Engineering Standard

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Cathodic Protection of Vessel and Tank Internals

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1 Scope

This standard prescribes the minimum mandatory requirements governing the design and installation of cathodic protection systems for the internal surfaces of steel vessels and tanks. Typical applications include water storage tanks, sand traps, condenser water boxes, salt water strainers, wet crude separation vessels, product tanks, sump tanks, and other types of hydrocarbon tanks that may accumulate a layer of water or sediment in the bottom.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department, Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department, Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*
SAEP-332	*Cathodic Protection Commissioning*
SAEP-333	*Cathodic Protection Monitoring*

Saudi Aramco Engineering Standards

SAES-B-068	*Electrical Area Classification*
SAES-P-100	*Basic Power System Design Criteria*
SAES-P-104	*Wiring Methods and Materials*

SAES-P-107	*Overhead Distribution Systems*
SAES-P-111	*Grounding*
SAES-Q-001	*Criteria for Design and Construction of Concrete Structures*

Saudi Aramco Materials System Specifications

17-SAMSS-004	*Tap Adjustable Rectifiers for Cathodic Protection*
17-SAMSS-005	*Cathodic Protection Phase Controlled Rectifiers*
17-SAMSS-006	*Galvanic Anodes for Cathodic Protection*
17-SAMSS-007	*Impressed Current Anodes for Cathodic Protection*
17-SAMSS-008	*Junction Boxes for Cathodic Protection*
17-SAMSS-017	*Cables for Cathodic Protection*

Saudi Aramco General Instruction

GI-0002.710	*Mechanical Completion and Performance Acceptance of Facilities*

Saudi Aramco Standard Drawings

The following standard drawings outline specific methods of designing and installing cathodic protection systems:

AD-036132	*Termination Detail Cable Identification*
AA-036276	*Multi-purpose Junction Box Details*
AB-036351	*Marker Plate Details*
AA-036353	*Water Storage Tanks Impressed Current C.P.*
AA-036354	*Water Storage Tanks Galvanic Anode C.P.*
AA-036378	*Rectifier Installation Details (Sheets 1 & 2)*
AB-036381	*Thermite Welding of Cables to Pipelines & Structures*
AC-036388	*Internal Galvanic Anodes Installation Details for Vessels*
AA-036389	*Galvanic Anode Details*
AB-036540	*Mounting Support Details for Junction Boxes*
AA-036675	*Installation Details, Direct Buried Cable, Cathodic Protection*

AA-036762	*Crude and Product Tank Bottom, Internal, Magnesium Anode Installation*
AE-036785	*Symbols for Cathodic Protection*

3.2 Industry Codes and Standards

National Fire Protection Association

NFPA 70	*National Electrical Code (NEC)*

4 Design

4.1 General

4.1.1 Cathodic protection is required for the internal surfaces of metallic tanks and vessels:

a) if the resistivity of the water (or sludge) is less than 2000 ohm-cm, or

b) if the resistivity of water (or sludge) is greater than 2000 ohm-cm and cathodic protection is deemed necessary by the Cathodic Protection Proponent Organization and concurred to by the Supervisor of the Cathodic Protection and Coatings Unit of Saudi Aramco's Consulting Services Department.

4.1.2 Cathodic protection shall be provided by galvanic or impressed current systems for water storage tanks according to Standard Drawings AA-036353 and AA-036354. Design drawings shall use standardized symbols for cathodic protection equipment in accordance with Standard Drawing AE-036785.

4.1.3 Only zinc alloy anodes specified by the manufacturer and approved by CSD/Cathodic Protection and Coatings Unit as suitable for service at elevated temperatures above 70°C, or aluminum alloy anodes shall be used in wet crude separation vessels. Refer to Standard Drawing AA-036389.

4.1.4 Sumps and bottoms of crude tanks and product storage tanks, with an exception of jet fuel storage tanks, shall be cathodically protected by galvanic anodes according to Standard Drawing AA-036762. Consult with CSD/Cathodic Protection and Coatings Unit for the cathodic protection of tank bottoms coated with thick type internal coating.

4.1.5 An impressed current system utilizing inert anodes shall be used where undesirable contamination of the contained liquid would occur due to the corrosion products of other anode materials.

4.2 Design Review and Approval

IT IS MANDATORY that the proposed cathodic protection design for every design package be submitted to the proponent cathodic protection organization and the Cathodic Protection & Coatings Unit of CSD for review and approval. The cathodic protection design shall include construction drawings, all field data, design calculations, and the scope of work.

The design agency shall not issue drawings for construction that have not been approved in writing by the proponent cathodic protection organization and the Cathodic Protection & Coatings Unit of CSD.

4.3 Design Life

4.3.1 The minimum design life for galvanic or impressed current anode systems shall be either 7 years, or the testing and inspection (T&I) period, whichever is greater.

4.3.2 The consumption rates detailed below in Table 1 shall be used for the calculation of the design life of galvanic anodes:

Table 1 – Consumption Rates for Galvanic Anodes (kg/A-Y)

	ANODE TYPE			
Structure	**Al**	**Mg**	**Zn**	**Zn (High Temp) (1)**
Water Storage Tanks	3.7	7.7	11.8	11.8
Process Vessels (2)	6.9	N/A	11.8	11.8
Process Vessels (3)	23.3	N/A	N/A	16.1

Notes:

(1) Zinc anodes shall be certified by the manufacturer for maximum consumption rates at 70°C of equal to or better than the consumption rates listed in Table 1.

(2) Process vessels for this application are those vessels that contain no dissolved H_2S and normally operate at temperatures below 50°C.

(3) Process vessels for this application are those vessels that contain dissolved H_2S and normally operate at temperatures above 50°C.

N/A indicates not applicable, or not suitable for this application.

The consumption rates listed in Table 1 include utilization factors and efficiency.

4.3.3 The consumption rates detailed in Table 2 shall be used for the calculation of the design life of impressed current anodes.

Table 2 – Consumption Rates for Impressed Current Anodes (kg/A-Y)

	ANODE TYPE		
Electrolyte Resistivity	**Platinum**	**HSCI**	**Mixed Metal Oxide (MMO) or Polymeric Anode**
500 ohm-cm or less	8.63×10^{-6}	0.45	Per Manufacturer Rating
Greater than 500 ohm-cm	4.32×10^{-5}	0.45	Per Manufacturer Rating

Note: Inert anodes (platinized and MMO) shall not be used in vessels that have hydrocarbon products (asphaltine).

4.3.4 The maximum allowable current density and voltage characteristics detailed in Table 3 shall be used for the design of impressed current anode systems.

Table 3 – Current Density and Voltage Maximums for Impressed Current Anodes

	ANODE TYPE (1)		
	Platinum	**HSCI**	**Mixed Metal Oxide**
Current (mA/ cm²)	40	0.7	60.0 (Salt Water) 11.0 (Fresh Water)
Voltage (volts)	60	100	Per Manufacturer Rating

Notes:

(1) Do not exceed manufacturer's rated current output of anodes in the applicable electrolyte.

(2) Inert anodes (platinized and MMO) shall not be used in vessels that have hydrocarbon products (asphaltine).

4.4 Current Density Criteria

The system design shall provide the minimum current density values for coated and uncoated surfaces shown in Table 4.

Table 4 – Minimum Current Density Requirements (mA/m²)

Surface	Current Density
Coated Tanks	0.5
Coated Vessels	3.0
Uncoated Tanks & Vessels	30.0

Note: For thick internal coatings consult with CP&CU for the recommended current density.

4.5 Protection Criteria

The cathodic protection potential shall comply with the following potential criteria:

4.5.1 The minimum steel-to-electrolyte potential shall be equal or more negative than negative 0.9 V (on) with reference to a silver/silver chloride electrode, or equal or less positive than 0.15 V (on) with reference to a zinc electrode.

4.5.2 The maximum steel-to-electrolyte potential for impressed current systems shall be equal or less negative than negative 2.95 V (on) with reference to a silver/silver chloride electrode, or equal or less negative than negative 1.9 V (on) with reference to a zinc electrode.

4.6 Anodes

4.6.1 Anode materials (manufactured in accordance with 17-SAMSS-006 or 17-SAMSS-007) shall be selected from Table 1 or Table 2 in Section 4.3.

4.6.2 The number and location of anodes shall depend upon the accessibility of components, the current requirement, and the configuration of the tank or vessel. Shielding by structural members or compartments shall be recognized and accounted for in the design.

4.6.3 Magnesium anodes shall not be used if the electrolyte resistivity at normal operating temperature is less than 500 ohm-cm.

4.6.4 Zinc anodes shall not be used in environments where temperature exceeds 50°C, except for high temperature zinc anodes which meets the requirements of Section 4.1.4.

4.6.5 Mercury activated aluminum anodes and zinc anodes shall not be used in water systems where humans and/or animals may consume the water.

4.7 D.C. Power Source

4.7.1 Install the rectifiers in non-hazardous areas where possible and use oil-immersed rectifier units (Type OA per 17-SAMSS-004 or 17-SAMSS-005) inside hydrocarbon plant areas, in all locations that are within 30 meters of hydrocarbon plant perimeter fencing (outside) and within 1 km of a coastline.

The rectifier enclosure type shall be determined based on the electrical classification requirements at the location where the rectifier will be

installed. However, if requested by the Cathodic Protection Proponent Organization, Type OA (oil-immersed) shall be used in coastal or plant areas where aggressive atmospheric corrosion may occur.

Exceptions:

The DC power supply for a grid or continuous impressed current anode CP system can be air cooled (NEMA 4X) and need not comply with the requirements of 17-SAMSS-004 and 005 but shall be supplied by a Saudi Aramco approved manufacturer.

DC power supplies shall have a maximum rated output voltage of no greater than 100 volts. The sizing of the rectifier shall be optimized and based on the overall circuit resistance. Rectifier sizes other than those listed in SAMSS category 17 can be used, but must be approved by the Supervisor of the Cathodic Protection and Coatings Unit of CSD. The power supply shall be sized to compliment the specific anode requirements and must be suitably classified for the area of installation.

4.7.2 Rectifiers shall be installed in locations accessible to operations and maintenance personnel for repair and periodic monitoring.

4.8 Cables

All cathodic protection cables including the primary positive and negative cables shall be sized to comply with the most recent edition of the National Fire Protection Association NFPA 70, National Electric Code (NEC).

Commentary Note:

Use Table 310-16, Column for 90°C rated cables of the latest NEC Handbook to calculate the ampacity of HMWPE cables, and consider an ambient temperature of 40°C.

5 Installation

5.1 Galvanic Anodes

Galvanic anodes shall be installed in accordance with latest revisions of Standard Drawings AA-036354, AA-036762 or AC-036388.

5.2 Impressed current Anodes

Impressed current anodes shall be installed in accordance with a latest revision of Standard Drawing AA-036353. Impressed current anode material properties are shown in Section 4.3.

5.3 D.C. Power Source

5.3.1 The rectifier shall be installed in accordance with SAES-P-100, SAES-P-104, SAES-P-107, SAES-P-111, SAES-B-068, 17-SAMSS-004, 17-SAMSS-005, and Standard Drawing AA-036378.

5.3.2 AC power input to the rectifier shall be through a fused disconnect switch or circuit breaker, enclosed in a NEMA 3, NEMA 4 or NEMA 4X (for locations within 1 km of the coast). The enclosure shall be fitted with lockout provision, located within 3 meters of the rectifier, and less than 1.8 meters high in an accessible location. For more details on the enclosures and hardware fittings, refer to SAES-P-104. The current rating of the protective device shall not be more than 125% (or as near as is commercially available) of the rectifier input current at rated load.

Commentary Note:

No overcurrent protection is required for the disconnect switch on the primary feeder of the rectifier, if the circuit breaker of the rectifier has a proper overcurrent protection.

5.4 D.C. Cables

5.4.1 All buried D.C. cables shall be installed in accordance with Standard Drawings AA-036675 and AD-036132. Junction boxes for the D.C. cables shall be manufactured in accordance with 17-SAMSS-008.

5.4.2 All buried D.C. cables (anode, bond, positive, and negative) shall be identified by cable route markers in accordance with Standard Drawing AB-036351.

5.4.3 Positive cables for direct burial or submerged usage shall be checked, just prior to installation, with a pulse-type holiday detector set at 18,000 D.C. volts. Cable that is found to have any holidays on its insulation jacket shall be rejected. Repair of the insulation jacket for buried or submerged positive cable by any method is not acceptable.

5.4.4 Negative cables for direct burial or submerged usage shall be visually checked for insulation jacket damages. Cable with visible insulation jacket damage shall be repaired with 3 half lap layers of plastic vinyl tape over 3 half lap layers of rubber tape.

5.4.5 All negative drain cable connections to steel pipes or other structures shall be made using thermite welds in accordance with Standard Drawing AB-036381.

5.5 Concrete Foundations and Footings

Concrete foundations, footings and supports shall be constructed in accordance with SAES-Q-001.

5.6 Fencing

5.6.1 Rectifiers shall not be located inside an electrical substation or other fenced area that is not normally accessible to cathodic protection operating and maintenance personnel, unless the fencing around the area is modified to allow access to the rectifier.

5.6.2 Guardrails are required around unfenced rectifiers and junction boxes located inside plants and exposed to potential damage from vehicular traffic.

5.7 Grounding

Grounding for cathodic protection installations and associated components shall comply with SAES-P-111.

6 Commissioning and Inspection

6.1 Commissioning

All pre-commissioning and commissioning shall be done in accordance with SAEP-332 and GI-0002.710. All cathodic protection systems for tanks and vessels shall be commissioned within 30 days after completing the system installation.

6.2 Inspection

Before the start of construction, Project Inspection shall be notified so that inspection coverage can be provided during construction. Test data sheets shall be provided to the Inspection Department for review at least three days before, and no more than one week before the start of construction.

7 Records

All Construction drawings shall be revised to show the "as-built" cathodic protection system. Copies of the as-built drawings shall be submitted to the cathodic protection proponent department and the Consulting Services Department within sixty (60) days of project completion. Corrections (if any) shall be completed within thirty (30) days and resubmitted.

Revision Summary

28 April, 2004	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.