Engineering Standard

14 May 2023

SAES-X-500
Cathodic Protection of Vessel and Tank Internals

Document Responsibility: Cathodic Protection Standards Committee

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Summary of Changes

Paragraph Number		Change Type (Addition, Modification, Deletion, New)	Technical Change(s)
Previous Revision 01 February 2021	**Current Revision** 14 May 2023		
6.2.14	6.2.14	Addition	Requirement to isolate internal members i.e., stainless steel coalescence packing at all points of contact between these two structures and testing requirement for isolation has been added.
6.3.3	6.3.3	Modification	Clarification on use of section 6.3.3 for multiple galvanic anodes.
6.3.7	6.3.7	Modification	Need to energize the CP system within 45 days or provide short term protection.
6.4	6.4	Addition	Current density values applicable for water resistivity values of below 100 ohm-cm

1 Scope

1.1 This standard prescribes the minimum mandatory requirements governing the design and installation of cathodic protection systems for the internal surfaces of new metallic vessels and tanks. For existing tanks and vessels this standard may be used as guideline considering the CP requirements mentioned in section 1.2 below.

1.2 This standard is applicable to but not limited to the vessels and tanks categorized in Table 1.

2 Conflicts and Deviations

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

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

3 References

All referenced specifications, standards, codes, drawings, and similar material are considered part of this Engineering Standard to the extent specified, applying the latest version, unless otherwise stated.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

SAEP-302	Waiver of a Mandatory Saudi Aramco Engineering Requirement
SAEP-303	Engineering Reviews of Project Proposal and Detail Design Documentation
SAEP-332	Cathodic Protection Commissioning
SAEP-333	Cathodic Protection Monitoring

Saudi Aramco Materials System Specification

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	Impressed Current Cathodic Protection Cables
17-SAMSS-018	Remote Monitoring System (RMS) for Cathodic Protection Applications

Saudi Aramco Best Practices

SABP-X-001	CP Design Package Preparation
SABP-X-003	Cathodic Protection Installation Requirements

Saudi Aramco Standard Drawings

AA-036353	Water Storage Tanks Impressed Current C.P.
AA-036354	Water Storage Tanks Galvanic Anode C.P.
AB-036378	Cathodic Protection Onshore Rectifier Installation Details
AA-036388	Internal Galvanic Anodes Installation Details for Vessels
AA-036389	Galvanic Anode Details
AA-036762	Crude and Product Tank Bottom, Internal, Magnesium Anode Installation
AD-036785	Symbols for Cathodic Protection

3.2 Other References

National Fire Protection Association

NFPA 70	National Electric Code (NEC)

The Association for Materials Protection and Performance (AMPP/NACE)

AMPP SP0388-2018	Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks
AMPP SP0196 – 2020	Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks
AMPP SP0575 – 2007	Internal Cathodic Protection (CP) Systems in Oil-Treating Vessels

4 Terminology

4.1 Acronyms

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers (USA)
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CP	Cathodic Protection
CSD	The Saudi Aramco Consulting Services Department
GOSP	Gas and Oil Separation Plant
ICCP	Impressed Current Cathodic Protection
MSAERs	Mandatory Saudi Aramco Engineering Requirements
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association (USA)
RSA	Saudi Aramco Responsible Standardization Agency
SAES	Saudi Aramco Engineering Standard
WIP	Water Injection Plant

4.2 Definitions

AA:	The ANSI cooling class for a dry-type self-cooled transformer or reactor that is cooled by the natural circulation of air. Syn.: AN (IEC), See definition 3.1 in IEEE C57.12.
Anode:	An impressed current or a galvanic anode for cathodic protection applications.
Anode Cable:	A cable directly connected to an impressed current or galvanic anode.
ANV:	The ANSI cooling class for a dry-type non-ventilated self-cooled transformer, which is so constructed as to provide no intentional circulation of external air through the transformer, and that operates at zero-gauge pressure. Syn.: ANAN (IEC), See definition 3.15 in IEEE C57.12.

Armored Cable:	Armored cable for cathodic protection is a single core insulated cable manufactured with a double layer spiral wound insulated galvanized steel sheath to provide mechanical protection, and typically used for subsea applications.
Bond Cable:	A cable installed between two metallic structures to provide electrical continuity between the structures for the purpose of cathodic protection.
Buyer:	Saudi Aramco Purchasing Department Representative
Buyer's Representative:	The person or persons designated by the Purchasing Department to monitor/enforce the contract. Normally, this is the on-site inspector.
CP Assessment Probe:	A CP assessment probe is a multi-electrode probe designed to enable measurement of the soil resistivity in addition to representative polarized and depolarized potentials for the pipeline or other buried or immersed metallic structure at the probe location.
CP Coupon:	A CP coupon is a single electrode coupon that has been designed to enable measurement of representative potentials, current densities, or corrosion rates on a pipeline or other buried or immersed metallic structure at the coupon location.
CP System Operating Circuit Resistance:	The total resistance seen at the output of a CP power supply or the total working resistance in a galvanic anode system.
CP System Rated Circuit Resistance:	The rated output voltage of a cathodic protection power supply divided by the rated output current. For photovoltaic power supplies, the rated output current is the design commissioning current.
Design Agency:	The organization responsible for the design of the pipeline and associated CP system. The Design Agency may be the Design Contractor, the Lump Sum Turn Key Contractor or an in-house design organization of Saudi Aramco.
Drain Point:	The location on the cathodically protected structure where the negative cable from the T/R or negative junction box is fastened to the structure.
Foundry (for anodes):	An anode foundry is a facility that produces metal castings from either ferrous or non-ferrous metals or alloys.
Galvanic Anodes:	Anodes fabricated from materials such as aluminum, magnesium or zinc that are connected directly to the buried structure to provide cathodic protection current without the requirement for an external cathodic protection power supply. Galvanic anodes are also referred to as sacrificial anodes.
Hazardous Areas:	Those areas where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or filings (see NEC Article 500).
Impressed Current Anodes:	Anodes typically fabricated from High Silicon Cast Iron (HSCI) or Mixed Metal Oxide (MMO) that are connected through a DC power supply to the buried or immersed structure to provide cathodic protection current.

Lead Wire (for anodes):	A cable directly connected to an anode.
Manufacturer:	The Company that assembles the components for the finished product and provides the finished product either through a Vendor or directly to Saudi Aramco.
Mill (for anodes):	An anode mill is a facility that produces anodes such as MMO or Platinized Niobium (without lead wires) for cathodic protection applications (or any other anode type that does not involve casting).
Negative Cable:	A cable that is electrically connected (directly or indirectly) to the negative output terminal of a cathodic protection power supply or to a galvanic anode. This includes bond cables to a cathodically protected structure.
Non-incendive Equipment:	Equipment having electrical/electronic circuitry that is incapable, under normal operating conditions, of causing ignition of a specified flammable gas-air, vapor-air, or dust-air mixture due to arcing or thermal means. (See NEC Article 100).
Off-Plot:	Off-plot refers to any area outside of the plot limits.
ONAN:	The ANSI cooling class for a transformer or reactor having its core and coils immersed in mineral oil or synthetic insulating liquid with a fire point less than or equal to 300▪C, the cooling being effected by the natural circulation of air over the cooling surface. (ONAN was previously termed OA). See definition 3.303 in IEEE C57.12.
On-Plot:	On-plot refers to any area inside the plot limits.
Perimeter Fence:	The fence which completely surrounds an area designated by Saudi Aramco for a distinct function.
Photovoltaic Module:	A number of solar cells wired and sealed into an environmentally protected assembly.
Pipeline:	The term "pipeline" is used generically in this standard and can be used to refer to any type of pipeline.
Plant Area:	A plant area is the area within the plot limits of a process or storage facility.
Plot Limit:	The plot limit is the boundary around a plant or process facility. The plot limit may be physical such as a fence, a wall, the edge of a road or pipe rack, chains and posts or a boundary indicated on an approved plot plan.
Positive Cable:	A cable that is electrically connected (directly or indirectly) to the positive output terminal of an impressed current cathodic protection power supply, including impressed current anode cables.
PMT:	Project Management Team used as a truncated version of Saudi Aramco Project Management Team or SAPMT.
Process Pipeline:	A pipeline typically associated with a plant process and typically above ground within a plant facility.
Production Pipeline:	A pipeline transporting oil, gas or water to or from a well. These include flow-lines, test-lines, water injection lines and trunk-lines.

Reference Electrode:	An industry standardized electrode used as a common reference potential for cathodic protection measurements. A copper/copper sulfate (Cu/CuSO4) reference electrode is typically used for soil applications. A silver/silver chloride (Ag/AgCl/0.6M Cl) reference electrode is typically used for aqueous applications.
Resistivity Meter (such as Megger Tester or equivalent):	A meter designed to measure ground resistivity, or can be connected to measure resistance in a format that excludes the resistance of the test wires.
Subject Matter Expert (SME):	For the purposes of this standard, the SME shall be the assigned Consulting Services Department cathodic protection specialist.
Thermite Weld:	An exothermic process for use in making electrical connections between two pieces of copper or between copper and steel.
T/R:	Transformer/Rectifier - A cathodic protection power supply that transforms and rectifies AC power into an adjustable output DC power for cathodic protection applications. Typically abbreviated or truncated as "T/R" or "Rectifier".
Utilization Factor:	Utilization factor is a constant value, depending upon the shape of anode and how it is attached, relates to reduction in anode size due to consumption to the minimum size before it ceases to provide the required current output.
Vendor:	A company that receives a purchase order to supply the finished product, material or equipment. The Vendor may also be the Manufacturer.

5 Design Review and Approval

5.1 The proposed construction drawings and the related cathodic protection design information for every design package in accordance with SAEP-303 shall be submitted to the CP Proponent organization and to Saudi Aramco's Consulting Services Department (CSD) for review and approval.

Notes:

1) *PMT may request assistance from CSD for the verification of the qualifications of the Design Contractor's engineer responsible for designing the CP systems.*
2) *It is recommended that the CP Design Agency hold a pre-design meeting with CSD and the Proponent CP Group to outline the design approach for the Project Proposal and Detailed Design.*

5.2 The Design Agency shall not issue drawings for construction until the drawings have been reviewed and approved in writing by CSD and the CP Proponent organization or where applicable by the Saudi Aramco approved local design office Engineers and the CP Proponent organization.

5.3 Product hardware and software specifications and relevant design information for all remote monitoring equipment proposed for cathodic protection systems shall be submitted to the Supervisor of IT/COD/SCSD (Information Technology/Communication Operations Dept/Satellite & Communication Support Div.) for review and approval during the Project Proposal and Detail Design phases of the Project.

5.4 The Project Proposal package shall provide all general design considerations that can be developed without requiring measurement of field data. The process data including but not limited to type of service, operating temperature, operating pressure, coating details, pH and

TDS of electrolyte, H2S, oxygen, and Cl content along with existing CP system details (if any) shall be provided as an input by the PMT team after collecting the same from Proponent.

5.5 DBSP and project proposal does not require conducting a site visit unless that is mandatory to complete the package. The proposed construction drawings and the related cathodic protection design information for every design package shall at minimum be submitted to the CP Proponent organization and to Saudi Aramco's Consulting Services Department (CSD) or where applicable to the Saudi Aramco approved local design office Engineers for review and approval. The most up to date list of approved design offices is posted on ShareK and also can be obtained from CSD (if required).

5.6 Unless specifically requested by PMT, DBSP does not need to be reviewed or approved by CSD per SAEP-303. The DBSP shall specifically state if cathodic protection is required, or is not required, as dictated by SAES-X-500. No other design considerations for cathodic protection are required for the DBSP.

5.7 Unless specifically requested by PMT, project proposal does not need to be reviewed or approved by CSD. Project Proposal packages submitted to CSD for review shall provide all design considerations that can be developed without requiring the measurement of field data or a site visit.

The Project Proposal and 90% Design package shall include (Refer to SABP-X-001 for details):

a. The detailed CP Design Philosophy, scope of work / basis of the CP design with reference to project specifications and applicable standards.
b. List all Critical CP Design's assumptions, limitations and exclusions clearly.
c. Calculations of surface area of the structure to be protected.

Notes:

1. *Surface area calculations shall be verified by PMT and/or proponent, review and approval of any design packages by CSD is based on verified surface area values provided in the design package.*
2. *Any change in surface area after CSD approval of CP design package shall be reconsidered by CP Designer / CP Contractor in revised CP Design package and require review and re approval from CSD.*

d. All design calculations and applicable field data required to verify design compliance with Saudi Aramco Cathodic Protection Engineering Standards.
e. Professionally drafted full size Index "X" CP drawings that:

- Detail each CP item by description and stock number if applicable.
- Detail the proposed location for each piece of CP equipment including but not limited to T/Rs, anodes, junction boxes and test stations.
- Detail and specifically identify all cathodic protection cables including all anode, structure, bond, and T/R cables.
- Clearly identify the specific and individual cable routing and termination points within the respective junction boxes, bond boxes, and T/Rs.
- Detail all cathodic protection equipment using the cathodic protection symbols shown on Standard Drawing AD-036785 "Symbols for Cathodic Protection".

f. All details for the Remote Monitoring System including details on the hardware, software, and connectivity.
g. Detail all existing CP installations that could have an effect on the new CP system, and also provide information on spare current capacity of existing CP systems that will be utilized by the project.
h. All calculations and applicable field data are required to verify design compliance with the Saudi Aramco Cathodic Protection Engineering Standards. CSD's approval of the design calculations, using average fluid resistivity values, does not relieve the designer from his responsibility of meeting the required potential criteria stated by this standard.

Notes:

1. *Cathodic protection design considerations begin at the Design Basis Scoping paper (DBSP) stage and shall be reasonably developed by the Project Proposal stage. The Project Proposal Design Package shall include all design considerations that can be developed without acquiring actual field measurement data, including spare system capacity within the plant, proposed anode type(s) and sizing of the cathodic protection power source(s).*
2. *The Detailed Design Package submitted to CSD for review, shall present a complete and comprehensive cathodic protection system design including all required field measurement data, calculations, a detailed description of the proposed cathodic protection equipment, and a set of detailed drawings that illustrate the proposed placement of all cathodic protection equipment and the associated protected structures.*

5.8 The Project Proposal and 90% Detailed Design Package shall include a specific statement in the scope of work that clearly identifies any requirement to provide CP based on the data provided.

5.9 The Project Proposal and 90% Detailed Design Package shall provide clear direction on the general design approach with respect to the following:

The CP system shall be:

- Galvanic, or
- AC powered impressed current TR considering
  - air cooled, or
  - oil cooled
  - single phase, or
  - three phase

5.10 The Project Proposal and 90% Detailed Design Package shall clearly state if remote monitoring equipment will be included per 17-SAMSS-018 with the CP power supplies and if so it shall provide the following general design information:

a. Will the CP power supply be provided with:
- signal transmitters, or
- a Remote Monitoring Unit (RMU)

b. What operating parameters are going to be monitored (must meet minimum requirements)

c. What communication system will be used for the remote monitoring system?

d. What software will be supplied for the CP Proponent? If the data is not transmitted to the area Saudi Aramco PI data base, then the software shall be provided through the Project.

6 General Design Requirements

6.1 Contractor/Designer Qualifications

6.1.1 Cathodic protection designs shall be completed by Saudi Aramco approved local design offices with a minimum of five years verifiable cathodic protection design experience and a minimum industry qualification of NACE CP Level 4 and BS degree. Indicate the NACE CP level, certification number, name of designer and/or his signature/initial in the design package.

6.1.2 Field measurements required for the design, survey, installation, walk-through, pre-commissioning, commissioning, inspection, monitoring, restoration, replacement, troubleshooting, field-investigation, assessment etc. shall be performed by an Engineer or Technician with a minimum industry certification level of NACE CP Level 2. Indicate the NACE CP level, certification number, name of designer and/or his signature/initial in the design package.

Note:

PMT may request assistance from CSD for the verification of the qualifications of the Design Contractor's engineer responsible for designing the CP systems and to approve new designers.

6.2 General / Philosophy / Limitations

When cathodic protection is required, based on recommendations from proponent considering important factors including but not only limited to mentioned in Note 1 of section 1.2, as appropriate corrosion mitigation measures, following CP design parameters shall be considered.

6.2.1 Cathodic protection is required for the internal surfaces of metallic tanks and vessels based on the following:

e. Cathodic protection shall be designed based on actual resistivity if the resistivity of the electrolyte is less than 2,000 ohm-cm

f. Cathodic protection shall be designed based on design input of 2,000 ohm-cm if the actual resistivity of the electrolyte is between 2,000 – 5,000 ohm-cm. In such cases, potential criteria is not applicable for commissioning or commissioning shall be carried out during hydrostatic test (where possible).

g. If the actual resistivity of electrolyte is greater than 5,000 ohm-cm, cathodic protection is only required if deemed necessary by the Cathodic Protection Proponent Organization and concurred by Saudi Aramco's Consulting Services Department.

6.2.2 Determination of Need for CP in oil treating vessels is further explained in section 3.2.1 of NACE SP0575.

6.2.3 Impressed Current Cathodic Protection (ICCP) is not recommended for hydrocarbon and chemical tanks due to safety reasons and galvanic CP shall be considered for such environments. For safety precautions while designing CP systems in oil-treating vessels refer to Section 9 "Safety" of NACE SP0575 – 2007.

6.2.4 Cathodic protection cannot reverse the corrosion damage that has already occurred. Moreover, cathodic protection cannot protect surfaces that are not in contact with electrolyte (non-submerged) during operation.

6.2.5 The CP system for vessels shall be based on internal configuration of the vessel. Compartmented vessels shall have at least one anode installed in each compartment exposed to the corrosive field. Anodes shall be placed such that CP current can reach to all surfaces exposed to electrolyte.

6.2.6 Number, weight and shape of anodes required for CP of vessels depends on surface area to be protected, current density required, anticipated anode output, vessel configuration and design life. For typical vessels requirements of CP system including number, type and weight of anodes etc. are governed by Standard Drawing AA-036388.

6.2.7 Only zinc alloy anodes typically known as "high temperature zinc (HTZ)" suitable for service at elevated temperatures from 50 - 70°C, aluminum alloy anodes shall be used above 70°C in all applications. Refer to Standard Drawing AA-036389.

6.2.8 Anode monitoring system (AMS) is mandatory requirement for CP system of all vessels regardless of application. Refer to Standard Drawing AA-036389.

6.2.9 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 AD-036785.

6.2.10 Cathodic protection of sumps and bottoms of crude tanks and product storage tanks shall be cathodically protected by galvanic anodes according to Standard Drawing AA-036762.

6.2.11 For galvanic anode system for tank internals, CP designers shall be aware of limitations of CP and tank design effects on CP. Please see sections A.5 and A.6 of NACE SP-0196.

6.2.12 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.

6.2.13 CP designs as per standard drawings AA-036389 and AA-036762 with no change / modification prepared by Saudi Aramco approved CP designers can go to construction without CSD approval; however, such designs shall still be reviewed by Area Technical Support and/or Proponent.

Notes:

1. *CP designs that use standard drawings but considers several modifications due to either changes to dimension of the tank/vessel or process parameters etc. shall be submitted to CSD for review and approval.*
2. *Anode quantity mentioned in the standard drawings shall be taken as the minimum requirements only.*

6.2.14 For Tank Internal CP system, all internal metallic structures, i.e., pipework and appurtenances shall be coated (where applicable) and included in CP surface area calculations where they are immersed. For galvanic CP system in oil treating vessels, coating shall be considered for all internal mixed metal structures. Where coating is not possible or not applicable, i.e., stainless steel coalescence packing, it shall be designed to remain electrically isolated from the structure at all points of contact between these two structures throughout the design life. This is required to avoid accelerated corrosion of the vessel surface due to excessive CP current drain to stainless steel internals.

To ensure proper isolation & to verify its integrity, testing shall be carried out at all points of contact between stainless steel (SS) & carbon steel (CS) vessel surfaces using equipment based on Radio Frequency insulation/isolation testing prior to commissioning of system and during every T&I. Any failure of isolation shall be rectified and re-tested to ensure its continued effectiveness prior to re-commissioning of system. Use of multimeter and/or megger for isolation testing is not acceptable.

6.2.15 For applications with sea water electrolyte where ICCP system is selected with MMO anodes, MMO coatings thickness required shall be calculated based on manufacturer's data sheet and required current demand for each project considering handling damages and consumption rates during design life to avoid titanium substrate exposure to sea water which may result in failure if reached to its breakdown voltage.

6.3 Design Life

6.3.1 The minimum design life for galvanic anode systems shall be either 8 years, or the testing and inspection (T&I) period plus one year, whichever is greater.

6.3.2 The minimum design life for impressed current cathodic protection (ICCP) systems shall be either:

- 25 years, or
- Equal to design life of the structure (tank / vessel) or
- Three times the testing and inspection (T&I) period plus one year {3 x (T&I period +1)}, whichever is greater.

Note:

T & I period mentioned above is usually 7 years, addition of one year is required due to possible extension / necessary arrangements, etc.

6.3.3 The consumption rates detailed below in Table 2 shall be used for the calculation of the design life of galvanic anodes. Each anode must serve the required life taking into account its current output, the equation detailed below:

$$\left[\frac{Anode\ Weight\ (kgs)\ \times Utilization\ Factor}{\left\{Consumption\ Rate\ \times \left(\frac{Anode\ Open\ Circuit\ Potential\ -\ Protected\ Potential}{Anode\ Resistance}\right)\right\}}\right] \geq Design\ Life\ (Years)$$

Note:

For the life calculation of a galvanic anode system, use the lowest water (electrolyte) measured resistivity value for the planned. In case of multiple galvanic anodes, calculations mentioned in Section 6.3.4 are applicable.

6.3.4 Following equations shall also hold true for the proposed CP design:

$$\left[\frac{Current\ Demand(Amp)\ \times Design\ Life\ (years) x\ 8760}{Utilisation\ factor\ of\ Anode\ x\ Efficiency\ of\ Anode}\right] \leq Total\ weight\ of\ all\ anodes$$

$$Individual\ anode\ current\ output\ \times Total\ Number\ of\ Anodes\ Proposed \geq\ Current\ Demand$$

Notes:

1. *Current demand shall be calculated by multiplying surface area to be protected with required current density.*
2. *Individual anode current output shall be calculated based on the resistance of selected anode (calculated using dimensions of anode) and electrolyte resistivity.*

6.3.5 The consumption rates detailed in Table 3 shall be used for the calculation of the design life of impressed current anodes using the equation detailed below:

$$\left[\frac{Total\ Weight\ of\ All\ Anodes(kgs)}{\{Consumption\ Rate\ \times\ CP\ Power\ Source\ Design\ Current\ Capacity\ \}}\right] \geq Design\ Life\ (Years)$$

6.3.6 The maximum allowable current density and voltage characteristics detailed in Table 4 shall be used for the design of impressed current anode systems.

6.3.7 Temporary CP is not required for tanks and vessels designed to be protected by galvanic anode CP system. For ICCP designed CP systems, CP system shall be energized as soon as possible (within 45 days) after the tank is filled with electrolyte, otherwise temporary CP shall be provided during installation / construction period and/or till ICCP system is turned ON.

6.4 Current Density Criteria

The system design shall provide the minimum current density values for coated and uncoated surfaces shown in Table 5.

6.5 Protection Criteria

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

6.5.1 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.

6.5.2 A minimum of 100 mV of cathodic polarization (potential decay) between steel-to-electrolyte. The "potential decay" is the decrease in potential between the "instant off" and the steady state off potential. Refer to NACE SP0388 for further details.

Note:

This criterion is applicable to ICCP system protected structures and shall not be used when mixed-metal components or dissimilar metals are in contact for example steel pipeline in contact with copper or stainless steel (pipe or tubing).

6.5.3 The maximum steel-to-electrolyte potential for impressed current systems shall be equal or less negative than negative 1.5 V (on) with reference to a silver/silver chloride electrode, or equal or less negative than negative 0.45 V (on) with reference to a zinc electrode.

Exception:

The maximum limit of the criteria can be exceeded subject to demonstration that polarized potential has not exceeded negative 1.15 V with respect to a silver/silver chloride electrode and negative 0.1 V with reference to a zinc electrode.

6.6 Anodes

6.6.1 Anode materials (manufactured in accordance with 17-SAMSS-006 or 17-SAMSS-007) shall be selected from Table 2 in Section 6.3.3 or Table 3 in Section 6.3.4.

6.6.2 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.

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

6.6.4 Zinc anodes shall not be used in environments where temperature exceeds 50°C, except for high temperature zinc anodes which meets the requirements in Table 2 of Section 6.3.3.

6.6.5 Mercury activated aluminum anodes and zinc anodes shall not be used in water systems where humans and/or animals may consume the water. All Saudi Aramco approved aluminum and zinc anodes do not contain mercury.

6.7 Circuit Resistance

6.7.1 For a T/R, the CP system rated circuit resistance shall be defined as the T/R rated voltage, divided by the T/R rated current. Rated voltages and currents are as detailed on the manufacturer's data sheet/plate.

Example, 1 ohm is the rated resistance for a 50V/50A rectifier.

6.7.2 The CP system operating circuit resistance for an ICCP system shall be defined as the total effective resistance seen by the output terminals of the respective ICCP power supply, and for calculation purposes shall include:

a. Anode resistance to water.
b. Positive cable resistance from CP power source to anodes.
c. Negative (cable)s resistance from CP power source to structure.
d. Effective resistance caused by +0.95 volts anode back emf for MMO in water plus the structure back emf -0.9 volts (example: -0.9 volts tank back emf + 0.95 volts anode bed back emf = 1.85 volts total between the anodes and structure).

6.7.3 ICCP system designs shall take into consideration the calculated operating resistance and shall size the positive and negative cables and voltage rating of the T/R such that the "calculated" operating output of the T/R complies with all of the following:

a. At the design stage only, the target commissioning current shall be achieved at a voltage between 40% and 60% of the T/R rated voltage output. The target commissioning current shall be achieved at a voltage between 30% and 70% of the T/R rated voltage output.
b. The normal operating output current shall be achieved with the voltage adjustment set at more than 10% of the available (rated) T/R voltage output.

Note:

The above section is a mandatory design requirement but is not a mandatory requirement for commissioning acceptance.

6.7.4 The CP system "operating" circuit resistance measured during commissioning of a new CP system shall not be greater than 90% of the CP power supply "rated" circuit resistance.

6.8 DC Power Source

6.8.1 Cathodic protection rectifiers shall be manufactured in accordance with 17-SAMSS-004 or 17-SAMSS-005.

6.8.2 Install the CP power supplies in accordance with Saudi Aramco Standard Drawing AB-036378 sheets 1 and 2.

6.8.3 Selection of type of T/R shall be as per Table 1 of 17-SAMSS-004. Use oil immersed T/Rs (type ONAN) inside hydrocarbon plant areas, for all outdoor marine environment applications, and for Class I Division 2 (Zone 2) applications.

6.8.4 DC power supplies shall have a maximum rated output voltage of no greater than 100 volts. The sizing of the T/R shall be optimized based on the circuit resistance in accordance with Section 6.7 of this standard.

6.8.5 For hazardous areas (maximum Class I, Zone 2), the design agency shall select a cathodic protection DC power supply (and other CP system equipment) that complies with the requirements of NEC Articles 500 to 504 for hazardous (Class I, Zone 2) areas. CP equipment shall not be placed in Class 1 Zone 1 areas.

6.8.6 Transformer/Rectifiers and junction boxes shall be permanently and systematically labeled in line with the plant electrical devices and equipment labeling system. Use T/R for transformer/rectifier and J/B for junction box. Transformer/rectifier example is ANDR-GOSP-1-T/R-07. Junction box example is ANDR-GOSP-1-T/R-07-J/B-12.

6.9 Cables

All cathodic protection cables including the primary positive and negative cables shall be as per 17-SAMSS-017 and sized to comply with the most recent edition of NFPA 70, National Electric Code (NEC).

Note:

For typical applications, use the 90°C column in Table 310.15(16) and refer to 310.15(B)(2) to consider an ambient temperature of 40°C to calculate the ampacity for HMWPE cables.

6.10 Junction Boxes

Cathodic protection junction boxes shall be manufactured in accordance with 17-SAMSS-008.

7 Installation, Records, Commissioning, and Inspection

Refer to Saudi Aramco Best Practice SABP-X-003. SABP-X-003 shall be deemed a mandatory document for this standard.

As built drawings and documents as well as Commissioning Reports shall be submitted to Proponent for review and approval.

Commissioning Reports shall be submitted to CSD for information and feedback.

Refer to Saudi Aramco Engineering Procedures SAEP-332 for commissioning and SAEP-333 for monitoring procedures.

Table 1: Cathodic Protection Requirements and Categories of Vessels and Tanks

A) List of Vessels and Tanks which shall be internally protected by CP	B) List of Vessels and Tanks for which CP Consideration depends on other factors
Water Storage Tanks, i.e., Potable Water, Fire Water, and Sea Water, etc. Sand Traps Condenser Water Boxes Salt Water Strainers Sewage Treatment Plant Slop Oil Tanks Wet Crude Separation Vessels, i.e., Desalters, Dehydrators, Oil and Water Separation Plants (WOSEP), Low Pressure Production Traps (LPPT), High Pressure Production Traps (HPPT) Effluents Tanks, Product Tanks, Sump Tanks, and all types of Chemical and Hydrocarbon Tanks that may accumulate a layer of water, condensate, or sediment in the bottom. Seawater Filters and Deaerators	RO Surge Tanks Hot Water Storage Tanks Cooling Water Surge Tanks Fresh or Lean DGA Storage Tanks Methanol Storage Tanks Glycol Storage Tanks Lube Oil Storage Tanks Gas Chiller Separators Regen Gas LP KO Drums Refrigerant Cooling Water Surge Drums Compressed Air Receivers LP Hot-water Expansion Tanks MP Hot-water Expansion Tanks Jet Fuel Tanks (Kerosene) Any other Tank / Vessel not included in the list A) and B)

Note:

For tanks and vessels listed in category B) CP requirement shall be considered based on Proponents past experience with similar structures and shall be based on many factors but not limited to electrolytic resistivity, corrosion inhibitor dosage, electrolyte's corrosiveness, possibility of water condensate, pH of electrolyte, Chloride, H2S, and oxygen concentration in the electrolyte.

Table 2: Consumption Rates for Galvanic Anodes (kg/A-Y)

Structure	ANODE TYPE			
	Al	Mg	Zn	Zn (High Temp) [1]
Water Storage Tanks	3.8	10.95	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

Note (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.

Note (2): Process vessels for this application are those vessels that contain no dissolved H2S and normally operate at temperatures below 50°C.

Note (3): Process vessels for this application are those vessels that contain dissolved H2S and normally operate at temperatures above 50°C.

Note (4): N/A indicates not applicable, or not suitable for this application

Note (5:) The consumption rates detailed in Table 2 are corrected for efficiency, however, a utilization factor of 0.85 shall be included in the calculations.

Table 3: Design Parameters for Impressed Current Anode Materials

Anode Material	Consumption (kg/A-Y)	Current Density Maximum (mA/cm^2)[2]
HSCI	0.5	0.7
MMO[1]	Not applicable (see manufacturer's specification for 25 years life)	7.0 (for fresh water) 35 (for sea water)

Note (1): Inert anodes (i.e., MMO) shall not be used in vessels that have hydrocarbon products (asphaltine).

Note (2): Use of manufacturer specification may be allowed backed by relevant test certificates from reputed third party laboratory or in-house R&DC test results and part of the CP calculations for review and approval by Saudi Aramco.

Table 4: Current Density and Voltage Maximums for Impressed Current Anodes

	ANODE TYPE (1)	
	HSCI	Mixed Metal Oxide
Current (mA/ cm^2)	0.7	60.0 (Salt Water)
Voltage (volts)	100	Per Manufacturer Rating

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

Note (2): Inert anodes (i.e., MMO) shall not be used in vessels that have hydrocarbon products (asphaltine).

Table 5: Minimum Current Density Requirements (mA/m^2)

Surface	Current Density(4)		
	Process / Water(1)	Process / Water(2)	Water Resistivity values of below 100 ohm-cm(3)
Coated Tanks	0.5	3	13.0
Coated Vessels	3.0	11.0	13.0
Uncoated Tanks & Vessels	30.0	108	65.0

Note (1): Tanks and vessels for this application are those vessels that contain no dissolved H2S and normally operate at temperatures below 50°C.

Note (2): Tanks and vessels for this application are those vessels that contain dissolved H2S and normally operate at temperatures above 50°C.

Note (3): The current density values mentioned in this column are also applicable for electrolytic resistivity values of below 100ohm.cm including sea water.

Note (4): Suitable temperature correction factor shall be applied to values mentioned above for tanks and vessels that contain no dissolved H2S and operating more than 50°C.

Document History

14 May 2023	Major	Reaffirmed the content of the document, and reissued with several changes and mandated the need for NACE CP qualifications.
01 February 2021	Editorial	Editorial revision to extend due date to 2023.
18 October 2018	Editorial	Editorial revision.
18 April 2018	Major	Major revision incorporating all ideas and comments accepted during value engineering workshop
24 July 2013	Editorial	Editorial revision.