material Manufacturer/Supplier's mill certificates shall be included in the certification documentation. These certificates shall show heat number, chemical analysis, and tensile properties and shall comply with ISO 10474 Test Report Type 3.1.B as a minimum.

### A1.2.3 Core Construction

Procured anode core material shall be splice free and shall be without welds made by the core material Manufacturer/Supplier.

The anode Manufacturer/Supplier shall maintain anode core material traceability relative to the anode production heat numbers.

Fabrication welding of cores shall be in accordance with written welding procedure specifications (WPS's) for welding anode cores by the anode Manufacturer/Supplier or his welding subcontractor shall be in compliance with NACE RP0387 Para. 3.7 and shall be approved by the Principal and Contractor, if applicable, and referenced in the MPS. All anode core welds shall be visually inspected to meet AWS D1.1 requirements for static structural welds.

### A1.2.4 Core Surface Preparation

#### A1.2.4.1 Cores for Al-Zn-In Anodes

As per NACE RP0387 Para. 3.8.1.

#### A1.2.4.2 Cores for Zinc Anodes

As per NACE RP0387 Para. 3.8.2 except that the following, or equivalent, as approved by the Principal and Contractor, if applicable, shall be added to the list of acceptable galvanizing standards:

ISO 1461

ISO 2081 Classification Code Fe/Zn 12 or Fe/Zn 25

### A1.2.5 Core Dimensions, Configuration and Positioning

As per NACE RP0387 Para. 3.5. Additionally, the method utilized to ensure proper anode core positioning in the mold during anode casting shall be described in the MPS.

## A1.3 ANODE FABRICATION

### A1.3.1 Weight

As per NACE RP0387 Para. 3.3.

### A1.3.2 Dimensions and straightness (bowing)

As per NACE RP0387 except that the straightness (bowing) criterion expressed in NACE RP0387 Para. 3.4.2 shall be tightened to 1%.

### A1.3.3 Exposed Core

There shall be no evidence of exposed core on any other anode surface except where the core exits the anode.

## A1.4 CASTING DEFECTS

An inspection of the physical appearance and workmanship of each anode shall be performed after the anodes have cooled to ambient temperature in order to verify compliance with NACE RP0387 Para. 3.9 and 3.10. The following additional criteria shall also apply.

- A1.4.1 In addition to the criterion stated in NACE RP0387 Para. 3.9.1, cavities shall not exceed 9.5 mm (0.375 in) in depth and 75.2 mm (3 in) in surface dimension when measured with a straight edge placed across the anode.
- A1.4.2 In addition to the depth criterion stated in NACE RP0387 Para. 3.9.4, cold shuts or surface laps shall not extend over a total length of 150 mm (6 in).
- A1.4.3 In addition to the criteria stated in NACE RP0387 Para. 3.10, there shall be no cracks which intersect, or can be projected to intersect other cracks or the anode core, in such a manner that spalling or loss of anode alloy could result.
- A1.5 ANODE-TO-CORE ELECTRICAL RESISTANCE
- Anode-to-core electrical resistance shall be measured for each anode and shall be  $\leq 1 \text{ m}\Omega$ . A written procedure for the determination of anode-to-core electrical resistance shall be referenced by the MPS and approved by the Principal and Contractor, if applicable. The instrument or set-up shall be verified with a precision  $1 \text{ m}\Omega$  shunt. Compliance with this criterion shall be stated in the certification documents.
- A1.6 ANODE MARKING (STAMPING)
- In addition to the unique heat number and sequence number as required by NACE RP0387 Para. 3.2, each anode shall be marked with the nominal net anode alloy weight and name or logo of the anode Manufacturer/Supplier. All required marking shall be legibly stamped or pressed on the exposed anode surface (i.e. not the mounting surface) using round-bottom "V" steel stamps or indenters having a minimum height of 6.4mm (0.25 in).

## A1.7 PAINTING

- A1.7.1 Each anode shall have its mounting surface painted with an epoxy paint system approved by the Principal and Contractor, if applicable, after completion of the anode inspection described in (A1.4). The anode Manufacturer/Supplier shall obtain and conform to recommendations from the paint Manufacturer/Supplier relevant to the particular paint formulation used regarding aspects of surface preparation, paint mixing and application, and prevailing ambient conditions during application and curing of the paint. A written procedure for the surface preparation and painting process, including repairs, shall be referenced in the MPS and approved by the Principal and Contractor, if applicable.
- A1.7.2 Surfaces to be painted shall be cleaned to remove oil, grease, oxidation, or other contamination, and shall then be thoroughly abraded, either by light blast cleaning or by mechanical abrasion, to provide a uniformly roughened surface.
- A1.7.3 The epoxy paint system shall be applied in two coats, each having a DFT of 150-230  $\mu\text{m}$  (6-9 mils), to achieve an overall DFT in the range of 300-450  $\mu\text{m}$  (12-18 mils). The paint Manufacturer/Supplier's recommended overcoating intervals shall be observed. Care shall be taken to ensure that the paint film penetrates surface irregularities, and provides a continuous protective film which shall have no visible holidays, and shall be free of runs, sags, and other similar visible defects.
- A1.7.4 DFT shall be measured at a minimum of three different locations per anode after each coat has been allowed to dry. DFT shall be confirmed with an Elcometer 345 coating thickness measuring instrument or equivalent as approved by the Principal and Contractor, if applicable. The DFT measuring instrument shall have been calibrated using shims of a known thickness placed on the anode surface after surface preparation and prior to coating.
- A1.7.5 Paint repairs, if required, shall be performed in accordance with the paint Manufacturer/Supplier's written recommendations.

## A1.8 PACKING AND SHIPMENT

In addition to the requirements of NACE RP0387 Para. 3.13, packing or palletising shall be such that anode heat numbers are readily visible.

## APPENDIX 2 STAND OFF ANODES

### A2.1 INTRODUCTION

This Appendix defines the minimum requirements specific to stand-off (pipe-through) anodes in addition to (1.) thru (7.) of this DEP. Typical uses for these anodes would be on subsea equipment, spar trusses, templates, guide cones, etc. Stand-off anodes shall be manufactured and inspected in accordance with NACE RP0387 unless specific deviations or modifications are prescribed in this appendix. Some statements or issues raised in NACE RP0387 are repeated or clarified herein for clarity or special emphasis.

### A2.2 ANODE CORES

#### A2.2.1 Core Material Specifications

NACE RP0387 Para. 3.6.4 shall be replaced by the following.

Unless otherwise specified in project documents or on AFC drawings, anode core tubulars shall be seamless and shall meet the requirements of one of the following, or equivalent, as approved by the Principal and Contractor, if applicable:

API SPEC 5L Grade B

ISO 3183-1, 2, or 3 Grade L245

ASTM A106 Grade B

ASTM A53 Grade B Type S

ASTM A500 Grades B,D

EN 10210-1 Grade S275

Compliance with the following may be substituted for NACE RP0387 Para. 3.6.3 if desired by the anode Manufacturer/Supplier or if specified in project documents or on AFC drawings.

Anode core materials shall have a  $P_{cm} \leq 0.23$  where:

$$P_{cm} = C + (Si/30) + [(Mn + Cu + Cr)/20] + (Ni/60) + (Mo/15) + (V/10) + (5B)$$

Note: All elements in wt.%

The following values shall be assumed for any of the elements in the  $P_{cm}$  formula that have not been reported on the mill certificate:

$$Si = 0.35, Mn = 1.2, Cu = 0.25, Cr = 0.10, Ni = 0.10, Mo = 0.05, V = 0.08, B = 0.0005$$

#### A2.2.2 Core Material Mill Certificates

The core material Manufacturer/Supplier's mill certificates shall be included in the certification documentation. These certificates shall show heat number, chemical analysis, and tensile properties and shall comply with ISO 10474 Test Report Type 3.1.B as a minimum.

#### A2.2.3 Core Construction

Anode core material shall be splice free and shall be without welds made by the core material Manufacturer/Supplier.

The anode Manufacturer/Supplier shall maintain anode core material traceability relative to the anode production heat numbers.

#### A2.2.4 Core Surface Preparation

##### A2.2.4.1 Cores for Al-Zn-In Anodes

As per NACE RP0387 Para. 3.8.1.

#### A2.2.4.2 Cores for Zinc Anodes

As per NACE RP0387 Para. 3.8.2 except that the following, or equivalent, as approved by the Principal and Contractor, if applicable, shall be added to the list of acceptable galvanizing standards:

ISO 1461

ISO 2081 Classification Code Fe/Zn 12 or Fe/Zn 25

#### A2.2.5 Core Configuration and Positioning

As per NACE RP0387 Para. 3.5. Additionally, the method utilized to ensure proper anode core positioning in the mold during anode casting shall be described in the MPS.

### A2.3 ANODE FABRICATION

#### A2.3.1 Weight

As per NACE RP0387 Para. 3.3.

#### A2.3.2 Dimensions and straightness (bowing)

As per NACE RP0387 except that the straightness (bowing) criterion expressed in NACE RP0387 Para. 3.4.2 shall be tightened to 1%.

#### A2.3.3 Exposed Core

There shall be no evidence of exposed core on any other anode surface except where the core exits the anode.

#### A2.3.4 Anode Core Centerline

Location of the longitudinal centerline of the anode core (as determined at each end of the anode where the core exits the anode) shall be centerline of the anode width and height dimensions  $\pm 9.5$  mm (0.375 in).

### A2.4 CASTING DEFECTS

An inspection of the physical appearance and workmanship of each anode shall be performed after the anodes have cooled to ambient temperature in order to verify compliance with NACE RP0387 Para. 3.9 and 3.10. The following additional criteria shall also apply.

A2.4.1 In addition to the criterion stated in NACE RP0387 Para. 3.9.1, cavities shall not exceed 9.5 mm (0.375 in) in depth and 75.2 mm (3 in) in surface dimension when measured with a straight edge placed across the anode.

A2.4.2 In addition to the depth criterion stated in NACE RP0387 Para. 3.9.4, cold shuts or surface laps shall not extend over a total length of 150 mm (6 in).

A2.4.3 In addition to the criteria stated in NACE RP0387 Para. 3.10, there shall be no cracks which intersect, or can be projected to intersect other cracks or the anode core, in such a manner that spalling or loss of anode alloy could result.

### A2.5 ANODE-TO-CORE ELECTRICAL RESISTANCE

Anode-to-core electrical resistance shall be measured for each anode and shall be  $\leq 1$  m $\Omega$ . A written procedure for the determination of anode-to-core electrical resistance shall be referenced by the MPS and approved by the Principal and Contractor, if applicable. The instrument or set-up shall be verified with a precision 1 m $\Omega$  shunt. Compliance with this criterion shall be stated in the certification documents.

A2.6 ANODE MARKING (STAMPING)

In addition to the unique heat number and sequence number as required by NACE RP0387 Para. 3.2, each anode shall be marked with the nominal net anode alloy weight and name or logo of the anode Manufacturer/Supplier. All required marking shall be legibly stamped or pressed on the exposed anode surface (i.e. not the mounting surface) using round-bottom "V" steel stamps or indenters having a minimum height of 6.4mm (0.25 in).

A2.7 PACKING AND SHIPMENT

In addition to the requirements of NACE RP0387 Para. 3.13, packing or palletising shall be such that anode heat numbers are readily visible.

## APPENDIX 3 BRACELET ANODES

### A3.1 INTRODUCTION

This Appendix defines the minimum requirements specific to bracelet anodes in addition to (1.) thru (7.) of this DEP. Typical uses for these anodes would be on offshore pipelines, steel-catenary risers, top-tensioned risers and TLP tendons. Stand-off anodes shall be manufactured and inspected in accordance with NACE RP0492 unless specific deviations or modifications are prescribed in this appendix. Some statements or issues raised in NACE RP0492 are repeated or clarified herein for clarity or special emphasis.

### A3.2 ANODE CORES

#### A3.2.1 Core Material Specification

NACE RP0492 Para. 3.6.4 shall be replaced by the following.

Unless otherwise specified in project documents or on AFC drawings, anode core materials shall be weldable structural steel in compliance with one of the following, or equivalent, as approved by the Principal and Contractor, if applicable:

ASTM A36

ASTM A131 Grades A, B, CS, D, DS, E

ASTM A283 Grades C, D

JIS G 3106 Grade SM400

EN 10025-2 Grades E295, S275

EN 10025-3 Grade S275

EN 10025-4 Grade S275

ISO 630 Grades E 275

Compliance with the following may be substituted for NACE RP0387 Para. 3.6.3 if desired by the anode Manufacturer/Supplier or if specified in project documents or on AFC drawings.

Anode core materials shall have a  $P_{cm} \leq 0.23$  where:

$$P_{cm} = C + (Si/30) + [(Mn + Cu + Cr)/20] + (Ni/60) + (Mo/15) + (V/10) + (5B)$$

Note: All elements in wt.%

The following values shall be assumed for any of the elements in the  $P_{cm}$  formula that have not been reported on the mill certificate:

$$Si = 0.35, Mn = 1.2, Cu = 0.25, Cr = 0.10, Ni = 0.10, Mo = 0.05, V = 0.08, B = 0.0005$$

Internal connecting rod material used within semi-cylindrical bracelet anodes shall be in compliance with one of the following:

ASTM A510 Grades 1005 thru 1019

ISO 16120-2 Grades C4D thru C18D

ISO 16120-4 Grades C3D2 thru C18D2

#### A3.2.2 Core Material Mill Certificates

The core material Manufacturer/Supplier's mill certificates shall be included in the certification documentation. These certificates shall show heat number, chemical analysis, and tensile properties and shall comply with ISO 10474 Test Report Type 3.1.B as a minimum.

### A3.2.3 Core Construction

Anode core material shall be splice free and shall be without welds made by the core material Manufacturer/Supplier.

A minimum of two longitudinal connecting rods within semi-cylindrical bracelet anodes shall be welded to each of the two circumferential mounting bands. The maximum spacing between rods shall be 150 mm (6 in), with the outermost rods a maximum of 75 mm (3 in) from the edge of the anode segment. On small diameter anodes, typically  $\leq 203$  mm (8 in) pipe, the two connecting rod requirement shall supersede the spacing requirement. Additionally, connecting rods shall be slightly relocated should they interfere with any core location guides in the mold. Position and diameter of the connecting rods shall be shown on anode fabrication drawings, which shall be approved by the Principal and Contractor, if applicable.

The anode Manufacturer/Supplier shall maintain anode core material traceability relative to the anode production heat numbers.

Fabrication welding of cores shall be in accordance with written welding procedure specifications (WPS's) for welding anode cores by the anode Manufacturer/Supplier or his welding subcontractor shall be in compliance with NACE RP0492 Para. 3.7 and shall be approved by the Principal and Contractor, if applicable, and referenced in the MPS. All anode core welds shall be visually inspected to meet AWS D1.1 requirements for static structural welds.

### A3.2.4 Core Surface Preparation

#### A3.2.4.1 Cores for Al-Zn-In Anodes

As per NACE RP0492 Para. 3.8.1 and 3.8.2.

#### A3.2.4.2 Cores for Zinc Anodes

As per NACE RP0492 Para. 3.8.3 and 3.8.4 except that the following, or equivalent, as approved by the Principal and Contractor, if applicable, shall be added to the list of acceptable galvanizing standards:

ISO 1461

ISO 2081 Classification Code Fe/Zn 12 or Fe/Zn 25

### A3.2.5 Core Configuration and Positioning

As per NACE RP0492 Para. 3.5 with the following additional requirements.

Prior to casting, configuration and positioning of the anode core shall be verified to be within tolerances specified in project documents or on AFC drawings. Fixturing shall be utilized, as necessary, to maintain anode core positioning during the casting and solidification processes. The method utilized to ensure compliance with this paragraph shall be described in the MPS. Longitudinal and circumferential/transverse locations of the anode core shall be within  $\pm 3.2$  mm (0.125 in) of the location shown on the approved anode fabrication drawings. Anode core depth relative to the anode thickness shall be  $\pm 1.6$  mm (0.063 in) of the location shown on the approved anode fabrication drawings.

For segmented bracelet anodes, cores within individual anode segments shall be located on the centerline of the segment. The maximum internal arc length of each individual segment shall be 150 mm (6 in).

### A3.3 ANODE FABRICATION

#### A3.3.1 Assembly

Anode weight and dimensions shall be as specified on the approved anode fabrication drawings.

The bracelet assembly shall be manufactured to ensure continuous tight contact between the anode internal diameter and the pipe outer diameter. The Principal or Contractor, if applicable, may request that the anode Manufacturer/Supplier demonstrate compliance by fitting selected anodes on representative sections of pipe, including pipe coating, or equivalent as approved by the Principal and Contractor, if applicable.

Anode bracelets shall consist of 2 (two) halves. The halves shall be either semi-cylindrical castings or individual cast segments welded on to semi-cylindrical steel bands of a suitable width to mechanically support the segments. Bracelet halves that are fabricated using individual segments shall contain only segments from the same anode alloy production heat.

#### A3.3.2 Weight

As per NACE RP0387 Para. 3.3.

#### A3.3.3 Dimensions and straightness (bowing)

As per NACE RP0492 Para. 3.4 except that:

The length criterion expressed in NACE RP0492 Para. 3.4.1.1 shall be tightened to  $\pm 9.5$  mm (0.375 in).

The straightness (bowing) criterion expressed in NACE RP0492 Para. 3.4.2 shall be tightened to 1%.

The anode core extension shall be within  $\pm 3.2$  mm (0.125 in) of that shown on AFC drawings.

Minimum core tab overlap shall be 19 mm (0.75 in)

#### A3.3.4 Exposed Core

There shall be no evidence of exposed core on any other anode surface except where the core exits the anode.

#### A3.3.5 Bonding Cables (If Required by Project Documents or on AFC Drawings)

If required by project documents or on AFC drawings, 2 (two), seven strand, No. 6 AWG, copper bonding cables having a minimum length of 305 mm (12 in) with HMWPE insulation, or equivalent as approved by the Principal and Contractor, if applicable, shall be provided with each anode bracelet. Both bonding cables shall be attached to the same bracelet half on the same longitudinal side, unless otherwise specified. Bonding cables shall be attached to the overlapping (outermost) core tabs.

#### A3.3.6 Bonding Cables Attachment

The bonding cables mentioned in (A3.3.5) shall, if applicable, be attached to the anode core in accordance with a written bonding cable attachment procedure approved by the Principal and Contractor, if applicable. The attachment shall be accomplished with a neat and workman-like thermite attachment weld, brazing or submerged arc welding or equivalent as approved by the Principal and Contractor, if applicable, and referenced in the MPS that securely fuses the copper conductor to the steel core tabs or bracelet bands. A CAB-112 Cadweld sleeve, or equivalent as approved by the Principal and Contractor, if applicable, shall be properly crimped to the cable, and shall be used when using the thermite weld connection process. A minimum of 25.4 mm (1.0 in) of wire shall be brazed with the wire strands completely covered by braze filler material when using the brazing process. Cables shall be attached using a CAB-112 Cadweld sleeve crimped to the wire and welded to the anode core when using the submerged arc welding process and the sleeve shall be completely welded to the core tab or bracelet band on both longitudinal sides and the end opposite the cable exit. For all types of bonding cable connections, a minimum of 38 mm (1.5 in) of bare wire (insulation removed) shall exist between connection and cable insulation for flexibility purposes. Each connection shall be coated with an epoxy paint as approved by the Principal and Contractor, if applicable.

Note: CAB-112 Cadweld sleeves are available from ERICO, 34600 Solon Road, Solon, Ohio 44139 USA  
[www.erico.com](http://www.erico.com)

Bonding cables shall be supplied without removal of the insulation on the loose end.

#### A3.4 CASTING DEFECTS

An inspection of the physical appearance and workmanship of each anode shall be performed after the anodes have cooled to ambient temperature in order to verify compliance with NACE RP0492 Para. 3.9 and 3.10. The following additional criteria shall also apply.

A3.4.1 In addition to the criterion stated in NACE RP0492 Para. 3.9.1, cavities shall not exceed 9.5 mm (0.375 in) in depth or 75.2 mm (3 in) in length when measured with a straight edge placed across the anode.

A3.4.2 Not more than 1% of the total surface of the anode casting shall be contaminated with non-metallic inclusions visible to the naked eye.

A3.4.3 In addition to the criteria stated in NACE RP0492 Para. 3.10, the following shall apply.

Longitudinal cracks described in NACE RP0492 Para. 3.10.4b shall not exceed 152.4 mm (6 in) in length.

There shall be no cracks which intersect, or can be projected to intersect other cracks or the anode core, in such a manner that spalling or loss of anode alloy could result.

#### A3.5 ANODE-TO-CORE ELECTRICAL RESISTANCE

Anode-to-core electrical resistance shall be measured for each anode and shall be  $\leq 1$  m $\Omega$ . A written procedure for the determination of anode-to-core electrical resistance shall be referenced by the MPS and approved by the Principal and Contractor, if applicable. The instrument or set-up shall be verified with a precision 1 m $\Omega$  shunt. Compliance with this criterion shall be stated in the certification documents.

#### A3.6 ANODE MARKING (STAMPING)

The heat number of each anode and nominal net anode alloy weight shall be legibly stamped or pressed on the exposed anode surface using round-bottom "V" steel stamps or indenters having a minimum height of 6.4mm (0.25 in). The anode identification method shall be described in the MPS.

A3.7 PAINT

The following applies in addition to NACE RP0492 Para. 3.12.

- A3.7.1 Each anode shall have its mounting surface painted with an epoxy paint system approved by the Principal and Contractor, if applicable. The anode Manufacturer/Supplier shall obtain and conform to recommendations from the paint Manufacturer/Supplier relevant to the particular paint formulation used regarding aspects of surface preparation, paint mixing and application, and prevailing ambient conditions during application and curing of the paint. A written procedure for the surface preparation and painting process, including repairs, shall be referenced in the MPS and approved by the Principal and Contractor, if applicable.
- A3.7.2 Surfaces to be painted shall be cleaned to remove oil, grease, oxidation, or other contamination, and shall then be thoroughly abraded, either by light blast cleaning or by mechanical abrasion, to provide a uniformly roughened surface.
- A3.7.3 The epoxy paint system shall be applied in two coats, each having a DFT of 150-230  $\mu\text{m}$  (6-9 mils), to achieve an overall DFT in the range of 300-450  $\mu\text{m}$  (12-18 mils). The paint Manufacturer/Supplier's recommended overcoating intervals shall be observed. Care shall be taken to ensure that the paint film penetrates surface irregularities, and provides a continuous protective film which shall have no visible holidays, and shall be free of runs, sags, and other similar visible defects.
- A3.7.4 DFT shall be measured at a minimum of three different locations per anode after each coat has been allowed to dry. DFT shall be confirmed with an Elcometer 345 coating thickness measuring instrument or other equivalent as approved by the Principal and Contractor, if applicable. The DFT measuring instrument shall have been calibrated using shims of a known thickness placed on the anode surface after surface preparation and prior to coating.
- A3.7.5 Paint repairs, if required, shall be performed in accordance with the paint Manufacturer/Supplier's written recommendations.

A3.8 PACKING AND SHIPMENT

In addition to the requirements of NACE RP00492 Para. 3.14, packing or palletising shall be such that anode heat numbers are readily visible. Only an even number of bracelet halves shall be packaged together.

**APPENDIX 4 ANODE HEAT DATA SHEETS**

**DATA SHEET 1**

<b>Project:</b>	<input type="text"/>	<b>Purchase Order N°:</b>	<input type="text"/>
<b>Heat Number:</b>	<input type="text"/>	<b>Number of anodes/segments/bracelet halves cast in heat:</b>	<input type="text"/>
<b>Anode Size/Type:</b>	<input type="text"/>	<b>Avg. Anode Net Weight (kg)</b>	<input type="text"/>
<b>Date Cast:</b>	<input type="text"/>	<b>Drawing Number</b>	<input type="text"/>

Alloy Chemical Analysis									
Sample	Zn	In	Si	Fe	Cu	Cd	Others Total	Others Each	Al
Certified Standard No. _____									
Certified Analysis									
Final Pre-Pour Calibration Analysis of Certified Standard									
Pre-Pour Analysis									
Mid-Pour Analysis									
End-of-Pour Analysis									

Fourteen Day Potential Test					
Test Started	Date	AM Potential	PM Potential	pH	Temperature
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					

<b>Avg. E Day 2-14</b>	<input type="text"/>	<b>E shift Day 2-14</b>	<input type="text"/>	<b>Ref. Electrode Check</b>	
<b>Max. Avg. E Day 3-14</b>	<input type="text"/>	<b>Avg. E Day 10-14</b>	<input type="text"/>	<b>Date</b>	<b>E Master v Working</b>
<b>Initial Sample Weight</b>	<input type="text"/>	<b>Avg. E Day 6-11</b>	<input type="text"/>		
<b>Final Sample Weight</b>	<input type="text"/>				
<b>Sample Weight Loss</b>	<input type="text"/>				
<b>Tests Current Passed</b>	<input type="text"/>				
<b>Test Duration</b>	<input type="text"/>				
<b>Alloy Capacity</b>	<input type="text"/>				

<b>QC Manager:</b>	<input type="text"/>	<b>Inspector:</b>	<input type="text"/>
<b>Date:</b>	<input type="text"/>	<b>Date:</b>	<input type="text"/>

**DATA SHEET 2**

Project:

Purchase Order N°:

Item	Specimen Heat Number	Quantity (Anodes/Segments/Bracelet Halves produced)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

## **APPENDIX 5 QUALIFICATIONS OF ANODE MANUFACTURERS/SUPPLIERS AND MANUFACTURING FACILITIES**

### **A5.1 SCOPE**

The purpose of this Appendix is to define the procedures for prequalification of anode Manufacturers/Suppliers for the supply of deepwater offshore sacrificial anodes.

### **A5.2 COMMUNICATIONS PRIOR TO PREQUALIFICATION**

The following information/documents shall be exchanged prior to execution of the qualification process.

#### **A5.2.1 INFORMATION/DOCUMENTS FROM ANODE MANUFACTURER/SUPPLIER PRIOR TO PREQUALIFICATION**

A5.2.1.1 Anode Manufacturing Process/Operations Manual, including detailed electrochemical performance test procedure.

A5.2.1.2 Anode Quality Assurance/Quality Control (QA/QC) Manual, including:

Sample of document package

Sample of process control plan

Sample of inspection and test plan

A5.2.1.3 Chemical Composition Analysis Procedure

A5.2.1.4 Coating Specification and Application Procedure (required for bracelets or flush-mount anode prequalification)

A5.2.1.5 ISO 9001 certificate or equivalent as approved by the Principal and Contractor, if applicable. Results or findings of the most recent 3<sup>rd</sup>-party audit.

#### **A5.2.2 INFORMATION/DOCUMENTS TO BE SUPPLIED TO ANODE MANUFACTURER/SUPPLIER PRIOR TO PREQUALIFICATION**

A5.2.2.1 This DEP and anode alloy type and configuration, i.e. (Appendix 1, 2 or 3), including basic dimensions, and net and gross weight for which prequalification is required.

A5.2.2.2 Request to conduct a formal on-site quality audit by quality specialists in addition to the technical qualification site visit described below, if deemed necessary after review of documentation supplied by anode Manufacturer/Supplier.

### **A5.3 TECHNICAL PREQUALIFICATION PROCESS**

#### **A5.3.1 TECHNICAL PREQUALIFICATION SITE VISIT**

##### **A5.3.1.1 INTERVIEW WITH KEY PERSONNEL**

The anode Manufacturer/Supplier shall make available certain key personnel to discuss specific technical issues during the prequalification site visit. Key personnel shall include but not be limited to:

Production Manager/Supervisor

QA/QC Manager/Supervisor

Laboratory Supervisor/Technician

#### A5.3.1.2 WITNESS OF THE MANUFACTURING PROCESS

During the qualification site visit the entire manufacturing process for at least two heats of each anode alloy type and configuration, i.e. flush-mount, stand off or bracelet, for which the anode Manufacturer/Supplier is to be prequalified shall be witnessed by members of the site visit team.

The two anode heats produced may be specially made for prequalification purposes or be from anode materials manufactured for other reasons, provided they are manufactured and tested in accordance with this DEP.

All testing and acceptance criteria from this DEP shall be applied to the two prequalification heats, and the final product inspection shall be witnessed. Test anodes from each heat shall be sectioned and examined for internal defects in compliance with NACE RP0387 Para. 3.11 or NACE RP0492 Para. 3.11, as applicable. Radiographic examination to verify internal anode soundness and positioning of the anode core may be required by the Principal or Contractor, if applicable, in addition to the specified inspection requirements.

Samples from the two heats shall be provided in accordance with this DEP for additional performance evaluation by the Principal's testing laboratory or a 3<sup>rd</sup>-party testing laboratory approved by the Principal and Contractor, if applicable.

#### A5.3.1.3 DEMONSTRATION OF THE CHEMICAL ANALYSIS EQUIPMENT AND METHOD

The anode Manufacturer/Supplier shall demonstrate the ability to accurately analyze the chemical composition of at least two certified compositional standards, which will be brought to the qualification site visit by the site visit team, within the limits prescribed in (Table 4).

OES is the preferred chemical analysis method. Other methods such as AA, ICP or DCP are also acceptable.

The chemical analysis of the certified standards and the two produced test heats shall be witnessed by a member of the site visit team.

#### A5.3.1.4 ELECTROCHEMICAL PERFORMANCE TEST LABORATORY AUDIT

The anode Manufacturer/Supplier shall make available the electrochemical test facility to be audited by members of the site visit team. The items that will be audited will include, but not be limited to:

General knowledge in conducting electrochemical performance testing

Ability to control temperature to simulate deepwater environment

Ability to accurately measure anode capacity, potential, current, pH, etc.

Specimen handling and cleaning techniques

#### A5.3.1.5 REVIEW OF ANODE MANUFACTURER/SUPPLIER'S DOCUMENTATION PROCESS

At the request of the site visit team, the following anode Manufacturer/Supplier's documentation shall be made available for review:

Material Data Sheets

Chemical Analysis Reports from previous jobs

Electrochemical Performance Test Reports from previous jobs

#### A5.3.1.6 REVIEW OF ANODE MANUFACTURER/SUPPLIER'S OFFSHORE POTENTIAL DATA

The anode Manufacturer/Supplier shall make available for the site visit team's review offshore performance data or references demonstrating satisfactory anode performance on actual offshore structures or host vessels. The performance data or reference shall be from a cathodic protection potential survey from a minimum of 3 different, recent projects where sacrificial anodes have been produced.

#### A5.3.2 OFFSITE EVALUATION

The following additional offsite evaluations may be requested or arranged for by the site visit team on the two heats produced during the prequalification site visit:

Chemical analysis

Electrochemical performance tests

Non-destructive and destructive testing

#### A5.4 APPROVAL PROCESS AND ESSENTIAL VARIABLES

After the site visit and offsite evaluations, a decision will be made by the Principal as to whether or not the anode Manufacturer/Supplier and manufacturing facilities are approved as "prequalified" status.

The prequalification and subsequent approval is contingent upon the following essential variables. Change in any one of these variables may cause a re-qualification to be required, subject to the decision of the Principal.

Change in key personnel

Significant change to manufacturing facilities

Change in anode alloy type to be produced

A period of inactivity for producing anodes to this DEP longer than 2 years