Materials System Specification

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Galvanic Anodes for Cathodic Protection

Document Responsibility: Cathodic Protection Standards Committee

Contents

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1 Scope

This specification together with the Purchase Order covers the minimum requirements for galvanic anodes for cathodic protection systems.

2 Conflicts and Deviations

2.1 Any conflicts between this document and other applicable Mandatory Saudi Aramco Engineering Requirements (MSAERs) shall be addressed to the EK&RD Coordinator.

2.2 Any deviation from the requirements herein shall follow internal company procedure SAEP-302.

3 References

All referenced Specifications, Standards, Codes, Forms, Drawings, and similar material shall be considered part of this specification to the extent specified herein and shall be the latest issue (including all revisions, addenda, and supplements) unless stated otherwise.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Standard Drawings

AA-036335	*Half Shell Bracelet Type Anodes for Pipe Sizes 4”-60”*
AA-036388	*Internal Galvanic Anodes Installation Details for Vessels*
AA-036389	*Galvanic Anode Details*
AA-036762	*Crude and Product Tank Bottom Internal Galvanic Anode Installation*

Saudi Aramco Inspection Requirements

Form 175-171300	*Galvanic Anodes: Aluminum, Magnesium, or Zinc for Cathodic Protection*

3.2 Industry Codes and Standards

American Society for Testing and Materials

ASTM D1141	*Substitute Ocean Water*
ASTM G97	*Standard Test Method for Laboratory Evaluation of Magnesium Sacrificial Anode Test Specimens for Underground Applications*

International Standards Organization

ISO 9001	*Quality Management Systems - Requirements*

National Association of Corrosion Engineers

NACE SP0387	*Metallurgical and Inspection Requirements for Cast Sacrificial Anodes for Offshore Applications*
NACE TM0190	*Standard Test Method Impressed Current Test Method for Laboratory Testing of Aluminum Anodes*

Swedish Standards Institute

SIS-05-5900	*Swedish Pictorial Surface Preparation Standards for Painting Steel Surfaces*

Steel Structures Painting Council

SSPC-SP 10	*Near-White Blast Cleaning*

Australian Standard

AS-2239	*Galvanic (Sacrificial) Anodes for Cathodic Protection*

4 General

4.1 Terms and Definitions

The following terms are used in this specification:

Anode: Where used in this specification, the term “Anode” shall refer to a galvanic anode.

Lead Wire: Where used in this specification, the term “Lead Wire” shall refer to a cable directly connected to a galvanic anode.

Buyer: Saudi Aramco Purchasing Department Representative.

Buyer's Representative: The person or persons designated by the Purchasing Department to monitor/enforce the contract.

CSD: Consulting Services Department.

EK&RD: Engineering Knowledge and Resources Division

Manufacturer: The Company that manufactures the anode.

Reference Electrodes: Standard silver/silver chloride (Ag/AgCl/0.6M Cl) reference cells.

SCC: Where used in this specification, SCC refers to the Standards Committee Chairman for cathodic protection material.

SME: Where used in this specification, SME refers to the cathodic protection Subject Matter Expert assigned to this material specification by the Standards Committee Chairman.

Vendor: The Company that receives the purchase order to supply the anode. The Vendor may also be the Manufacturer if both definitions apply.

4.2 Ordering Information

The following shall be included with the Purchase Order:

- Type of anode material
- Net anode material mass
- Critical dimensions, e.g., length of core, size of core, dimensions of finished anode
- Anode mounting details

4.3 Vendor Document Submittals

The Vendor shall submit the following documents to the Buyer and Vendor inspection. Any proposed alternative designs in addition to the required design shall be clearly described in these submittals. All documents, drawings and labels etc. shall be in English language.

a) Manufacturer's name
b) Manufacturer’s number
c) Minimum anode energy capacity
d) Anode material composition
e) Test data and certificate of compliance with Section 6 of this specification

f) Certified drawings, fully dimensioned and scaled, showing details of anode assembly

4.4 Labeling

Each anode shall be labeled with the following information on either a waterproof paper tag with waterproof ink, or a traffolyte type plate with contrasting letters:

a) Type of Anode
b) Anode Dimensions
c) Date of Manufacture and Heat Number (hard stamped on the anode)
d) Purchase Order Number
e) Manufacturer
f) Casting Foundry
g) Material Number

Ribbon type anodes shall have one label (waterproof tag) tagged to each coil of ribbon.

5 Material Qualifications

5.1 General Test Requirements

5.1.1 Anodes supplied by foundry shall be technically pre-qualified by Saudi Aramco to produce each anode material of different composition. The anodes must be tested at a reputable third party laboratory for open circuit potential test, chemical composition test and an energy capacity test according to ASTM G97 for magnesium anodes and according to NACE TM0190 for aluminum and zinc anodes.

5.1.2 The test results including anode efficiency calculations shall meet the acceptance values of Section 6 for the anode material tested.

5.2 Material Test Requirements

A sample anode from an approved foundry shall be tested at Saudi Aramco R&DC or a reputable third party lab. Pass/fail criteria will be based on the acceptance values detailed in Section 6 for the anode material tested. For sample sizing details, see sections 5.2.1 and 5.2.2.

5.2.1 Magnesium

The manufacturer shall provide one 60 pound (27 kg) anode (backfill and cable not required) for testing as per ASTM G97.

5.2.2 Aluminum and Zinc

The manufacturer shall provide four samples in each composition for testing as per NACE TM0190.

5.3 Technical Document Submittals

5.3.1 All documents, drawings and labels etc. shall be in English language.

5.3.2 The Manufacturer shall submit the following documents to the Saudi Aramco Vendor Inspection Division and to the Consulting Services Department.

a) Manufacturer's material specification including service restrictions and recommended service, if applicable.

b) Manufacturer certified drawings showing all dimensions and details.

c) Manufacturer certified test data for the electrochemical properties and anode material composition confirming compliance with Section 6 of this specification.

Submittal of the above documents will not be required on repeat orders. However, if any modifications are made to the previously supplied (approved) materials, then all relevant data shall be resubmitted to the Saudi Aramco for approval.

6 Material Properties

Anode materials covered within the scope of this document are

- Aluminum
- Magnesium
- Zinc

Commentary Note:

The conversion from manufacturer's data for reference potentials provided with respect to CSE shall be made by adding -50 mV to the Ag/AgCL potentials listed in this Material Specification.

Example; -1050 Ag/AgCl is equivalent to -1100 CSE

6.1 Aluminum

6.1.1 Aluminum anodes shall exhibit an open circuit potential, when immersed in ASTM D1141 "Substitute Ocean Water" at ambient temperature (23 ± 3°C), of -1050 mV or more negative with reference to an Ag/AgCl electrode.

6.1.2 Aluminum anodes shall have an efficiency sufficient to provide an anode energy capacity greater than 2300 amp-hrs per kilogram in accordance with NACE TM0190.

6.1.3 Aluminum anodes shall conform to the following Specification:

Zn	2.0-6.5%
Fe	0.12% Maximum
Si	0.08-0.20%
Cu	0.006% Maximum
In	0.01-0.02%
Hg	none
0.02%	Maximum, any one other impurity and
0.06%	Maximum, total of all other impurities
Al	Balance

6.2 Magnesium

6.2.1 Magnesium anodes shall exhibit an open circuit potential, when immersed in ASTM D1141 “Substitute Ocean Water” at ambient temperature (23 ± 3°C), of -1650 mV or more negative with reference to an Ag/AgCl electrode.

6.2.2 Magnesium anodes shall have an efficiency sufficient to provide an anode energy capacity greater than 800 amp-hrs per kilogram measured in accordance with ASTM G97-97.

6.2.3 Magnesium anodes shall conform to the following Specification:

Cu	0.02% Maximum
Al	0.01% Maximum
Fe	0.03% Maximum
Mn	0.5 - 1.3%
Ni	0.001% Maximum
0.05%	Maximum, any one other impurity and
0.30%	Maximum, total of all other impurities
Mg	Balance

6.3 Zinc for Operation at 50°C or Less

6.3.1 Zinc ribbons and zinc anodes to be operated at 50°C or less shall exhibit a potential of -1050 mV or more negative in reference to an Ag/AgCl

electrode when tested in ASTM D1141 "Substitute Ocean Water" at ambient temperature (23 ± 3°C).

6.3.2 Zinc anodes for 50ºC or less operation shall have an efficiency sufficient to provide an energy capacity of 770 ampere-hours per kilogram at 23 ± 3°C in accordance with NACE TM0190.

6.3.3 Zinc anodes for 50°C or less operation shall conform to the following specification:

Al	0.005% Maximum
Cu	0.002% Maximum
Fe	0.0014% Maximum
Pb	0.003% Maximum
Cd	0.003% Maximum
Zn	Balance

6.3.4 Zinc anodes used for permanent reference cells shall meet the requirements of 6.3.1, 6.3.2, and the requirements of Material Number 6000001043.

6.4 Zinc for Operation between 50°C to 70°C

6.4.1 Zinc anodes for wet crude handling vessels operating at temperatures between 50°C and 70°C shall exhibit a potential more negative than -900 mV with reference to an Ag/AgCl reference electrode, when immersed in ASTM D1141 "Substitute Ocean Water" at 70°C. These anodes shall be immersed at least one hour before taking the potential (the stated potential value is to verify and confirm the anode's ability to provide protection at 70°C and this value should not be used for design calculations).

6.4.2 Zinc anodes shall have an efficiency sufficient to provide an anode energy capacity greater than 770 amp-hrs per kilogram at 50°C (throughout the test period).

6.4.3 Zinc anodes for wet crude handling vessels operating at temperatures between 50°C and 70°C shall conform to the following specification:

Al	0.10% - 0.25%
Mg	0.05% - 0.15%
Cd	0.001% Maximum
Fe	0.002% Maximum
Cu	0.001% Maximum

Pb	0.006% Maximum
0.10%	maximum, total of all other impurities
Zn	Balance

6.4.4 Zinc anodes shall not be used for operating temperatures above 70°C. For temperatures more than 70°C, Aluminum anode shall be used.

6.5 Steel Core (Insert) Material

Cast galvanic anode inserts shall be fabricated from weldable structural steel plates or sections, or steel pipes. The carbon equivalent of insert materials shall be as per NACE SP0387.

7 Design Details

7.1 Anode Casting

Galvanic anodes shall be made by casting the alloy material around a steel core. Prior to casting the melt, the cores shall be descaled, degreased, and abrasive blasted to SSPC-SP 10 or Swedish Standard Sa 2½ (SIS-05-5900) within 24 hours of casting or sooner so that rust bloom is not present. Construct Bracelet anodes according to Saudi Aramco Standard Drawing AA-036335. Construct magnesium anode according to Saudi Aramco Standard Drawing AA-036762. Construct other galvanic anodes according to Saudi Aramco Standard Drawing Numbers AA-036388 and/or AA-036389.

7.2 Anode Lead Wires and Inserts

7.2.1 Lead wires on packaged anodes shall be 10 mm² (No. 8 AWG) stranded copper insulated wire suitable by NEC Table 310.13 for burial in wet locations.

7.2.2 Lead wires on packaged magnesium and zinc anodes shall be brazed or silver soldered to the steel core and the connection shall be sealed with potting compound.

7.2.3 Anode-to-insert and anode-to-cable connection resistance and mechanical test result and methodology shall conform to AS-2239.

7.2.4 Conduct the electrical resistance and mechanical tests as per section 7.2.3 on at least one anode for every 100 anodes or if the order lot is smaller than 100, then one anode per order must be tested.

7.3 Packaged Anodes

Packaged anodes are anodes that have been placed in a water absorbent cotton bag with the backfill described below. The bag shall be filled and tightly compacted with a mix of 75% gypsum, 20% bentonite, and 5% sodium sulfate for Magnesium and 50% Gypsum and 50% bentonite for Zinc. The minimum acceptable weights for anodes shall be as detailed in Section 8 of this specification. The nominal weights of packaged magnesium anodes shall be:

14.5 Kg net - 31 Kg total (32 lb net – 68 lb total)

27 Kg net - 80 Kg total (60 lb net – 176 lb total)

The minimum weights of packaged zinc reference electrodes shall be:

2.8 Kg net - 5.44 Kg total (6.2 lb net – 12 lb total)

8 Inspection and Quality Control

8.1 Inspection Requirements

The items manufactured to this specification are subject to verification by the Buyer's inspector per Form 175-171300. The appropriate anode material form shall be attached to the Purchase Order.

8.2 Quality Control Program

The manufacturer or vendor shall implement and maintain a quality control program that shall include clearly defined and documented procedures for the relevant quality control functions and procedures according to ISO 9001. The quality program documents shall be made available to the buyer's representative for review and inspection.

8.3 Manufacturer Production Quality Control

8.3.1 Two samples shall be taken for chemical analysis at the beginning and end of each heat poured. If heats are smaller than one metric ton, one sample shall be taken per batch. The test sample should be taken at the beginning of the first batch, at the end of the next batch and at the end of each subsequent batch.

8.3.2 The samples shall be analyzed to determine the concentration of alloying elements and the contaminants. The test results shall meet the acceptance values of Section 6 of this specification for the anode material tested.

8.3.3 For aluminum, magnesium and zinc anodes, surface irregularities on the anode casting and cracks in the cast anode material shall comply with paragraphs 3.9 and 3.10 of NACE RP0387.

8.3.4 Dimensions and mass shall conform to the purchase order description. Anode dimension tolerances shall confirm to NACE SP0387. Net mass of each individual anode shall be no less than 95% of nominal. Total mass of all anodes in an order shall be 100% or greater of that specified on the order.

9 Packing and Shipping

9.1 The anodes shall be packed on a shock absorbing material such as wood, polyurethane foam, etc., on a pallet or skid sized to accommodate the total anode size. The packing of anodes and attached cable shall be suitable for long-term outdoor storage. All anode cables longer than ten (10) meters shall be wound on disposable wooden or plastic reels with the reel securely attached to the pallet or skid.

9.2 The length of the pallet or skid assembly shall exceed the anode length to allow sufficient room for the anode cables or cable reels. Anode cables or cable reels are to be at the end of each anode when shipping; they shall not be stored on top of the anode.

9.3 Anodes shall be securely fastened to the pallet or skid to prevent movement during shipping.

9.4 Total net anode assembly mass per crate shall not exceed 1,360 kg (3,000 lb).

Revision Summary

1 June 2014	Revised the Next Planned Update, reaffirmed the content of the document, and reissued as major revision.
1 September 2019	Revised the Next Planned Update, reaffirmed the content of the document, and reissued as major revision. Value Engineering (VE) conducted and agreed comments as per VE are implemented.

Summary of Change (rev. 1 September 2019)

#	Paragraph No.	Change Type (New, Modification,...etc.)	Technical Change
1	3.2 Industry Codes and Standards	Addition	Australian Standard AS-2239 added
2	4.4 Labeling	Modification	Hard stamping specifically included
3	5 Materials Qualification	Modification	Revised section title and wording from Manufacturer Qualifications to Materials Qualifications
4	5.2 Requalification Testing	Deleted	It will be part of periodic technical assessment
5	5.1.2.2 Aluminum and Zinc	Modification	Anode Sample size for testing included
6	6.5 Steel Core (Insert) Material	Addition	Section on steel-core added
7	7.2 Anode Lead Wires and Inserts	Addition	Anode to Lead wire resistance and mechanical test added
8	7.3 Packaged Anodes	Modification	Backfill materials for zinc has been specifically included
9	8.3.4 Inspection and Quality Control	Modification	Anode dimension tolerances shall confirm to NACE SP0387