



Engineering Standard

SAES-X-400

13 December 2011

Cathodic Protection of Buried Pipelines

Document Responsibility: Cathodic Protection Standards Committee

Saudi Aramco DeskTop Standards

Table of Contents

1	Scope.....	3
2	Conflicts and Deviations.....	3
3	References.....	3
4	Definitions.....	6
5	Design Review and Approval.....	9
6	General Design Requirements.....	11
7	CP System Performance Criteria	24
8	CP System Equipment Requirements.....	29
9	Installation and Records.....	33
	Appendix 1 – Quality Assurance Check List for Pipeline CP System Designs.....	34

Detailed Index of Contents

1	Scope.....	3
2	Conflicts and Deviations.....	3
3	References.....	3
3.1	Saudi Aramco References.....	3
3.2	Industry Codes and Standards	6
4	Definitions and Abbreviations	6
5	Design Review and Approval	9
6	General Design Requirements	11
6.1	Contractor/Designer Qualifications and Equipment Requirements.....	11
6.2	Fundamental Design Calculations	11
6.3	Field Data.....	13
6.4	Production Pipelines - Special Considerations.....	15
6.5	Impressed Current Cathodic Protection	15
6.6	Galvanic Cathodic Protection.....	15
6.7	Temporary Cathodic Protection	17
6.8	Using Existing Cathodic Protection Capacity for New Pipelines.....	18
6.9	Electrical Isolation.....	19
6.10	Bonding	20
6.11	Monitoring.....	22
6.12	Induced AC Voltages	23
7	CP System Performance Criteria.....	24
7.1	Cathodic Protection Criteria.....	24
7.2	Anode Bed Design Life	25
7.3	Anode Bed Current Capacity and Consumption Rates	25
7.4	Circuit Resistance Criteria	26
8	CP System Equipment and Material Requirements.....	28
8.1	Anode/Anode Bed General Requirements	29
8.2	DC Power Supply	30
8.3	DC Cables	30
8.4	Junction and Bond Boxes	31
8.5	Pipeline CP Assessment Probes	31
9	Installation, Records, Commissioning and Inspection.....	33
	Appendix 1 – Quality Assurance Check List for Pipeline CP System Designs	34

1 Scope

- 1.1 This standard prescribes the minimum mandatory requirements governing the design and installation of cathodic protection systems for onshore pressurized buried metallic pipelines located outside of plant facilities. Typical pipelines addressed by this standard are; cross-country, production and utility pipelines.
- 1.2 Subsea pipelines and pipelines operated by Saudi Aramco Community Maintenance Departments are outside the scope of this standard.

2 Conflicts and Deviations

- 2.1 Conflicts between this standard and other applicable Saudi Aramco Engineering Standards, Material Specifications, Standard Drawings or forms shall be resolved in writing by the Design Agency representative through the Saudi Aramco Consulting Services Dept. Cathodic Protection Subject Matter Expert (SME).
- 2.2 Requests to deviate from this standard shall be submitted electronically through the SAP Waiver Process in accordance with [SAEP-302](#).

3 References

Referenced standards and specifications shall be the latest edition/revision unless stated otherwise.

Saudi Aramco's Engineering Standards intranet web site (<http://standards.aramco.com.sa/>) contains the latest revisions of all standards and standard drawings.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

[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-064](#)

Onshore and Nearshore Pipeline Safety

[SAES-X-600](#)

Cathodic Protection of Plant Facilities

Saudi Aramco Best Practices

[SABP-X-001](#)*CP Design Package Preparation*[SABP-X-003](#)*Cathodic Protection Installation Requirements*

Saudi Aramco Materials System Specifications

[02-SAMSS-008](#)*Insulating Joints/Spools for Cathodic Protection*[02-SAMSS-010](#)*Flanged Insulation Joints/Spools for Cathodic Protection*[17-SAMSS-004](#)*Conventional (Tap Adjustable) Rectifiers for Cathodic Protection*[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-012](#)*Photovoltaic Power Supply for Cathodic Protection*[17-SAMSS-017](#)*Impressed Current Cathodic Protection Cables*[17-SAMSS-018](#)*Remote Monitoring System (RMS) for Cathodic Protection Applications*

Saudi Aramco Standard Drawings

The following Saudi Aramco Standard Drawings provide installation and equipment fabrication details for cathodic protection systems:

[AA-036069](#)*Galvanic Anodes at Thrust Anchors*[AD-036132](#)*Termination Detail Cable Identification*[AA-036145](#)*Cable Splice Junction Box*[AA-036157](#)*Galvanic Anode 3-Pin Test Station*[AB-036273](#)*Surface Marker Underground Electric Cable*[AB-036274](#)*5 Terminal Junction Box*[AB-036275](#)*12 Terminal Junction Box*[AA-036276](#)*Multi-Purpose Junction Box*[AA-036277](#)*5 Terminal Bond Box Details*[AA-036280](#)*Photovoltaic Power System*

<u>AA-036346</u>	<i>Surface Anode Bed Details - Horizontal and Vertical Anodes (Sheets 1 & 2)</i>
<u>AA-036347</u>	<i>20 Terminal Junction Box</i>
<u>AA-036349</u>	<i>3 Terminal Bond Box Details</i>
<u>AA-036350</u>	<i>2 Terminal Bond Box Details</i>
<u>AB-036351</u>	<i>Marker Plate Details</i>
<u>AA-036352</u>	<i>Galvanic Anodes for Road and Camel Pipeline Crossings (Sheets 1 & 2)</i>
<u>AB-036378</u>	<i>Rectifier Installation Details (Sheets 1 & 2)</i>
<u>AB-036381</u>	<i>Cable Connections to Pipelines and Structures</i>
<u>AA-036385</u>	<i>Deep Anode Bed without Anode Support Pipe</i>
<u>AA-036389</u>	<i>Galvanic Anode Details</i>
<u>AB-036540</u>	<i>Mounting Support Details for Junction Boxes</i>
<u>AC-036660</u>	<i>Road Crossings for Pipelines</i>
<u>AA-036674</u>	<i>Bonding Details for Onshore Pipelines and Flowlines</i>
<u>AA-036675</u>	<i>Direct Buried Cable - Installation Details</i>
<u>AB-036677</u>	<i>An Overview - Architectural, Security & General Purpose Fencing</i>
<u>AA-036678</u>	<i>Security & General Purpose Fencing - Post & Fabric Details</i>
<u>AD-036785</u>	<i>Symbols - Cathodic Protection</i>
<u>AA-036865</u>	<i>Electrical Insulating/Isolating Assemblies</i>
<u>AB-036907</u>	<i>Test Stations for Buried Pipelines</i>

Saudi Aramco General Instructions

<i>GI-0002.710</i>	<i>Mechanical Completion and Performance Acceptance of Facilities</i>
<i>GI-0428.001</i>	<i>Cathodic Protection Responsibilities</i>

Saudi Aramco Inspection Procedure

<u>17-SAIP-50</u>	<i>Inspection Coverage of Cathodic Protection Deep Anode Beds</i>
-----------------------------------	---

3.2 Industry Codes and Standards

International Standards Organization

IS-15589-1 2003 Petroleum and Natural Gas Industries - Cathodic Protection of Pipeline Transportation Systems - Part 1: On-land pipelines

National Fire Protection Association

NFPA/NEC Handbook National Fire Protection Association Publication of the National Electrical Code

National Association of Corrosion Engineers

NACE RP0177 - 2000 Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems

NACE TM-0497-2002 Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems

4 Definitions and Abbreviations

This standard uses the following terminology:

Bond Cable: A cable installed between two metallic structures to provide electrical continuity between the structures for the purpose of cathodic protection.

Calcined Petroleum Coke Breeze: A carbonaceous backfill used as a conductive backfill media for impressed current anodes in soil.

CP: Cathodic Protection

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 or current densities on a pipeline or other buried or immersed metallic structure at the coupon location.

CP System Operating Circuit Resistance: The total effective resistance seen by the output terminals of the cathodic protection power supply, or the total working resistance in a galvanic anode system.

CP System Rated Circuit Resistance: The cathodic protection power supply rated output voltage divided by the rated output current. For photovoltaic power supplies, the rated output current for this calculation is the design current.

Cross Country Pipeline: A pipeline between; two plant areas, another cross-country pipeline and a plant area, or between two cross-country pipelines.

CSD: Consulting Services Department

Deep Anode Bed: Anode or anodes connected to a common CP power supply installed in a vertical hole (typically 25 cm diameter) with a depth exceeding 15 m (50 ft).

Design Agency: The organization or company contracted by Saudi Aramco for the design of a 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 rectifier or negative junction box is fastened to the structure.

Flow-line: A pipeline connected to a well.

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.

GOSP: Gas and Oil Separation Plant

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).

ICCP: Impressed Current Cathodic Protection

Impressed Current Anodes: Anodes fabricated from materials such as High Silicon Cast Iron (HSCI) or Mixed Metal Oxide (MMO) that are immersed or buried and are connected to the positive terminal of a DC power supply to provide cathodic protection current.

Megger: 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.

MSAER: Mandatory Saudi Aramco Engineering Requirements

NEC: National Electric Code

NEMA: National Electrical Manufacturers Association (USA)

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.

Off-Plot: Off-plot refers to any area outside of the plot limits.

On-Plot: On-plot refers to any area inside the plot limit.

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 hydrocarbon storage facility. Scraper trap and launcher areas are not Plant areas.

Plot Limit: The plot limit is the boundary around a plant, process or hydrocarbon storage 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 ICCP 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/CuSO_4) reference electrode is typically used for soil applications. A silver/silver chloride ($\text{Ag}/\text{AgCl}/0.6\text{M Cl}$) reference electrode is typically used for aqueous applications.

RSA: Responsible Standardization Agent - usually the Saudi Aramco CSD cathodic protection Subject Matter Expert or the Supervisor of the CSD Cathodic Protection Team.

SAES: Saudi Aramco Engineering Standard

SAPMT: Saudi Aramco Project Management Team (often shortened to PMT)

Soil Transition Point: The on grade location where a pipeline enters or exits the soil, i.e., above grade to below grade transition, or below grade to above grade transition.

Subject Matter Expert (SME): For the purposes of this standard, the SME shall be the assigned Consulting Services Department cathodic protection specialist.

Surface Anode Bed: Anode or anodes connected to a common CP power supply, installed either vertically or horizontally at a depth of less than 15 m (50 ft.).

Test-line: A pipeline that is used for testing an individual well or group of wells.

Thermite Weld: An exothermic process to make electrical connections between two pieces of copper or between copper and steel.

Transmission Pipeline: A cross country pipeline transporting product between GOSPs WIPs or other process facilities.

Trunk-line: A pipeline designed to distribute or gather product from two or more wells, typically connecting flow-lines or injection lines to the associated GOSP or WIP.

Utility-line: A pipeline designed to deliver an end use service product (typically water, gas or air).

WIP: Water Injection Plant

5 Design Review and Approval

- 5.1 The proposed construction drawings and the related cathodic protection design information for every design package shall be submitted to the CP Proponent organization (as defined by GI-0428.001) and to Saudi Aramco's Consulting Services Department (CSD) for review and approval.

Commentary Notes:

- 1) *As noted in GI-0428.001, PMT should 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.

- 5.3 Product hardware and software specifications and relevant design information for all remote monitoring equipment proposed for cathodic protection systems for the Saudi Aramco Pipelines organization shall be submitted to the Supervisor of IT/CIED/WEG 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 Project Proposal package should include:
- a. A scope of work including a specific statement that clearly identifies any additional requirement to provide CP for any existing pipeline.
 - b. Proposed locations of new cathodic protection systems on an overall CP system layout drawing, including proposed anode type(s) and estimated output ratings of the proposed cathodic protection power source.
 - c. Information on spare cathodic protection capacity (from nearby or adjacent pipelines) along the route of the proposed pipeline.
 - d. Information on all locations where the proposed pipeline will be mechanically connected to other facilities (plants, pipelines etc) with clear details on whether these other facilities will be electrically isolated.
- 5.5 The 90% Detailed Design package shall contain at minimum:
- a. The completed and signed "Quality Assurance Check List for CP Designs" attached to the cover letter or transmittal sheet for the design package (See [Appendix 1](#)).
 - b. The scope of work.
 - c. One full size professionally drafted Index "X" CP drawing illustrating the entire pipeline length; containing the following details:
 - The proposed location of each piece of CP equipment including but not limited to; rectifiers, anodes, junction boxes, bond stations, test stations, and bonds to structures.
 - Cathodic protection cables including all structure, bond, and rectifier cables; clearly identifying the termination points, cable size, type and length for each cable.
 - All proposed and existing CP installations in the area that may affect the new CP system or pipeline.
 - Existing pipelines that parallel within 50 meters, or cross the proposed pipeline.
-

- All mechanical tie-ins with details on placement of electrical isolation.
- d. All calculations and applicable field data required to verify design compliance with Saudi Aramco Engineering Standards for Cathodic Protection.
- e. All details for the Remote Monitoring System including details on the hardware, software and connectivity.
- f. The design package shall be submitted in the format specified in Best Practice [SABP-X-001](#) “CP Design Package Preparation.”

6 General Design Requirements

6.1 Contractor/Designer Qualifications and Equipment Requirements

Cathodic protection designs shall be completed by Engineers with a minimum of five years verifiable cathodic protection design experience and a minimum industry qualification of NACE CP Level 3. Field measurements required for the design shall be collected by an Engineer or Technician with a minimum industry certification level of NACE CP Level 2.

6.2 Fundamental Design Calculations

The detailed design and for a cathodic protection system for a new pipeline shall consider the new pipeline and associated CP equipment to be an independent system unless stated otherwise in the Project Proposal. The Project Proposal shall identify all locations where the new pipeline will be mechanically connected to existing facilities with or without electrical isolation and additional cathodic protection requirements shall be assessed accordingly.

Fundamental design calculations shall include:

- a) Determination of the total current required.
 - b) Optimum placement and sizing of the anode beds and CP power supplies with consideration given to maintaining potentials on the pipeline within the criteria detailed in [Table 1](#).
 - c) For calculations pertaining to permanent CP, assume the following:
 - A native state potential of -600 millivolts, and
 - A pipeline coating conductivity for FBE of 10 micro-Siemens/meter for typical backfill conditions.
-

Commentary Note:

For more detailed calculations, the following coating conductivities may be used:

- *30 micro-Siemens/M for pipelines in wet sand areas (subkha areas)*
 - *10 micro-Siemens/M for damp sand (typical)*
 - *1 micro-Siemens/M for dry sand (areas such as Shaybah dunes).*
- For calculations pertaining to temporary CP, assume a pipeline coating conductivity for FBE of 3 micro-Siemens/M for typical backfill conditions;

Commentary Note:

For more detailed calculations, the following coating conductivities may be used:

- *10 micro-Siemens for pipelines in wet sand areas (subkha areas)*
 - *3 micro-Siemens for damp sand (typical)*
 - *0.3 micro-Siemens for dry sand (areas such as Shaybah dunes).*
- d) Though not mandatory, it is preferred that the design include a current and potential attenuation model that considers:
- Permanent ICCP systems operating at 75% of rated current output.
 - Permanent galvanic anodes installed on the pipeline at locations such as road crossings or thrust anchors. For these calculations, magnesium anodes shall be considered to have an open circuit potential of -1.7 volts. Unless field data verifies otherwise, the soil resistivity for the calculation of the resistance to ground of the permanent magnesium anode(s) shall be assumed to be:
 - 10,000 ohm-cm in normally dry areas
 - 3,000 ohm-cm in areas where the backfill sand is likely to contain small amounts of moisture, and
 - 300 ohm-cm in normally wet areas including subkha.
 - Bonds to existing pipelines using the measured potential on the existing pipeline and an assumed resistance to ground of 0.015 ohms for the existing pipeline unless otherwise measured.
-

6.3 Field Data

6.3.1 Project Proposal

The project proposal does not require measurement of field data.

6.3.2 Detailed Design

The following field data are required to complete a detailed design package for a cathodic protection system for a new pipeline, and shall be included with all detailed design packages submitted for review.

a. Pipe-to-Soil Potentials

Pipe-to-soil potentials shall be measured along the proposed pipeline route on all buried pipelines that parallel within 30 meters of the proposed pipeline or cross the proposed pipeline route.

b. Existing CP Power Supplies

The location and equipment designation for any existing CP power supply within 250 meters of the proposed route for the new pipeline shall be recorded. If practical, the rating and operating output of these rectifiers shall also be recorded. If the rectifier ratings and operating outputs cannot be ascertained in the field, a list of these rectifiers shall be submitted by the PMT to the appropriate Proponent organization for determination of the ratings and updated operating outputs.

c. Soil Resistivity

Soil resistivity (conductivity) measurements shall be taken at the locations listed below.

- Proposed locations for impressed current anodes.
- Proposed locations for galvanic anodes.

6.3.3 Soil Resistivity Measurement

6.3.3.1 Surface Anode Beds

- a. Conduct soil resistivity or soil conductivity measurements at 10 meter intervals over the full length of the proposed surface anode bed location.

- b. The four pin Wenner method may be used in areas with nominal soil resistivities below 2000 ohm-cm. A “Geonics” or other non-contact electromagnetic soil resistivity/conductivity instrument shall be used in areas where the nominal soil resistivity exceeds 2000 ohm-cm.
- c. Measurements shall be taken for the planned installation depth of the anode bed.
- d. Mark the selected location of the surface anode bed with wooden or metal stakes at each end of the proposed anode bed location. Show the location on a detailed site sketch, and include this information on the CP design drawings.

6.3.3.2 Deep Anode Beds

- a. Soil resistivity or soil conductivity measurements for deep anode beds are recommended but are not mandatory for design.
- b. Mark the selected location of the deep anode bed with a wooden or metal stake. Show the location on a detailed site sketch, and include this information on the CP design drawings.

6.3.3.3 Distributed Anode Beds

- a. Conduct soil resistivity or soil conductivity measurements over a representative sample of the distributed anode installation locations.
- b. Ensure that the measurements are representative for the planned installation depths of the anodes based on the finished grade levels at the site.
- c. Show the location that each measurement was taken on a detailed CP layout drawing.

6.3.3.4 Galvanic Anode Locations

Measure the soil resistivity at the approximate location and depth for the anodes. This resistivity data shall be used in the detailed design to determine approximate anode discharge levels and the effect of the galvanic anode on the attenuation of impressed current on the new pipeline.

6.4 Production Pipelines - Special Considerations

- 6.4.1 The cathodic protection of buried “production” pipelines (i.e. flow-lines, test-lines, water injection lines and trunk-lines, or other pipelines connected directly to a well casing) shall be provided by the CP systems for the well casing(s) associated with the respective production pipeline.
- 6.4.2 Production pipelines that extend more than 25 kilometers away from the nearest well casing CP system shall be addressed in the detailed design of the CP system(s) for the associated well casing(s) and evaluated to determine if additional ICCP is required to maintain acceptable levels of cathodic protection. Additional CP shall be provided if required.
- 6.4.3 Production pipelines shall be provided with test stations, bond stations and bonding in accordance with this standard.

6.5 Impressed Current Cathodic Protection

Cathodically protect buried pipelines covered by the scope of this standard with impressed current cathodic protection (ICCP) within 30 days of burial of any section of the pipeline. If this schedule cannot be met, provide temporary cathodic protection in compliance with this Standard.

Exceptions:

Galvanic anodes with a calculated life greater than 20 years may be used instead of ICCP for buried sections of pipelines that are:

- reliably electrically isolated from all other underground metallic structures and require less than 2 amperes of current, or are*
- normally above-ground but have short buried sections such as camel crossings or road crossings.*

6.6 Galvanic Cathodic Protection

Unless otherwise noted in this Standard, galvanic anodes are supplemental to the ICCP system and shall be installed according to Standard Drawings AA-036352 and [AA-036069](#) for the structures detailed below in Table 1.

Table 1 – Magnesium Anode Requirements

Structure Type	Number of Magnesium Anodes ⁽¹⁾	Additional Comment
Buried Mechanical Fitting	One 32# prepackaged anode	Connect the anode to the fitting through a galvanic anode test station.
Casings (i.e., Road or Railway crossings)	Two 60# prepackaged anodes at each end of the casing for a total of four anodes per casing.	Splice each pair of anode cables together and connect to the casing through a galvanic anode test station at each end of the casing.
SSD fence crossings with bare copper ground cables	Two 60# prepackaged magnesium anodes buried within 3 meters of each side of the bare copper ground cable.	Splice the two anode cables together and connect to the pipe in a single test station located outside the SSD fence at a location convenient for CP Operations.
Thrust bored road crossings or Horizontal Directional Drilled	Two 60# prepackaged anodes at each end of the bore hole, for a total of four anodes per casing.	Splice each pair of anode cables together and connect to the casing through a galvanic anode test station at each end of the casing.
Below grade road crossings and camel crossings on normally above-ground pipelines without dedicated ICCP systems	One 60# prepackaged anode per pipe, plus one additional 60# prepackaged anode, i.e., one pipe requires two anodes, and two pipes would require three anodes.	For one pipe, place an anode on each side of the pipe along the center line of the crossing. Connect through a galvanic anode test station. For more than one pipe, place an anode on each side of the corridor and an anode in between, or beneath each pipe along the center line of the crossing. Splice the anodes to one cable and terminate in a bond box. Connect a wire directly to each pipeline and terminate each wire inside the bond box.
Pipeline thrust anchors located inside fenced areas	Two 60# prepackaged anodes, one on each side of the pipe.	Splice the two anode cables together and connect to the pipe through a galvanic anode test station.

Note ⁽¹⁾ Permanent galvanic anode installations in wet soil conditions or where resistivities are expected to be below 1000 ohm-cm, shall use bare (not prepackaged) 100 pound magnesium anodes instead of prepackaged 60 or 32 pound magnesium anodes.

Exceptions for Table 1:

- 1) *Pipeline thrust anchors at well sites with ICCP systems do not require supplemental galvanic anodes.*
- 2) *Galvanic anodes are not required for buried flare lines or blow-down lines or associated thrust anchors at well sites if the lines are permanently electrically continuous with the well casing ICCP system.*
- 3) *Impressed current anodes may be used instead of galvanic anodes if an existing impressed current distributed anode system is nearby.*

6.7 Temporary Cathodic Protection

6.7.1 Temporary CP shall be installed to provide short term cathodic protection only when:

- a. The permanent ICCP will not be energized within 30 days of burial of any portion of the pipeline, and
- b. The magnesium anodes and cross bonds installed during pipeline construction for permanent cathodic protection requirements will not provide enough CP (to achieve temporary criteria) for the new pipeline or pipeline segment.

Commentary Note:

The current density requirements and protection levels required for temporary CP can be found in Table 2 of this Standard.

- 6.7.2 The design for temporary cathodic protection shall consider the effect of the CP current that will be provided through the bonds that are going to be installed to parallel and crossing pipelines, and galvanic anodes installed at road crossing and thrust anchors.
 - 6.7.3 Where supplemental galvanic anodes are determined to be necessary for temporary cathodic protection, wherever practical, they shall be installed at permanent galvanic anode locations. The permanent junction box or test station facilities shall be used to terminate the supplemental galvanic anodes.
 - 6.7.4 Pipe-to soil potential survey data verifying that the temporary system is providing adequate protection shall be provided by PMT and submitted to the CP proponent monthly for the first 6 months, and every 6 months thereafter.
-

- 6.7.5 At locations where the permanent galvanic anode equipment will not work for effective temporary cathodic protection:
- Select low resistivity locations to maximize the current output and minimize the number of anodes required.
 - Install galvanic anodes on an "as required" basis, i.e., use the calculated numbers of anodes as a guide, and install anodes as required based on meeting the temporary CP protection criteria (Table 2).
- 6.7.6 Terminate galvanic anodes for temporary cathodic protection in a 3-pin test station using the installation details given in Standard Drawing AA-036352. The number of anodes required per location shall be based on the actual requirement and not as shown on the standard drawing. If the location for the 3-pin test station location coincides with a KM marker/CP test station location, a 1-pin test station is not required.

6.8 Using Existing Cathodic Protection Capacity for New Pipelines

- 6.8.1 The design of a new cathodic protection system for a pipeline shall take into consideration all aspects of existing cathodic protection that may affect the new pipeline.
- 6.8.2 Prior to beginning the detailed design for an impressed current CP system for a new pipeline or section of a new pipeline, the Design Agency shall determine the protection levels (pipe to soil potentials) of close by pipelines (within 50 meters) that may be influenced by the same cathodic protection system(s).
- 6.8.3 The output levels and capacities of the existing CP systems shall be determined by the Design Agency in cooperation with the CP Proponent.
- 6.8.4 The Design Agency shall consider the use of surplus capacity from the existing CP systems for the protection of new pipelines or pipeline segments. Designs for permanent ICCP systems that propose the use of surplus capacity from existing systems require written concurrence from the CP Proponent Organization.

Commentary Note:

Proponent or CSD signatures on review packages do not satisfy or substitute for the requirement for written concurrence from the CP Proponent Organization for the use of surplus CP capacity from the CP Proponent Organizations' existing CP facilities.

- 6.8.5 Where new pipelines share a common corridor with existing pipelines and will be bonded to the new pipelines, upgrading of the existing CP systems may be more cost effective than adding new CP systems in the parallel pipeline corridor. The Design Agency shall specifically address this point in the project proposal design package and include a statement confirming that this has been discussed with the CP Proponent, noting the final agreement on this subject.

6.9 Electrical Isolation

- 6.9.1 Electrical isolation is mandatory between new pipelines and all equipment and facilities operated by a different Proponent Organization. Typical locations where a change in Proponent may occur are:

- a. Onshore-offshore transitions
- b. Pipeline to Plant transitions

Exception:

If commissioning potentials are inadequate due to shorted conditions that cannot be corrected cost effectively, supplemental distributed ICCP may be provided in lieu of electrical isolation with written concurrence from the Pipeline CP Proponent and the CSD CP SME for pipelines.

- 6.9.2 Electrical isolation or supplemental cathodic protection is mandatory at the following locations:
- a. Scraper traps and valve stations
 - b. Product pipeline to bulk plant transitions
 - c. Pipelines between GOSPs, WIPs or other production facilities operated by a common Proponent.
 - d. Metallic supports including above ground bypasses and crossovers
 - e. Motor-operated valves not in seawater service
- 6.9.3 See materials specification [02-SAMSS-008](#) and [02-SAMSS-010](#), and Standard Drawing AA-036865 for details of pipeline isolation devices.
- 6.9.4 Do not install electrical isolating devices in buried or submerged portions of pipelines or in areas classified as hazardous locations.
-

6.10 Bonding

6.10.1 Bonding Requirements for Buried Pipelines

Bonding shall be provided at the following locations:

- a. Within 500 meters of the start and finish of parallel pipelines.
- b. Wherever parallel pipelines converge or diverge within 50 meters.
- c. At buried pipeline crossings. If crossing a corridor, bonds are only required to the two pipelines on the outer edges of the corridor, providing the separation between adjacent pipelines in the corridor is less than 50 meters.
- d. At all negative drain points (connection point for the negative cable) for ICCP power supplies for pipelines in parallel within 50 meters.

6.10.2 All pipeline bond terminations shall be made above grade in an approved electrical enclosure (bond box or junction box complying with [17-SAMSS-008](#)).

6.10.3 Bonding shall be completed according to Standard Drawing AA-036674.

6.10.4 The minimum bond conductor size shall be 16 mm² (#6 AWG).

6.10.5 Foreign pipelines bonded to Saudi Aramco pipelines shall be bonded through a variable resistor installed inside the bond box.

6.10.6 Bonding is mandatory at the following locations:

- a. ICCP system negative connection to pipe (drain point):

A bond box shall be installed above or immediately adjacent to the pipeline at the termination location (drain point) for the negative cable from the ICCP supply. A separate bond cable shall be installed to each buried non-abandoned pipeline located within 50 meters of the drain point bond box and shall be terminated in the drain point bond box. The cable from each pipeline shall be sized to facilitate balanced potentials on the pipelines based on field measurements of the potentials, and resistance to remote earth.

- b. New pipelines buried in an existing corridor:

New pipelines buried in an existing pipeline corridor within

50 meters of an existing pipeline shall be bonded to the nearest non-abandoned pipeline in the corridor through a bond box at:

- The beginning and end of a parallel segment.
- ICCP power supply locations.
- 10 km intervals along the parallel segment not already satisfied by at least one of the above two bullets.

Commentary Note:

If a new pipeline is 20 km long with the ICCP power supply located at the midpoint of the line, bonds to all paralleling pipelines within 50 meters of the new pipeline would be required at each end of the line, and at the ICCP power supply location. This arrangement would comply with item iii) above without need for additional bonding.

c. Buried pipeline crossings:

Bonding through an approved bond box shall be provided at all locations where buried; in-service, mothballed, or foreign metallic pipelines cross.

Exception:

Bonding is only required between a crossing pipeline and the outer pipelines in multiple pipeline corridor, provided adjacent pipelines in the corridor are not more than 50 meters apart.

6.10.7 Common Camel and Road Crossings

Bond normally above grade parallel pipelines, or a combination of above grade and buried pipelines that are separated by a distance of 50 meters or less at least once every 10 kilometers at the nearest common camel or road crossing. Place the bond on one side of the crossing according to Standard Drawing AA-036674.

Exception:

For normally above grade parallel pipelines, if there are no camel or road crossings within a 10km parallel section, (i.e., 10 km with no below grade section), then no bonding is required in this 10 km section. Bonds should be placed at the nearest road or camel crossing on each side of the 10 km above grade section.

6.10.8 Electrically Isolated Inline Spools

Electrically isolated spool joints typically used for instrumentation or

other applications shall be bonded around, preferably with a metal bond strap bolted to the outer flange on each end of the spool joint.

6.10.9 Electrically Isolating Devices

Provide bond boxes for all isolating devices installed in a pipeline. Bonding to piping on the non-Saudi Aramco plant side of an isolating device shall be through a variable resistor installed inside the bond box.

Exception:

Bond boxes are not required for isolation devices installed for short sections of buried piping protected by galvanic anodes.

6.11 Monitoring

Monitoring of cathodic protection systems shall be conducted by the Proponent CP organization in accordance with [SAEP-333](#).

6.11.1 Remote Monitoring

6.11.1.1 Remote monitoring equipment shall be provided with ICCP power supplies used for cross-country pipelines. Material specifications shall be provided by the respective CP Proponent Department.

6.11.1.2 The remote monitoring equipment shall be constructed to interface with the existing remote monitoring system being used by the respective CP Proponent Department.

6.11.1.3 PMT shall determine the specifications for the existing remote monitoring system and shall be fully responsible for providing this information to the CP Design Contractor and ICCP power supply vendor.

6.11.2 Test Stations

Provide a test station for measuring pipe-to-soil potential according to Standard Drawing AB-036907 at each:

- a. Kilometer marker of the buried sections of pipelines
 - b. Negative connection
 - c. Thrust anchor
 - d. Insulated cased crossing
-

e. Thrust bored road crossing

f. Paved road crossing

6.11.3 Soil Access Test Holes

Install soil access test holes, according to Standard Drawing AB-036907, in concrete and asphalt (paved) areas directly over the top of the pipe to be monitored. In concrete or asphalt areas, install one soil access hole at each of the following locations:

- a. Over the pipe, midway between each pair of distributed anodes.
- b. Over the pipe, in line with each distributed anode (directly across)
- c. One at each test station or riser used as a test station if there is no direct close proximity access to the soil.
- d. Above a pipeline at maximum 30 meter spacings in asphalt or concrete paved areas.

6.11.4 Below Ground to Above Ground Transition Areas

At pipeline transitions through asphalt or concrete, provide 30 cm of unpaved soil around the transition. A soil access test hole is not required at transition points with the 30 cm of clearance.

6.12 Induced AC Voltages

6.12.1 Qualitative Testing

Qualitative testing for induced AC voltages shall be completed for new pipelines that parallel (within 100 meters) high voltage overhead AC power lines (69 kV or greater) for a distance of more than 500 meters. The qualitative testing shall be completed as part of the investigative field work required for the detailed design of the CP system.

6.12.2 Quantitative Study

If qualitative testing indicates that AC voltages on the new pipeline may exceed the safe level specified in [SAES-B-064](#) (higher than 12 volts AC, steady state), PMT shall commission a detailed study to quantify expected induced AC voltages during peak load, and shall implement the studies recommendations for mitigation to reduce the voltages to a safe level.

7 CP System Performance Criteria

7.1 Cathodic Protection Criteria

Table 2 - Cathodic Protection Criteria for Buried Pipelines												
Structure Type	Coating Type	Design Criteria ⁽¹⁾			Commissioning Criteria ⁽¹⁾					Temporary Criteria ⁽¹⁾		
		Average Current Density (mA/m ²)	Minimum "On" Potential (-mV)	Maximum Potential (-Volts)	Minimum Potential (-mV) (must comply with at least one)			Maximum Potential (-Volts) (must comply with at least one)		Average Current Density (mA/m ²)	Minimum "On" Potential (-mV)	Maximum Potential (-Volts)
					"On" ⁽³⁾	"Instant Off" ⁽⁴⁾	"Potential Decay" ⁽⁵⁾	"On" ⁽³⁾	"Instant Off" ⁽⁴⁾			
Buried Pipeline (except inside fenced areas)	Not Coated (bare)	20.0	950	12.0	900	850	100	12.0	n/a	20.0	850	12.0
	Coated ⁽²⁾	0.10	1200	3.0	1100	850	100	3.0	1.15	0.005	1000	3.0
	Coated Production Pipelines	Included with CP system for associated well casing ⁽⁶⁾			1000	850	100	5.0	1.25	Included with CP system for associated well casing ⁽⁶⁾		
Buried Pipeline Fittings	Coated ⁽²⁾	0.10	1200	3.0	1000	850	100	3.0	1.15	0.005	1000	3.0
Buried Pipeline inside fenced areas (valve stations, etc.)	Not Coated (bare)	20.0	950	12.0	900	850	100	12.0	n/a	20.0	850	12.0
	Coated ⁽²⁾	0.20	1200	3.0	1000	850	100	3.0	1.15	0.005	1000	3.0

Note 1: All pipe-to-soil potentials measured with reference to a Cu/CuSO₄ reference electrode.

Note 2: Applies to single layer coated pipelines per SAES-H-002. Consult CSD if any other coating system is to be used.

Note 3: The "On" potential is measured with all influencing CP power supplies turned ON.

Note 4: The "instant off" potential is measured (within 100 milliseconds) after interrupting all influencing CP power supplies. It is recommended this measurement be taken using a permanently installed CP probe or coupon (approx. 10 mm dia. x 110 mm long –see Figure 2). The probe or coupon should be installed approximately 500mm from the side of the pipe, and 1000 mm deep (see Figure 1)

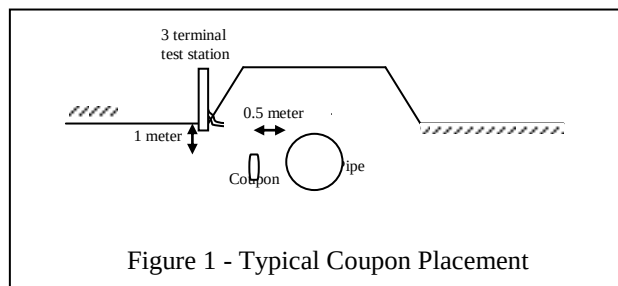


Figure 1 - Typical Coupon Placement

Note 5: The "potential decay" is the decrease in potential between the "instant off" and the steady state off potential. A probe or coupon typically reaches a steady state off potential within 60 seconds to 60 minutes. Refer to ISO15589-1 and NACE TM-0497 for depolarization measurement procedures.

Note 7: With respect to cathodic protection requirements, a production pipeline that extends more than 25 km past the nearest CP power supply shall be treated as a cross-country pipeline. The appropriate attenuation calculations shall be completed and a dedicated CP system shall be provided where required.

7.2 Anode Bed Design Life

- 7.2.1 The anode bed shall be sized to discharge the CP power source rated current at the anode consumption rate detailed in Table 3, for a minimum of 20 years.

$$\left[\frac{\text{Total Weight of all Anodes (kgs.)}}{\text{Anode Consumption Rate} \times \text{CP Power Source Design Current Capacity}} \right] \geq 20 \text{ Years}$$

- 7.2.2 The minimum design life of galvanic anode systems for electrically isolated short pipeline sections shall be 20 years.

- 7.2.3 The minimum design life of temporary CP systems shall be 2 years.

7.3 Anode Bed Current Capacity and Consumption Rates

- 7.3.1 The total current capacity of an anode bed shall be equal to or greater than the design current for the associated CP power source.

Table 3 – Impressed Current Anode Design Parameters

Anode Material	Consumption Rate (kg/Ay)	Maximum Current Density (mA/cm ²)
High Silicon Cast Iron	0.45	0.7
MMO (only for use in subkha, coke breeze optional, watering pipe/vent pipe not required)	Not applicable (see manufacturer's specification for 20 year life)	7.0

Table 4 – Impressed Current Anode Design Data

Type	Dimensions	Weight	Nominal Design Current	Maximum Commission Current
TA-2 HSCI	56 mm x 2133 mm	20.9 kg	2.63 amps	4.0 amps
TA-4 HSCI	95 mm x 2133 mm	38.6 kg	4.45 amps	7.0 amps
TA-5A HSCI	121 mm x 2133 mm	79.4 kg	5.67 amps	10.0 amps
Tubular MMO	1.9mm x 122mm	n/a	5.0 amps	7.0 amps

Commentary Notes:

- 1) The consumption rates detailed in Table 3 include utilization factor and effective anode shortening due to end caps.
- 2) Consult with the CP SME in CSD for special applications of other types of impressed current anode materials such as polymeric.

Table 5 – Galvanic Anode Design Parameters

Anode Material	Consumption Rate (kg/Ay)	Potential (mV) (Cu/CuSO ₄)
Magnesium	7.71	-1700
Zinc	11.8	-1100

Commentary Note:

The galvanic anode consumption rates detailed in Table 5 are corrected for efficiency; however, a utilization factor of 0.85 may be included at the designer's discretion.

7.4 Circuit Resistance Criteria

- 7.4.1 The “rated” circuit resistance for an impressed current CP power supply shall be defined as the power supply rated dc voltage divided by the rated dc current. Rated voltages and currents are as detailed on the manufacturer's data sheet/plate.
- 7.4.2 The "operating" circuit resistance for CP system shall be defined as the total effective resistance seen by the output terminals of the respective rectifier or photovoltaic output control center (OCC).
- 7.4.3 For a galvanic CP system the “operating” circuit resistance shall be defined as the open circuit voltage difference between the anodes and the protected pipeline.
- 7.4.4 For calculation purposes, the operating circuit resistance shall include:
- Anode bed resistance to ground.
 - Positive cable resistance from CP power source to anodes.
 - Negative cable resistance from CP power source to structure.
 - Resistance of the pipeline to remote earth (for calculation purposes shall be 0.055 ohms unless site testing is completed to verify a more accurate value).
 - Effective resistance caused by 0.8 volts anode bed back emf (ICCP only) plus the 1.2 volt structure back emf (example: 1.2 volts pipeline + 0.8 volts ICCP anode bed back emf = 2.0 volts total between the anode with coke breeze backfill, and a coated pipeline).

$$R_{\text{emf}} = (0.8\text{v} + 1.2\text{v}) / I_{\text{rated}}$$

$$I_{\text{rated}} = \text{CP power supply "rated" current}$$

Exception:

CP power supplies with a rated voltage of 12 volts or less shall consider the total back emf to be 1.2 volts for calculation purposes.

Commentary Note:

When using R_{emf} to calculate the maximum allowable anode bed resistance to provide 70% of R_{rated} , the value of R_{emf} must be multiplied by 0.7.

Example: $R_{\text{anodebed maximum}} = (0.7 \times (R_{\text{rated}} - R_{\text{emf}})) - R_{\text{cables}} - R_{\text{structure}}$

- 7.4.5 New CP systems shall be designed to achieve an “operating” circuit resistance less than or equal to 70% of the CP power supply “rated” circuit resistance.

$$\text{For design: } R_{\text{op}} \leq 0.7 \times R_{\text{rated}}$$

Where:

R_{op} = CP system “operating” circuit resistance

R_{rated} = CP power supply “rated” circuit resistance

- 7.4.6 The maximum acceptable CP system “operating” circuit resistance measured during commissioning of a new CP system shall be less than or equal to 90% of the CP system "rated" circuit resistance.

Exception:

If a CP system commissions at greater than 90% of the rated circuit resistance, but operating conditions are such that the CP system will be able to provide the required CP for the lesser of 20 years or the predicted life of the structure, supplementation of the anode bed may not be cost effective and deserves additional consideration. In such cases, the requirement for additional anodes shall be at the discretion of the CP proponent organization.

- 7.4.7 If the soil resistivities within a proposed anode bed vary by more than 100%, either additional anodes shall be provided, or, anodes of the same composition with a higher current capacity can be placed in the low resistivity areas so that no anode exceeds the maximum commission current ([Table 3](#)).

7.4.8 Remote Surface Anode Bed

- a. Soil resistivity or soil conductivity measurements shall be taken at 10 meter intervals and at 3 and 6 meter depths in parallel and perpendicular orientations over the full length of the proposed surface anode bed location.
- b. If the average of the measured soil resistivities is above 4000 ohm-cm, the resistance of each anode, and the combined resistance of all anodes in the anode bed shall be recorded during installation and emailed to the CP SME in CSD for approval before the construction equipment is released from the site.

7.4.9 Remote Deep Anode Bed: Soil resistivity or soil conductivity measurements for deep anode beds are recommended but not mandatory.

Commentary Note:

The intent of 7.4.6 is to eliminate the requirement for "Geonics" soil conductivity surveys in areas that have a low probability of being designed with surface anode beds.

7.4.10 Deep anode holes shall be drilled with water or mud solutions in the bore hole unless otherwise approved by the CP SME in CSD and the CP Proponent organization.

7.4.11 For deep anode bed designs, drill stem resistance measurements and test anode resistance measurements shall be recorded by the construction contractor on the form contained in Appendix 1 of [SABP-X-003](#) and submitted for review and analysis to the CP SME in CSD (or designate). The drill stem and test anode measurements shall be taken in accordance with the requirements detailed in Standard Drawing [AA-036385](#). CSD in consultation with the Groundwater Division shall determine the final acceptable borehole depth, and anode distribution.

Exception:

Deep anode holes drilled dry (without water or mud solutions in the bore hole) do not require drill stem and test anode measurements unless specifically requested by the CP SME in CSD.

8 CP System Equipment and Material Requirements

It is mandatory that cathodic protection power supplies, junction boxes and anodes be pre-approved by a CP SME in CSD for cathodic protection material in compliance with the respective SAMSS.

8.1 Anode/Anode Bed General Requirements

- 8.1.1 Impressed current anode materials for soil applications shall be HSCI complying with [17-SAMSS-007](#) unless otherwise approved in writing by the SME in CSD and the CP Proponent organization.
- 8.1.2 Galvanic anodes for soil applications shall comply with [17-SAMSS-006](#). Design parameters are detailed in [Table 6](#).
- 8.1.3 Anodes installed deeper than 15 meters are “deep” anode beds, and require drilling depth pre-approval in writing by the Groundwater Protection Division of the Saudi Aramco Reservoir Characterization Department.
- 8.1.4 Remote anode beds shall maintain the minimum clearances detailed in [Table 6](#) from any other cathodically protected structure.

Table 6 – Minimum Distance to Nearest Buried Metallic Structure

Anode Bed Rated Output Current (Amps)	Minimum Distance in Meters as a Function of Average Soil Resistivity at Anode Bed			
	$\rho < 500 \Omega\text{-cm}$	$500 \Omega\text{-cm} \leq \rho \leq 1000 \Omega\text{-cm}$	$1000 \Omega\text{-cm} < \rho \leq 3000 \Omega\text{-cm}$	$\rho > 3000 \Omega\text{-cm}$
0 – 35	20 meters	25 meters	50 meters	75 meters
36 – 50	30 meters	35 meters	75 meters	150 meters
51 – 100	65 meters	75 meters	150 meters	250 meters
101 – 150	100 meters	125 meters	225 meters	350 meters

For higher current outputs, the above distances can be pro-rated as 75 meters distance for every 50 amperes of rectifier output.

Commentary Notes:

- 1) *The distances detailed in Table 6 are provided to limit the structure polarized (instant off) potential to less than 1.2 volts and to minimize interference effects on other independent cathodically protected structures. Polarized potentials may be measured using a CP potential probe/coupon, as detailed in [SAEP-333](#) Appendix A-2.*
- 2) *The "Rectifier Rated Output" values apply only to new CP systems being installed by projects. Where a new pipeline is too close to an existing anode bed, the rectifier "normal operating level" should be used with Table 6 to determine the required separation.*
- 3) *Multiple deep anode beds can be treated as individual anode beds if the separation between the anode beds meets or exceeds the*

minimum distances detailed in Table 6. Example: Two 50 amp deep anode beds placed 75 meters apart in 1000 ohm-cm can be installed 75 meters away from a buried pipeline.

8.1.5 Maintain a minimum separation of 50 meters between adjacent anode beds (deemed remote) powered from different power sources.

8.1.6 Install distributed impressed current anodes where a remote anode bed will not provide satisfactory current distribution, or will not be practical.

Commentary Note:

Distributed anodes are used for pipelines installed in congested areas, at SSD fence crossings where bare copper grounding wires or bare metallic ground rods are connected to the fence, at full-thrust anchors inside plant areas or fenced areas, at GOSP manifolds or flowline corridors.

8.1.7 Unless otherwise specified in this standard, the number, placement, current loading, and length of distributed anodes shall be determined by calculating the soil voltage gradients using the “earth potential rise” equations detailed in Appendix 1 of [SAES-X-600](#).

8.2 DC Power Supply

8.2.1 Cathodic protection rectifiers and photovoltaic systems shall be manufactured in accordance with [17-SAMSS-004](#) and [17-SAMSS-012](#) respectively and shall be equipped with remote monitoring equipment in accordance with [17-SAMSS-018](#).

Commentary Note:

Photovoltaic arrays are modular 6V-15A assemblies that can be coupled together to provide the optimum voltage and current for the facility requirements and site conditions.

8.2.2 Install rectifiers and photovoltaic systems in accessible locations, with an all-weather marl road and as far away from sand dunes as possible. Perform sand stabilization, where necessary, to prevent sand dune encroachment.

8.2.3 Do not use DC power supplies with a rated output voltage greater than 100 volts.

8.2.4 Do not install DC power supplies in hazardous locations.

8.3 DC Cables

- 8.3.1 Cathodic protection DC cables shall be manufactured in accordance with [17-SAMSS-017](#).
- 8.3.2 DC cables connected to a CP power supply either directly or through a junction box shall be optimized in size to compliment the current capacity and resistance requirements of the respective CP system, but shall be #6 (16 mm²) or larger to facilitate the use of stock material.
- 8.3.3 NEC Table 310-16 (90°C rating column) shall be used to determine the minimum size (allowable ampacity) for HMWPE/HDPE cables. The cable size shall be corrected for an ambient temperature of 40°C.
- 8.3.4 NEC Table 8, Chapter 9, shall be used to determine resistance properties. The resistance of the cables shall be considered in the anode bed design.

Commentary Note:

It is not necessary to use High Molecular Weight Polyethylene (HMWPE) cables for negative circuit wiring (test station leads, rectifier to pipeline negative cable, bond wire, etc.). Use of THHN, THWN, and other alternatives noted in [17-SAMSS-017](#) may be more cost effective and may have less delivery lead time from the vendor.

8.4 Junction and Bond Boxes

Cathodic protection Junction Boxes and Bond Boxes shall be manufactured in accordance with [17-SAMSS-008](#).

8.5 Pipeline CP Assessment Probes

CP assessment probes used for cathodic protection applications on buried pipelines shall be of the same outer dimensions as shown below in Figure 2. The method of construction shown in Figure 2 is intended to be used as typical and is not mandatory. A sample CP assessment probe must be provided to CSD for testing and approval before it is deemed acceptable for installation with Saudi Aramco pipelines.

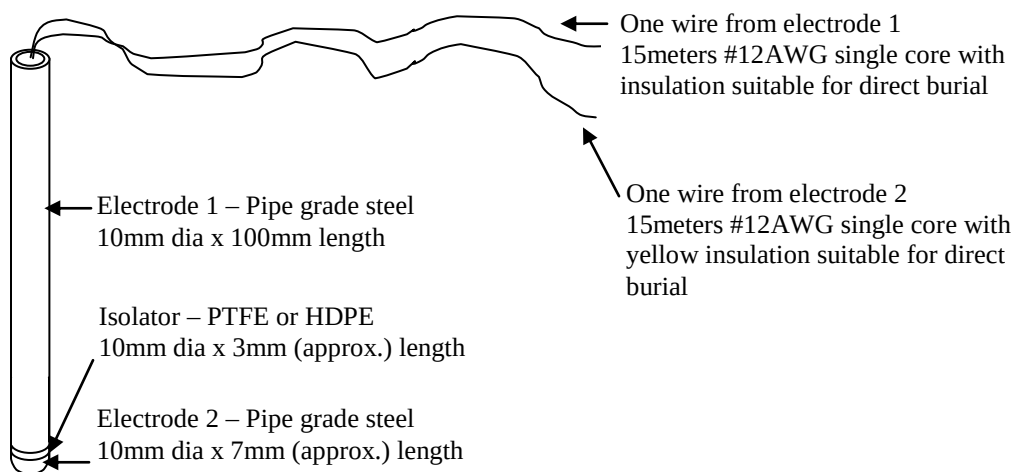


Figure 2 – Saudi Aramco Cathodic Protection Assessment Probe

8.6 Grounding

8.6.1 Ground conductors shall be jacketed in compliance with [SAES-P-111](#). For locations where existing bare copper grounding is installed, follow the guidelines given below.

- a. Insulate buried bare copper conductors crossing a pipeline for a minimum of 6 meters on each side of the pipeline crossing. The insulation may be PVC conduit, coated cable or other approved method.
- b. Do NOT use bare copper conductors when running parallel within 3 meters of a buried pipeline or piping.
- c. Do NOT connect a ground cable from the site ground grid to a cathodic protection junction, splice or bond box, nor in any other way establish direct electrical continuity between these boxes and the site electrical ground grid.

8.6.2 Ground rods that are electrically continuous with the pipeline shall not be copper or copper clad.

8.6.3 Where practical, ground rods shall not be installed within 3 meters of a buried pipeline or piping.

9 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.

Revision Summary

13 December 2011	Revised the "Next Planned Update." Reaffirmed the content of the document, and reissued with minor revision to incorporate field improvement ideas.
------------------	---

Appendix 1 – Quality Assurance Check List for Pipeline CP System Designs

BI-___ Pipeline Description___

"Full Size" Pipeline Plan Drawing with CP Layout:			
Item	Done	N/A	Pipeline Plan Drawing with all CP Equipment (new and existing)
1	☐	☐	A full size drawing of the pipeline (end to end) illustrating placement of all CP equipment, including: ☐ rectifiers, ☐ junction boxes, ☐ bond stations, ☐ test stations, ☐ Mg anodes, ☐ electrical isolation equipment, and ☐ locations where useable AC power is available?
Item	Done	N/A	Details for each Proposed Anode Bed on Drawing
2	☐	☐	The number and type of anodes (TA-4 or TA-5), and configuration i.e. surface or deep
3	☐	☐	If deep then approved maximum depth from Groundwater Protection Division stated in notes section of drawing
4	☐	☐	☐ Diameter, depth, and spacing of the holes if more than one hole
5	☐	☐	The distance between the pipeline and the proposed anode bed(s)
6	☐	☐	The location of other buried pipelines within 200 meters of the proposed anode bed(s)
Item	Done	N/A	Details for Existing ICCP Systems if applicable on Drawing
7	☐	☐	The number, type and age of existing ICCP system anodes
8	☐	☐	Rated and operating, voltage and amperage of existing CP power supplies
9	☐	☐	Existing nearest parallel pipeline (within 200M) on drawing with low protection areas illustrated
Detailed Drawings of Proposed CP Installations and Electrical Isolation Equipment:			
Item	Done	N/A	
9	☐	☐	Isometric sketches of the piping arrangement at the locations where electrical isolation equipment has been proposed and detailed drawings of each ICCP system?
Item	Done	N/A	Details for Proposed DC Power Supplies, Test Stations, Junction Boxes etc.
10	☐	☐	Rated DC volts and amps
11	☐	☐	Remote monitoring equipment details (compatibility with existing monitoring system)
12	☐	☐	The size and length of all DC cables for the proposed CP system(s)
13	☐	☐	CP junction boxes and bond stations
Calculations:			
Item	Done	N/A	Calculations for Anode Beds and Miscellaneous Requirements
14	☐	☐	Maximum allowable CP system resistance
15	☐	☐	Maximum allowable anode bed resistance
16	☐	☐	Calculated surface anode bed resistance based on soil resistivity measurements taken at site (not required for deep anode bed)
17	☐	☐	Calculations showing CP attenuation characteristics and associated expected pipeline potentials
18	☐	☐	Verification statement that "ALL" buried ground cables electrically continuous with the subject pipeline are insulated (jacketed)
Note: N/A is used in this table as an abbreviation for "not applicable".			

Please provide remarks below for any item from above that is applicable but not done:

Item _____

Item _____

Designer Name (Print) _____ Signature and Date _____

PMT Eng. Name (Print) _____ Signature and Date _____