



# Best Practice

SABP-X-003

7 February 2012

Cathodic Protection Installation Requirements

Document Responsibility: Cathodic Protection Standards Committee

## Saudi Aramco DeskTop Standards

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Revised paragraphs are indicated in the right margin

Primary contact: [Umair, Ahmed Abdul Rahman](#) on +966-3-8760190

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## **1 Introduction**

### **1.1 Purpose**

This Best Practice provides standardized methods and requirements for constructing, installing, and pre-commissioning cathodic protection systems and equipment for Saudi Aramco.

### **1.2 Scope**

This Best Practice covers the construction, installation, and pre-commissioning of cathodic protection systems and equipment for new and existing facilities.

### **1.3 Disclaimer**

This Best Practice is being provided for the Proponent Organizations, Project Management Teams and associated Contractors.

Use of this Best Practice for the design or installation of cathodic protection material for Saudi Aramco does not absolve the designer or the installation Contractor from his responsibility to verify the accuracy of any information presented, or from his contractual liability to provide safe and reliable installations that conform to Mandatory Saudi Aramco Engineering Requirements. Use of the information or material contained herein is no guarantee that the resulting installation will satisfy the applicable requirements of any project.

Saudi Aramco assumes no responsibility or liability whatsoever for any reliance on the information presented herein or for installations completed in accordance with this Best Practice. Use of this Best Practice by installation Contractors and Designers is intended solely for, and shall be strictly limited to, Saudi Aramco facilities.

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### **1.4 Conflicts with Mandatory Standards**

In the event of a conflict between this Best Practice and any Mandatory Saudi Aramco Engineering Requirement (MSAER), the MSAER shall govern.

## 2 References

Use the latest revision of the references listed below.

### 2.1 Saudi Aramco References

#### Saudi Aramco Engineering Procedure

[SAEP-332](#) *Cathodic Protection Commissioning*

#### Saudi Aramco Engineering Standards

[SAES-B-068](#) *Electrical Area Classification*

[SAES-P-100](#) *Basic Power System Design Criteria*

[SAES-P-104](#) *Wiring Methods and Materials*

[SAES-P-107](#) *Overhead Distribution Systems*

[SAES-P-111](#) *Grounding*

[SAES-Q-001](#) *Criteria for Design and Construction of Concrete Structures*

[SAES-Q-005](#) *Concrete Foundations*

[SAES-X-400](#) *Cathodic Protection of Buried Pipelines*

[SAES-X-500](#) *Cathodic Protection of Vessel and Tank Internals*

[SAES-X-600](#) *Cathodic Protection of Plant Facilities*

[SAES-X-700](#) *Cathodic Protection of Onshore Well Casings*

[SAES-X-800](#) *Cathodic Protection for Existing Reinforced Concrete Structures*

#### Saudi Aramco Materials System Specifications

[17-SAMSS-004](#) *Tap Adjustable Rectifiers for Cathodic Protection*

[17-SAMSS-005](#) *Cathodic Protection Phase Controlled Rectifiers*

[17-SAMSS-008](#) *Junction Boxes for Cathodic Protection*

[17-SAMSS-012](#) *Photovoltaic Power Supply for Cathodic Protection*

#### Saudi Aramco General Instructions

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

*GI-0428.001 Cathodic Protection Responsibilities*

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### Saudi Aramco Standard Drawings

|                                  |                                                                                      |
|----------------------------------|--------------------------------------------------------------------------------------|
| <a href="#"><u>AB-036008</u></a> | <i>Mixed Metal Oxide Anode for Offshore Pile Mounted Anode</i>                       |
| <a href="#"><u>AA-036073</u></a> | <i>CP Cable Connection to Well Head</i>                                              |
| <a href="#"><u>AD-036132</u></a> | <i>Termination Detail Cable Identification</i>                                       |
| <a href="#"><u>AA-036145</u></a> | <i>Cable Splice Junction Box</i>                                                     |
| <a href="#"><u>AB-036273</u></a> | <i>Surface Marker Underground Electric Cable</i>                                     |
| <a href="#"><u>AB-036274</u></a> | <i>5 Terminal Junction Box Details</i>                                               |
| <a href="#"><u>AB-036275</u></a> | <i>12 Terminal Junction Box Details</i>                                              |
| <a href="#"><u>AA-036276</u></a> | <i>Multi-Purpose Junction Box Details</i>                                            |
| <a href="#"><u>AA-036280</u></a> | <i>Photovoltaic Power System</i>                                                     |
| <a href="#"><u>AA-036304</u></a> | <i>Offshore Pile Mounted Anodes</i>                                                  |
| <a href="#"><u>AA-036335</u></a> | <i>Half Shell Bracelet Type Anode for Pipe Sizes 4-60 Inch</i>                       |
| <a href="#"><u>AA-036346</u></a> | <i>Surface Anode Bed Details - Horizontal and Vertical Anodes (Sheets 1 &amp; 2)</i> |
| <a href="#"><u>AA-036347</u></a> | <i>20 Terminal Junction Box Details</i>                                              |
| <a href="#"><u>AA-036348</u></a> | <i>Galvanic and Impressed Anodes on Offshore Structures</i>                          |
| <a href="#"><u>AB-036351</u></a> | <i>Marker Plate Details</i>                                                          |
| <a href="#"><u>AA-036352</u></a> | <i>Galvanic Anodes for Road and Camel Pipeline Crossings (Sheets 1 &amp; 2)</i>      |
| <a href="#"><u>AA-036353</u></a> | <i>Water Storage Tanks Impressed Current</i>                                         |
| <a href="#"><u>AA-036354</u></a> | <i>Water Storage Tanks Galvanic Anode</i>                                            |
| <a href="#"><u>AA-036355</u></a> | <i>Tank Bottom Impressed Current</i>                                                 |
| <a href="#"><u>AA-036356</u></a> | <i>Deep Anode Bed - With Support Pipe</i>                                            |
| <a href="#"><u>AB-036378</u></a> | <i>Rectifier Installation Details (Sheets 1 &amp; 2)</i>                             |
| <a href="#"><u>AB-036381</u></a> | <i>Thermite Welding of Cables to Pipelines &amp; Structures</i>                      |
| <a href="#"><u>AA-036385</u></a> | <i>Deep Anode Bed without Anode Support Pipe</i>                                     |
| <a href="#"><u>AA-036388</u></a> | <i>Internal Galvanic Anodes Installation Details for Vessels</i>                     |
| <a href="#"><u>AA-036389</u></a> | <i>Galvanic Anode Details</i>                                                        |

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|                                  |                                                                              |
|----------------------------------|------------------------------------------------------------------------------|
| <a href="#"><u>AB-036540</u></a> | <i>Mounting Support Details for Junction Boxes</i>                           |
| <a href="#"><u>AA-036675</u></a> | <i>Direct Buried Cable - Installation Details</i>                            |
| <a href="#"><u>AB-036677</u></a> | <i>An Overview - Architectural, Security &amp; General Purpose Fencing</i>   |
| <a href="#"><u>AA-036678</u></a> | <i>Security &amp; General Purpose Fencing - Post &amp; Fabric Details</i>    |
| <a href="#"><u>AA-036762</u></a> | <i>Crude and Product Tank Bottom, Internal, Magnesium Anode Installation</i> |
| <a href="#"><u>AD-036763</u></a> | <i>Offshore PLIDCO Sleeve Anode</i>                                          |
| <a href="#"><u>AA-036780</u></a> | <i>Offshore Tension Spring and Rope Impressed Current System</i>             |

#### Saudi Aramco Inspection Procedure

|                                   |                                                                   |
|-----------------------------------|-------------------------------------------------------------------|
| <a href="#"><u>17-SAIP-50</u></a> | <i>Inspection Coverage of Cathodic Protection Deep Anode Beds</i> |
|-----------------------------------|-------------------------------------------------------------------|

#### Saudi Aramco Library Drawings

|                                  |                                                                         |
|----------------------------------|-------------------------------------------------------------------------|
| <a href="#"><u>DA-950068</u></a> | <i>Bonding for Offshore Structures - Installation Details (Sheet 1)</i> |
| <a href="#"><u>DA-950068</u></a> | <i>Offshore Junction Box Mounting (Sheet 2)</i>                         |
| <a href="#"><u>DA-950068</u></a> | <i>Offshore Rectifier Installation Details (Sheet 3)</i>                |

#### Saudi Aramco Pre-commissioning Forms

|                                 |                                                                                      |
|---------------------------------|--------------------------------------------------------------------------------------|
| <a href="#"><u>SA-X-001</u></a> | <i>Pre-commissioning – Cathodic Protection Rectifier</i>                             |
| <a href="#"><u>SA-X-002</u></a> | <i>Pre-commissioning – Cathodic Protection Photovoltaic Power Supply</i>             |
| <a href="#"><u>SA-X-003</u></a> | <i>Pre-commissioning – Cathodic Protection Plant Potential Survey</i>                |
| <a href="#"><u>SA-X-004</u></a> | <i>Pre-commissioning – Cathodic Protection External Tank Bottom Potential Survey</i> |
| <a href="#"><u>SA-X-005</u></a> | <i>Pre-commissioning – Cathodic Protection Tank Internal Potential Survey</i>        |
| <a href="#"><u>SA-X-006</u></a> | <i>Pre-commissioning – Cathodic Protection Well Casing/Flowline Potential Survey</i> |
| <a href="#"><u>SA-X-007</u></a> | <i>Pre-commissioning – Cathodic Protection Pipeline Potential Survey</i>             |

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[SA-X-008](#)

*Pre-commissioning – Cathodic Protection  
Submarine Pipeline Potential Survey*

[SA-X-009](#)

*Pre-commissioning – Cathodic Protection Offshore  
Platform/Well Casing Potential Survey*

## 2.2 Industry Codes and Standards

American Concrete Institute Standards

[ACI 506.2-95](#)

*Specification for Shotcrete*

[ACI 506R-90](#)

*Guide to Shotcrete*

National Fire Protection Association

[NFPA 70](#)

*National Electrical Code (NEC)*

## 3 Definitions

This Best Practice uses the following terminologies:

**Bond Cable:** A cable installed between two metallic structures to provide electrical continuity between the structures.

**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 respective 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 commissioning current.

**Deep Anode Bed:** Anode or anodes connected to a common CP power supply installed in a drilled hole with a depth exceeding 15 m (50 ft).

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

**Design Agency:** The organization completing the detailed design of the project. The Design Agency could be a Design Contractor, a Lump Sum Turn Key Contractor or an in house design organization.

**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).

**Honeycombing:** Voids left in the concrete when it is poured and consolidated. It is caused by the failure of the mortar to completely fill the spaces among coarse aggregate particles.

**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 connected through a DC power supply to the buried structure to provide cathodic protection current.

**Laitance:** A milky substance formed on the surface of fresh concrete due to the accumulation of fine particles on the surface caused by the upward movement of water.

**Megger:** A four terminal 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.

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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 surrounds an area designated 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.

**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 ( $\text{Cu}/\text{CuSO}_4$ ) 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.

**Shotcrete:** A mortar or concrete that is pneumatically projected at high velocity onto a prepared surface.

**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).

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

**Thermite Weld:** An exothermic process for use in making 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 respective GOSP or WIP.

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

**WIP:** Water Injection Plant

## 4 Installation Requirements

### 4.1 Marine Structures

#### 4.1.1 Galvanic Anodes for Marine Structures

Install galvanic anodes according to the latest revisions of Standard Drawing Nos. [AA-036335](#), [AA-036348](#), [AA-036389](#) and [AD-036763](#).

#### 4.1.2 Impressed Current Anodes for Marine Structures

4.1.2.1 Install impressed current anodes according to the latest revisions of Standard Drawing Nos. [AB-036008](#), [AA-036304](#), [AA-036348](#) and [AA-036780](#).

4.1.2.2 Use a Megger type instrument set at 5000 volts to conduct an insulation resistance test between all armor wires twisted together and the central copper conductor. Conduct the test just before installing the anodes. If the measured resistance is less than one mega-ohm, reject the entire anode/cable assembly. The test shall be witnessed by the Proponent Operation Inspection Unit or Projects Inspection.

4.1.2.3 Use care when bending armored cables to avoid damage. The radius of the curve of the inner edge of any bend shall not be less than five times the diameter of the cable. If the cable becomes “kinked” or the armor is damaged, reject the anode and cable assembly.

- 4.1.2.4 Make certain that all non-metallic packaging material has been removed from mixed metal oxide (MMO) anodes before installation. In some instances, there may be copper sleeves over the MMO surfaces. The copper sleeves should be left on the anode.
- 4.1.2.5 Offshore MMO anodes or other dimensionally stable anode materials without copper sleeves shall be energized to at least  $0.5 \text{ mA/cm}^2$  within 90 days of installation. Offshore MMO anodes or other dimensionally stable anode materials provided with copper sleeves pre-approved by CSD, shall be energized when the required power source has been installed and commissioned.
- 4.1.2.6 Use a rope, sling or support pipe to lift or lower anodes weighing more than 40 kg.
- 4.1.2.7 Terminate impressed current anode cables for offshore cathodic protection systems in anode junction boxes located on the platform decks for offshore platforms. Connect positive header cables from anode junction boxes to rectifiers or to other positive junction boxes in accordance with Standard Drawing [AA-036276](#).

#### 4.1.3 DC Power Sources for Marine Structures

- 4.1.3.1 Rectifiers for marine applications are manufactured in accordance with [17-SAMSS-004](#). Install the rectifiers as detailed on the respective construction drawings and Library Drawing [DA-950068](#) Sheet 3. Install in compliance with the electrical restrictions detailed in [SAES-P-111](#), [SAES-P-107](#), [SAES-P-104](#) and [SAES-B-068](#).
- 4.1.3.2 Rectifier mounting locations shall be in non-hazardous areas whenever practical.
- 4.1.3.3 Open the rectifier lid and ensure the exposed components are free of sand, dust or metal filings before filling the rectifier oil enclosure with insulating oil.
- 4.1.3.4 Provide AC power to the rectifier through a dedicated circuit breaker rated at the nearest commercially available size for 125% of the rectifier input current at rated load. Rectifiers for offshore applications will also be supplied with a fused

disconnect switch or circuit breaker mounted directly on the rectifier enclosure.

#### 4.1.4 DC Cables for Marine Structures

4.1.4.1 Thermite weld all cable connections to steel pipes and structures according to Standard Drawing [AB-036381](#). Do not thermite weld on stainless steel. It is recommended to use pin brazing on internally coated pipelines with a wall thickness less than 0.5 inches (127mm), or verify through prior testing (using project specific coatings and pipe) that thermite welding will not damage the internal coating for a wall thickness less than 0.5 inches.

4.1.4.2 Mechanically protect cathodic protection cables by using steel conduit, armored cable, covered cable trays, or flexible conduit in accordance with [SAES-P-104](#). Negative cables attached to structures may extend out of the conduit up to 1.5 meters between the conduit and the structure connection.

4.1.4.3 Splicing of anode cables is not permitted.

#### 4.1.5 Well Casing and Platform Bonding

Follow the guidelines of Saudi Aramco Library Drawing [DA-950068](#), Sheet 1, and Saudi Aramco Standard Drawing [AB-036381](#), to ensure that accessible concentric well casings at the platform deck level for each well are electrically continuous (can be achieved through cable bond, welded centralizing gussets or welded donut plates) and each well is then bonded to the platform with a dedicate bond cable.

#### 4.1.6 Bond Boxes and Junction Boxes for Marine Structures

4.1.6.1 Mount junction boxes in accordance with Library Drawing [DA-950068](#) Sheet 2 in non-hazardous areas on the cellar deck walkway such that the junction box door faces inward and is accessible without scaffolding or ladders.

4.1.6.2 Show all bond box locations on the as-built drawings.

4.1.6.3 Identify all cables inside bond boxes and junction boxes with a permanent tag according to Standard Drawing [AD-036132](#). Properly label the cables and the terminals to designate the anodes or the structures to which they are connected.

- 4.1.6.4 Provide an outside nameplate on all junction and bond boxes to identify the structure and/or the rectifier unit to which they are connected.

#### 4.1.7 Electrical Area Classification

All electrical equipment used for CP installations shall comply with the requirements of the electrical area classification of the location in which it will be installed in accordance with [SAES-B-068](#).

### 4.2 Onshore Facilities

#### 4.2.1 Galvanic Anodes for Onshore Facilities

- 4.2.1.1 Install galvanic anodes vertically or horizontally in accordance with Standard Drawing [AA-036352](#).
- 4.2.1.2 Do not lift or lower the anode using the anode cable.
- 4.2.1.3 Before installing prepackaged anodes, remove any plastic covering and verify that the cotton bag will absorb water.
- 4.2.1.4 Thoroughly soak packaged anodes before installation before installation.

#### 4.2.2 Impressed Current Anodes for Onshore Facilities

##### 4.2.2.1 General

- 4.2.2.1.1 The design agency or its representative shall mark or stake all proposed surface and deep impressed current anode bed locations to correlate with soil resistivity measurements where applicable.  
At locations where deep anode beds have been designed without soil resistivity measurements, the design agency shall mark or stake the proposed deep anode bed location so as to ensure compliance with the anode bed placement restrictions detailed in [SAES-X-400](#), [SAES-X-600](#) and [SAES-X-700](#).

##### 4.2.2.1.2 Only install anodes:

- a) at locations that have been pre-marked (staked) by the design agency or its representative, and
- b) have been inspected as detailed below (anode cable inspections must be witnessed by a Saudi

Aramco inspection organization or designated representative)

- 4.2.2.1.3 Inspect impressed current anode cable leads for insulation damage just before installation using a pulse type holiday detector set at 18,000 volts DC. Return anodes that fail this test to the anode manufacturer.
- 4.2.2.1.4 Conduct a visual and touch inspection of the anode cable insulation immediately adjacent to the head of the anode. Do not install anodes that are found to have noticeable “necking” or an obvious reduction in diameter of the insulation near the head of the anode.
- 4.2.2.1.5 Do not use repaired impressed current anode cable leads, anodes, or anodes with repaired anode-to-cable connections.

*Exception:*

*If a cable becomes damaged after installation, you may repair the cable using a below grade anode junction box, or a Scotch 3M type underground cable splicing kit. Splicing kits must be installed by a certified electrician familiar with the use of underground splice kits for power cable applications.*

- 4.2.2.1.6 Backfill the anode cable trench immediately following successful completion of the insulation tests.
- 4.2.2.1.7 Anode cable ends shall be durably tagged as shown in Standard Drawing [AD-036132](#). The anode leads shall be tagged before anode installation to identify the anode at the termination point inside the anode lead junction box.

*Exception:*

*Anode cables that will be spliced in an approved below grade anode junction box, or spliced directly to a positive header cable and buried do not require identification tagging. The direct splice and burial procedure shall only be used if pre-approved by the CP Proponent organization and the Supervisor of the Cathodic Protection group of CSD.*

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*Commentary Note:*

*Never roll anodes, especially when the anode cable is still on the cable spool. Rolling an anode while the anode lead wire is on the spool can cause "necking" of the anode cable insulation at the head of the anode where the anode cable exits the epoxy plug. This installation-induced defect results in premature anode failure and is not detectable with the electronic holiday detector.*

- 4.2.2.1.8 Each impressed current anode shall be connected to the positive circuit of the respective rectifier through an individual anode lead wire connected through a dedicated shunt mounted in an appropriately sized anode junction box.

*Exception:*

*Shunts are not required for the individual anode connection in the individual anode boxes (GUB boxes) installed at the tank shell (Standard Drawing [AA-036355](#), Sheet 1) or for approved underground anode junction boxes.*

- 4.2.2.1.9 Do not install centralizers on anodes unless specifically stated in the design documents and approved by CSD.
- 4.2.2.1.10 Use a rope, sling or support pipe to lift or lower anodes weighing more than 40 kg.

4.2.2.2 Surface Anode Beds

- 4.2.2.2.1 Install surface anode beds according to Standard Drawing [AA-036346](#). Install the anode bed at the location (designated by the stakes) and the depth determined from soil resistivity measurements. The location of the stakes must correlate to the location specified on the project site layout drawing.
- 4.2.2.2.2 Install the number one anode at the farthest location to the right of the anode junction box when facing the front of the junction box.

4.2.2.3 Deep Anode Beds

- 4.2.2.3.1 Install deep anodes according to Standard Drawings
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[AA-036385](#) and [AA-036356](#). Refer to [17-SAIP-50](#) “*Inspection Coverage of Cathodic Protection Deep Anode Beds*” for inspection guidelines to be followed during installation.

- 4.2.2.3.2 Deep anode bed installations (deeper than 15 meters) require pre-approval for the maximum allowed drilling depth by the Groundwater Division of the Saudi Aramco Reservoir Characterization Department. The design agency is responsible for obtaining the approval. The installation contractor should not begin drilling without knowledge of the maximum allowed drilling depth, and documented verification that the approval has been received.
- 4.2.2.3.3 When anode holes are drilled with water or drilling mud, take drill stem resistance and test anode resistance measurements during drilling of the anode hole in accordance with the requirements detailed in Standard Drawing [AA-036385](#). Use a calibrated 4-pin resistance meter to take these measurements. Submit this data to the Supervisor of the Cathodic Protection group in CSD (with a copy to the CP engineering group of the proponent organization). Use the form sheet contained in Appendix 1 of this Best Practice.

CSD will determine the final acceptable bore hole depth and anode placement for optimal current distribution and anode bed resistance.

At locations where the anode holes are drilled dry, water shall not be added to the hole, and drill stem and test anode measurements shall not be taken unless specifically requested by the Supervisor of the Cathodic Protection group in CSD.

- 4.2.2.3.4 Install the number one anode at the bottom of the bore hole.
- 4.2.2.3.5 When coupling sections of support pipe, care should be taken to ensure that cables are not rotated in the well and if practical, pipe support brackets are aligned with the preceding sections of the pipe support.
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- 4.2.2.3.6 Unless specified otherwise by CSD, mix the calcined petroleum coke with water to form a slurry. Remove all floating particles and pump the calcined petroleum coke slurry from the bottom of the hole at a slow rate, allowing the hole to fill from the bottom up.
- 4.2.2.3.7 Calculate the amount of backfill required as specified on [AA-036385](#) and place the full amount in the hole.
- 4.2.2.3.8 The calcined petroleum coke slurry must be allowed at least 24 hours to settle before installation of the backfill material (usually cement) above the calcined petroleum.
- 4.2.2.3.9 A measurement of the resistance to ground of each anode and of all anodes combined shall be taken immediately before installing any backfill or cement above the coke breeze section of the bore hole. Measurements that indicate problems with the anodes shall be resolved before backfilling or cementing of the anode hole.

*Exception:*

*The individual resistances of anodes installed with a metallic support pipe cannot be accurately measured due to the continuity developed with the support pipe.*

4.2.2.3.10 Drilling Equipment

Unless approved otherwise by CSD, drill deep anode holes with rotary type drilling equipment that circulates the drillings to surface by water (or water/mud mixture) through the hollow center of the drill pipe. Unless approved otherwise by CSD, do NOT use equipment that drills a dry hole, or uses a hammering mechanism.

4.2.2.3.11 Use of Casing

Case the top 3 to 6 meters as required to maintain hole integrity through poorly consolidated surface soils. Metallic or non-metallic casing can be used.

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Do not install anodes inside any cased section of the hole unless approved otherwise by CSD.

Use cement plugs to seal lost circulation areas. Do not use casing (the casing will later corrode and the coke breeze backfill will dissipate into the formation).

If a water table is reached, casing can be installed to the top of the water table, but all anodes should be installed below the top of the water table to facilitate equalized current loading on the anodes.

#### 4.2.2.3.12 Drilling Fluid

Use water in locations where hole sloughing is not a problem.

Drill with bentonite or foam (or other CSD approved drilling mud additives) where sloughing is a problem, but do not use bentonite or additives to seal lost circulation zones unless pre-approved by CSD.

### 4.2.3 DC Power Sources for Onshore Facilities

- 4.2.3.1 Rectifiers for onshore applications are manufactured in accordance with [17-SAMSS-004](#) and [17-SAMSS-005](#). Install the rectifiers as detailed on the respective construction drawings maintaining compliance with Standard Drawing [AB-036378](#) (Sheets 1 & 2) and the electrical restrictions detailed in [SAES-P-111](#), [SAES-P-107](#), [SAES-P-104](#) and [SAES-B-068](#).
- 4.2.3.2 Photovoltaic power supplies for cathodic protection are manufactured in accordance with [17-SAMSS-012](#). Install photovoltaic power supplies as detailed on the respective construction drawings maintaining compliance with Standard Drawing [AA-036280](#).
- 4.2.3.3 Rectifiers and photovoltaic systems for well casings and pipelines shall be installed in accessible locations as far away from drifting sand as practical. The construction contractor shall provide sand stabilization where conditions in the area indicate a high probability for sand dune encroachment. Mount

rectifiers for pipelines and well casings a minimum of 300 mm above ground to minimize sand accumulation against the rectifier.

- 4.2.3.4 Where security fences are required for the cathodic protection above grade equipment, install them according to Standard Drawings [AB-036677](#) and [AA-036678](#).
  - 4.2.3.5 The DC power source and associated surface equipment for well casings shall not be installed on the well pad area unless:
    - a) located in an area common to other electrical equipment or,
    - b) situated in a location that is accessible to the CP Operations field technicians and will not be affected or interfered with during well workover or other maintenance procedures associated with the operation of the well site.
  - 4.2.3.6 Install an external fused disconnect switch or circuit breaker device in the AC power input to the rectifier. Select the device to include all of the following features:
    - a) an externally operable handle mechanism with lock out provision
    - b) enclosed in a NEMA 3, 4 or 4X enclosure as required by NFPA 70 (NEC), with the exception that NEMA 4X enclosures shall be used for all locations within one kilometer of a shoreline or inside a Plant or process facility where exposure to corrosive gasses may occur
    - c) mounted in an accessible location approximately 1.8 meters above grade, and within 3 meters of the rectifier
    - d) current rated at 125% of the rectifier maximum input current at rectifier rated load, or the nearest rating to 125% commercially available
  - 4.2.3.7 Photovoltaic Power Supplies for Onshore Facilities
    - 4.2.3.7.1 Photovoltaic power supplies for cathodic protection applications are manufactured in accordance with [17-SAMSS-012](#). Install photovoltaic power supplies according to the construction drawings and Saudi Aramco Standard Drawing [AA-036280](#).
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4.2.3.7.2 At installations where more than one module is used, place up to four modules side by side, with all panels facing due south. Use additional rows for more than 4 modules. Place the modules such that shadows from any module do not affect any other module.

#### 4.2.4 DC Cables for Onshore Facilities

- 4.2.4.1 Install buried DC cathodic protection cables according to Standard Drawings [AA-036675](#) and [AD-036132](#).
- 4.2.4.2 Mechanically protect above grade DC cathodic protection cables by using steel conduit, armored cable, covered cable trays, or where flexibility is required in flexible conduit in accordance with [SAES-P-104](#).
- 4.2.4.3 Negative cables attached to above grade structures may extend out of the conduit up to 1.5 meters between the conduit and the structure connection.
- 4.2.4.4 For multi-structure CP systems with multiple negative cables, carefully pre-measure and cut the length of each negative cable to the length specified in the design document and verify the size of the conductor to ensure agreement with the construction drawing. Using an incorrect size or length will adversely affect the current distribution to the structures.
- 4.2.4.5 Install cable route markers according to Standard Drawings [AB-036351](#) and [AB-036273](#) above buried DC cables (anode, bond, positive, and negative).

*Exception:*

*Cable route markers are not required if requested otherwise by the CP Proponent organization. The use of cable markers may increase the probability of theft and vandalism.*

- 4.2.4.6 Inspect all cables connected to the positive circuit of the rectifier for insulation damage immediately prior to installation. Use a pulse type holiday detector set at 18,000 volts DC. Repair of the insulation for buried positive cable should be avoided but may be accepted if an above grade junction box is used and preapproved by the Supervisor of the Cathodic Protection Group in CSD. See Standard Drawing [AA-036145](#) for cable junction box details for above grade splice.

*Exception:*

*If a cable becomes damaged **after** installation, you may repair the cable using a below grade anode junction box, or a Scotch 3M type underground cable splicing kit. Splicing kits must be installed by a certified electrician familiar with the use of underground splice kits for power cable applications.*

- 4.2.4.7 Visually inspect all negative cables, including bond cables and galvanic anode cables, for insulation damage or defects. Negative cables with visible insulation damage but no conductor damage may be repaired with three half lap layers of rubber tape covered by three half lap layers of plastic vinyl tape. For negative cables with conductor damage, see [Appendix 2](#) for splice procedure.

- 4.2.4.8 Install intermediate splices in above-grade splice boxes at 300 meter intervals for buried cable sections longer than 300 meters. For sections of cable between 300 meters and 600 meters in length, locate the splice box approximately at the midpoint. See Standard Drawing [AA-036145](#) for cable splice box details.

*Exception:*

*Intermediate splices are not required if requested otherwise in writing by the CP Proponent organization (reduce theft and vandalism).*

- 4.2.4.9 If an above grade cable termination of a CP cable greater than 50 meters in length is outside a secured fenced area, install a below grade cement anchor within 5 meters of the above grade termination point. A cement anchor is not required inside fenced plant areas or fenced well site areas.
- 4.2.4.10 Use a bolted mechanical connection to the lowest above grade flange for negative drain cable connections to well casings. Refer to Standard Drawing [AA-036073](#).
- 4.2.4.11 Use thermite welds or pin-brazing for all below grade negative drain cable and bond connections to steel pipes and structures. Refer to Standard Drawing [AB-036381](#).
- 4.2.4.12 Terminate the negative drain cable from a pipeline in an above-grade junction box located as close to the connection point as practical, but away from the pipeline berm.
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4.2.4.13 At multiple pipeline locations, use a bond box instead of a junction box to connect the individual pipeline negative cables to the CP power source. Do not terminate the test leads inside this bond box. Install an individual test lead with marker post above the respective pipeline at the negative connection.

4.2.4.14 Install individual shunts for each multiple positive and negative cable circuit, in all above grade junction or bond boxes.

#### 4.2.5 Ground Conductors for Onshore Facilities

4.2.5.1 Ground conductors in areas where CP is provided for buried piping shall be insulated (jacketed) as specified in [SAES-P-111](#).

4.2.5.2 Insulate existing bare ground conductors crossing a pipeline for a minimum of 6 meters on each side of the pipeline crossing. The insulation may be non-metallic conduit or insulated cable.

4.2.5.3 Do not use bare copper conductors when running parallel within 3 meters of a buried pipeline.

4.2.5.4 Grounding for cathodic protection junction, splice or bond boxes is not required. There are no AC components in the boxes and no components with unacceptable touch voltages. However, if grounding is installed, it shall be accomplished with one isolated ground rod and **shall not be** connected in any way to the ground grid.

##### *Commentary Note:*

*A fault condition in a positive bond or junction box connected to a common ground grid would result in electrical continuity between the positive circuit of the CP system and all equipment connected to the same ground grid. This is dangerous and could result in rapid corrosion of the ground grid and any associated buried metallic structure.*

#### 4.2.6 Test Stations, Bond Boxes, and Junction Boxes for Onshore Facilities

4.2.6.1 Junction boxes, bond boxes and test stations shall be manufactured in accordance with [17-SAMSS-008](#).

4.2.6.2 Each junction box, bond box and test station shall be constructed in accordance with the respective Saudi Aramco Standard Drawing.

- 4.2.6.3 Install test stations, bond boxes, and junction boxes on supports constructed according to Standard Drawing [AB-036540](#). Do not ground junction boxes associated with the positive circuit of the rectifier (see paragraph 4.2.5.4). Show all test stations and box locations on the construction drawings.

*Exception:*

*Below grade junction and bond boxes may be used with written approval from the CP Proponent organization and the Supervisor of the Cathodic Protection group of CSD, Dhahran.*

*Commentary Note:*

*Below grade junction and bond boxes that are approved for use by Saudi Aramco have been tested by the RSA. Tests completed by the RSA involve pressurized immersion tests energized at 200 VDC for 60 days to assess reliability.*

- 4.2.6.4 Identify all cables inside test stations, bond boxes, and junction boxes with durable tags according to Standard Drawing [AD-036132](#). Label the cable and the terminals to indicate the structures to which they are connected.

*Exception:*

*Cable identification is not required inside one pin test stations, above grade splice boxes or buried junction boxes.*

- 4.2.6.5 Install an inside and outside nameplate for all above grade junction and bond boxes indicating the identifying number of the structure and/or the rectifier unit to which they are connected.
- 4.2.6.6 Multiple positive or negative cables in above grade junction and bond boxes shall have individual shunts installed for each active circuit.

- 4.2.6.7 Install the negative drain junction box for multiple structures at the exact location shown on the construction drawing.

*Commentary Note:*

*The placement of the junction box and the lengths and sizes of the cables are determined in the design and have been optimized to provide the required current distribution for the CP system.*

- 4.2.6.8 Install and connect the bond station, including wire labeling for all bonding station installations within 7 days from the date the berm over the new pipeline is completed.

*Commentary Note:*

*The bond wire from a new pipeline should be connected to all crossing and adjacent parallel pipelines as soon as possible to avoid interference currents.*

- 4.2.6.9 Complete the installation of all test lead wiring to a new pipeline, including wire labeling within 7 days from the date the berm over the new pipeline is completed. If the test stations are not installed when the test leads are fastened to the pipe, coil the labeled test leads above grade to facilitate CP potential measurements.
- 4.2.6.10 Complete the installation of the test station including termination of the labeled wires within 30 days from the date the berm over the new pipeline is completed.

4.2.7 Electrical Area Classification

All electrical equipment used for CP installations shall comply with the requirements of the electrical area classification of the location in which it will be installed in accordance with [SAES-B-068](#).

4.2.8 Concrete Foundations and Footings

Concrete foundations, footings and supports shall be constructed according to Saudi Aramco Engineering Standards [SAES-Q-001](#) and [SAES-Q-005](#).

4.2.9 Fencing and Guardrails

- 4.2.9.1 Where dictated by security requirements, protect transformers, rectifiers, and photovoltaic power supplies located outside plant security fences with a Type IV fence. Details of Type IV fencing are shown on Standard Drawings [AB-036677](#) and [AA-036678](#).
- 4.2.9.2 Install guardrail facilities for unfenced rectifiers, anode bed junction boxes, and watering pipes, at sites where vehicular traffic or other conditions in the area indicate a possibility of damage.
- 4.2.9.3 Do not place rectifiers inside an electrical substation or any other fenced area that is not normally accessible to CP operating and maintenance personnel, unless the fencing
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around the area is modified with a separate entry to allow access to the rectifier.

#### 4.3 Vessel and Tank Internals

##### 4.3.1 Galvanic Anodes for Vessel and Tank Internals

Install galvanic anodes in accordance with the latest revisions of Standard Drawings [AA-036354](#), [AA-036762](#) or [AA-036388](#).

##### 4.3.2 Impressed Current Anodes for Vessel and Tank Internals

Install impressed current anodes in accordance with the latest revision of Standard Drawing [AA-036353](#).

##### 4.3.3 D.C. Power Source for Vessel and Tank Internals

4.3.3.1 Install rectifiers in accordance with [SAES-X-500](#), [SAES-P-100](#), [SAES-P-104](#), [SAES-P-107](#), [SAES-P-111](#), [SAES-B-068](#), and Standard Drawing [AB-036378](#).

4.3.3.2 Install an external fused disconnect switch or circuit breaker device in the AC power input to the rectifier. Select the device to include all of the following features:

- a) an externally operable handle mechanism with lock out provision
- b) enclosed in a NEMA 3, 4 or 4X enclosure as required by NFPA 70 (NEC), with the exception that NEMA 4X enclosures shall be used for all locations within one kilometer of a shoreline or inside a Plant or process facility where exposure to corrosive gasses may occur. Refer to [SAES-P-104](#) for enclosure NEMA rating requirements
- c) mounted in an accessible location approximately 1.8 meters above grade, and within 3 meters of the rectifier
- d) current rated at 125% of the rectifier maximum input current at rectifier rated load, or the nearest rating to 125% commercially available

##### 4.3.4 D.C. Cables for Vessel and Tank Internals

4.3.4.1 Install buried DC cathodic protection cables according to Standard Drawings [AA-036675](#) and [AD-036132](#).

- 4.3.4.2 Mechanically protect above grade DC cathodic protection cables by using steel conduit, armored cable, or covered cable trays, or where flexibility is required in flexible conduit in accordance with [SAES-P-104](#). Negative cables attached to above grade structures may extend out of the conduit up to 1.5 meters between the conduit and the structure connection.
- 4.3.4.3 Inspect all cables connected to the positive circuit of the rectifier for insulation damage immediately prior to installation. Use a pulse type holiday detector set at 18,000 volts DC. Repair of the insulation for buried positive cable by any method is prohibited. Above-grade repair connections for anode bed positive cables in splice boxes are acceptable. See Standard Drawing [AA-036145](#) for cable splice box details.
- 4.3.4.4 Visually inspect all negative cables, including bond cables and galvanic anode cables, for insulation damage or defects. Negative cables with visible insulation damage but no conductor damage may be repaired with three half lap layers of rubber tap covered by three half lap layers of plastic vinyl tape.

#### 4.3.5 Electrical Area Classification

All electrical equipment used in CP installations shall comply with the requirements of the electrical area classification of the location in which it will be installed in accordance with [SAES-B-068](#).

#### 4.3.6 Concrete Foundations and Footings

Concrete foundations, footings and supports shall be constructed according to Saudi Aramco Engineering Standards [SAES-Q-001](#) and [SAES-Q-005](#).

#### 4.3.7 Fencing and Guardrails

Install guardrail facilities for rectifiers and anode bed junction boxes at sites where vehicular traffic or other conditions in the area indicate a possibility of damage.

### 4.4 Existing Reinforced Concrete Structures

#### 4.4.1 Anode Installation

- 4.4.1.1 Clean and prepare the surface according to Section 6.5.2 of [SAES-X-800](#) and the requirements of the cementitious overlay prior to anode installation.
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- 4.4.1.2 Place anode mesh panels as designed and interconnect them with current distributor bars. Install the current distributor bars on the concrete surface with the anode mesh placed on top.
- 4.4.1.3 Weld the current distribution bars to the mesh at every mesh strand crossing.
- 4.4.1.4 Do not exceed a distance of 100 mm between adjacent anode mesh panels.
- 4.4.1.5 Securely fasten the anode mesh to the concrete surface using nonmetallic fasteners to prevent movement during overlay placement.
- 4.4.1.6 Do not exceed a distance of 100 mm in each direction for interconnection welds if overlapping of anode mesh panels is required.

#### 4.4.2 Positive Connections

- 4.4.2.1 Weld the positive connections to each current distribution bar in the following manner:
  - a) Prepare a 150 mm long, 3.175 mm diameter titanium rod.
  - b) Connect the pre-stripped copper core of the positive cable to the titanium rod by compression crimp.
  - c) Encapsulate the assembly with a suitable, mechanically strong adhesive lined heat shrink tube, which extends 50 mm either side of the crimp. Care shall be taken during the heat shrink operation to ensure no damage results to the cable insulation.
  - d) At the proposed locations for each current distribution bar, connect the assembly along the bar in the manner as described below:
    - i. Position the assembly in the correct orientation and secure it to the current distribution bar.
    - ii. Fasten the positive cable to the current distribution bar and then to the concrete surface using non-metallic cable ties.
    - iii. Make the connection between the assembly and current distribution bar by tack welding (minimum of

6 welds). Take care to ensure that the process in no way damages the current distribution bar or the cable connection.

- 4.4.2.2 Inspect the system positive connections and get Saudi Aramco representative approval prior to overlay placement.

#### 4.4.3 Negative Connections

- 4.4.3.1 At the locations of the negative connections, clean the reinforcement thoroughly to expose clean bright steel around its full circumference. Then, connect the system negative to the reinforcing steel by brazing as follows:

- a) Drill a 30 mm deep hole off-center in the end of a 10 mm diameter rebar which is 100 mm long.
- b) Place the pre-stripped copper core of the negative cable inside the hole and braze welded to the rebar.
- c) Encapsulate the connection with an adhesive lined heat shrink tube extending 50 mm either side of the connection point.
- d) Weld the bare portion of the rebar along the designated steel reinforcement of the structure to be protected.

- 4.4.3.2 Record the DC resistance between and within zones. If the resistance is more than 2 ohms, install more connections until a value less than 2 ohms resistance is achieved. Then, record the resistance between any one single cable and the remaining cables.

- 4.4.3.3 Inspect the system negative connections and get Saudi Aramco representative approval prior to overlay placement.

#### 4.4.4 Reference Electrodes

- 4.4.4.1 Install the reference electrodes at the predetermined locations.
- 4.4.4.2 Place the reference electrode at the level of, and parallel to the reinforcing steel.
- 4.4.4.3 Provide an instrument negative connection at the location. The connection shall follow the same procedure described for the system negative connections.

- 4.4.4.4 Mark all reference electrodes on the electrode case and at the cable termination point.
- 4.4.4.5 Encapsulate (pre-cast) each reference electrode in concrete similar to the overlay materials with the addition of 3% sodium chloride to the mix water to facilitate a low resistivity connection. Cover the electrode with at least 20 mm of concrete over all surfaces of the electrode. The encapsulation shall occur at least three days prior to the placement. Roughen the surface of the encapsulation prior to placement to prevent a shrinkage interface being formed.

#### 4.4.5 Overlay

##### 4.4.5.1 General

- 4.4.5.1.1 Extend the overlay over the whole of the area covered by cathodic protection anodes.
- 4.4.5.1.2 Ensure that application of the overlay does not damage any anode, cables, etc., either within the pouring panel or on adjacent panels.
- 4.4.5.1.3 Protect all items which are not designated for total encapsulation during installation.

##### 4.4.5.2 Surface Preparation

- 4.4.5.2.1 Carry out surface preparation to all surfaces to which anodes are to be installed irrespective of whether the substrate is original concrete or repair material.
- 4.4.5.2.2 Remove all traces of laitance to expose clean aggregate by chipping or abrasive blasting.
- 4.4.5.2.3 Provide a profile that is a minimum of 50% of the aggregate size or 8 mm peak, whichever is greater.
- 4.4.5.2.4 Ensure that the surface preparation activities do not cause weakness of the interface due to the fracture of aggregate or loosening of the bond. If this does occur, carry out further surface preparation by grit blasting or water blasting only, until this situation is remedied.

#### 4.4.5.3 Overlay Application

- 4.4.5.3.1 Following preparation and anode installation, pre wet the surfaces with potable water for 24 hours immediately prior to overlay application to reduce absorption of curing water by the substrate concrete. Where considered necessary, take additional precautions such as shading or polythene sheeting, in order to assist the saturation of the existing concrete before application.
- 4.4.5.3.2 Limit the maximum time between mixing and application to 20 minutes.
- 4.4.5.3.3 Use external surface vibrators to compact the concrete, if the overlay is poured onto the deck areas on top of the anodes.
- 4.4.5.3.4 Apply the poured overlay to each section in a single layer. Minimize the time between pours of adjacent sections to avoid cold joints.
- 4.4.5.3.5 Fix formwork securely to the base substrate to make it rigid and watertight. Construct the framework such that it does not bulge or sag during pouring.
- 4.4.5.3.6 Use a form oil to prevent surface blemishes being created on form removal. If such blemishes do arise, repair them by hand application of a similar mix to the pour with due consideration for aggregate size.
- 4.4.5.3.7 For sprayed concrete, the application shall conform to the requirements of [ACI 506.2-95](#) "Specification for Shotcrete" and [ACI 506R-90](#) "Guide to Shotcrete."
- 4.4.5.3.8 CONTRACTOR shall install a test panel of his proposed mix and procedure to ensure compliance with the specification. Perform all tests on site, witnessed by the Saudi Aramco Inspection representative.
- 4.4.5.3.9 Follow the manufacturer's instructions totally if proprietary materials are to be used.

4.4.5.3.10 Cure all concrete overlays with potable water for 28 days minimum. Provide shading for surfaces in direct exposure to sunlight.

4.4.5.3.11 Do not use curing agents.

#### 4.4.5.4 Weather Precautions

Refer to [SAES-Q-001](#) for hot weather precautions.

#### 4.4.5.5 Repair of Defects

Remove, discard and replace any overlay which lacks uniformity, exhibits segregation, honeycombing, lamination or which contains dry patches, voids or sand pockets.

## 5 Precommissioning Cathodic Protection Equipment

### 5.1 General

5.1.1 Precommissioning responsibilities and requirements are specified in GI-0002.710 and further detailed in this document. Precommissioning is the responsibility of PMT.

5.1.2 Precommissioning forms for cathodic protection systems are available on the Saudi Aramco Standards Online site <http://standards.aramco.com.sa/>. Typical precommissioning forms that will be required for the respective structure are as listed below:

|                            |                                                     |
|----------------------------|-----------------------------------------------------|
| Marine Structure:          | SA-X-001, 008, 009, 011                             |
| Plant Facilities:          | SA-X-001, 003, 004, 005                             |
| Pipelines:                 | SA-X-001, 002, 007                                  |
| Tank & Vessel Internals    | SA-X-001, 005                                       |
| Onshore Well Casings       | SA-X-001, 002, 006, 007                             |
| Onshore Multi-Well Casings | SA-X-001, 007, <a href="#">App. 3</a> of SABP-X-003 |

5.1.3 Precommissioning of cathodic protection equipment shall be performed by trained and certified cathodic protection technicians (minimum NACE CP Level 1 but preferably NACE CP Level 2 or higher) typically contracted through a recognized CP Design Engineering agency.

### 5.2 Remote Monitoring Equipment

5.2.1 Precommissioning of remote monitoring equipment for the cathodic protection operating parameters shall be considered part of the cathodic

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protection system precommissioning requirements and shall be the responsibility of the PMT in accordance with GI-0002.710.

- 5.2.2 Precommissioning of the remote monitoring equipment for cathodic protection operating parameters requires documented verification that the cathodic protection outputs being monitored are accurately received into the respective Operations PI data base, or directly to the CP Proponent's dedicated data base as specified in the Design Documents.

## **6 Inspection for Cathodic Protection Installations**

### **6.1 CP Systems for Marine Structures**

Notify Project Inspection and the Proponent Operations Inspection Unit at least four days prior to the start of construction to ensure that inspection coverage can be provided for the complete duration of the job. Provide full inspection during anode installation, cable installation, and positive and negative cable hookups to rectifier. Submit test data sheets to the inspection agency for review.

### **6.2 CP Systems for Onshore Facilities**

- 6.2.1 Notify Project Inspection and/or the Proponent Operations Inspection before the start of construction. Provide test data sheets to the inspection agency for review at least three days, but not more than one week prior to the start of construction. Copies of the instrument calibration certificates for the instruments that will be used during installation shall be made available to the Project Inspection group before the start of construction. Inspection is critical for:

- a) deep anode bed drill stem and test anode measurement
- b) anode cable insulation holiday detection
- c) loading of the anodes into surface or deep holes
- d) pre-measurement and pre-cutting of the negative cables used for cathodic protection systems involving multiple structures

- 6.2.2 Comply with [17-SAIP-50](#) for inspection of deep anode bed installations.

## **7 Records**

### **7.1 General**

Revise all construction drawings to show the "as-built" CP system. The as-built drawings shall show the location of all installed cathodic protection equipment and shall detail the respective size and rating for each piece of the installed

cathodic protection equipment. PMT shall submit copies of the as-built drawings to the cathodic protection Proponent Organization defined by GI-0428.001 for review within sixty days of project completion. Corrections shall be completed within thirty days and resubmitted.

## 7.2 Existing Reinforced Concrete Structures

Provide the following documents to the Proponent Department and Consulting Services Department:

- a) Description of Structure and Systems
- b) As-Built Drawings of Cathodic Protection System
- c) Commissioning Data
- d) Periodic Inspection Requirements and Monitoring Method Statement
- e) System Output Parameters
- f) Rectifier Operating Instructions and Maintenance Requirements
- g) Rectifier Circuit Drawings
- h) Reinforcement and Permanent Reference Electrode Potential Data
- i) Electrical Continuity and Electrical Isolating Data
- j) Current Requirement Data
- k) Chloride Test Results and Other Chemical and Physical Analyses
- l) Delamination Survey Data
- m) Depth of Cover Data

**Revision Summary**

- 16 July 2011 Added statement to clarify the requirement to remove all non-metallic protective packaging material from offshore MMO anodes, but not to remove or damage copper sleeves installed to minimize marine growth.  
Added statements clarifying the use of drill stem and test anode measurements for wet drilled anode holes, but not for dry drilled anode holes.  
Added statement to clarify the requirement to use cement anchors for cables terminated outside secure fenced areas and for cables terminated at a rectifier that is not in a plant area or fenced well site location.  
Added statements and a procedure ([Appendix 2](#)) for below grade splicing of damaged cables  
Removed all statements related to commissioning and clarified precommissioning requirements (Commissioning requirements are addressed by [SAEP-332](#) and do not belong in this document).  
Added statements to clarify the requirement to pre-measure and cut the negative cables for cathodic protection systems with multiple negatives connected to multiple structures.  
Added [Appendix 3](#), Precommissioning form for multi-well CP systems.  
Added statements to clarify PMT's responsibility to pre-commission remote monitoring systems associated with new cathodic protection systems.  
Added a statement to allow thermite welding to internally coated pipes with a wall thickness of 0.5 inches or greater, and recommended pin brazing for an internally coated pipe with a wall thickness less than 0.5 inches.  
Added a Detailed Table of Contents.
- 7 February 2012 Added paragraph 4.1.2.5 to allow for the installation of copper sleeves which provide protection for the MMO or other dimensionally stable anode materials surfaces from the marine growth during the time that the anode is not energized.

## Appendix 1 – Drill Stem and Test Anode Resistance Measurements

Well or P/L Name: \_\_\_\_\_ Field Name or P/L Km.: \_\_\_\_\_ Submitted By: \_\_\_\_\_ Date: \_\_\_\_\_

### Design Data:

| CP Power Supply |         | Anode Hole(s)       |                 |               | Anodes         |              |                   |                    |
|-----------------|---------|---------------------|-----------------|---------------|----------------|--------------|-------------------|--------------------|
| DC Volts        | DC Amps | Hole No. ___ of ___ | Target Depth(m) | Max. Depth(m) | Type TA-4 or 5 | Total Number | Target Resistance | Maximum Resistance |
|                 |         |                     |                 |               |                |              |                   |                    |

### Existing CP System Data ☐ Not Applicable ☐ Applicable

| Existing CP Power Supply |                   | Existing Anode Hole(s) |                  |                 |                                                 | Existing Anodes |        |                   |
|--------------------------|-------------------|------------------------|------------------|-----------------|-------------------------------------------------|-----------------|--------|-------------------|
| Rated Volts              | Rated Amps        |                        |                  |                 |                                                 |                 |        |                   |
| Operating DC Volts       | Operating DC Amps | Manufacture Date       | Surface or Deep? | Number of Holes | Measured Resistance to Well Head <sup>(1)</sup> | Type TA-4 or 5  | Number | Installation Year |
|                          |                   |                        |                  |                 |                                                 |                 |        |                   |

### Measurement Equipment Data:

| Resistance Measurements                                         | Length (meters) | Size (AWG or mm <sup>2</sup> ) | Resistance (ohms) |
|-----------------------------------------------------------------|-----------------|--------------------------------|-------------------|
| Megger Calibration Cable <sup>(1)</sup> and Cable to Drill Stem | 20              | 2 wire #14AWG                  |                   |
| Cable Connected to Pipeline or Well Casing <sup>(2)</sup>       | 200             | 2 wire #14AWG                  |                   |
| Cable Connected to Test Anode <sup>(3)</sup>                    | 100             | 16 mm <sup>2</sup>             |                   |
| Drill Stem to Drill Truck                                       |                 |                                |                   |

### Drill Stem and Test Anode Resistance Measurement Data (Report directly as read from meter)

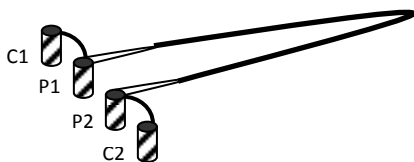
| Depth (m)                                                                                                                        | Drill Stem <sup>(4)</sup> Resistance (ohms) | Test Anode <sup>(5)</sup> Resistance (ohms) | Soil Type | Remarks |
|----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|---------------------------------------------|-----------|---------|
| Water level in the anode hole must be kept constant and within 1 meter of surface for all Drill Stem and Test anode measurements |                                             |                                             |           |         |
| 6                                                                                                                                |                                             |                                             |           |         |
| 9                                                                                                                                |                                             |                                             |           |         |
| 12                                                                                                                               |                                             |                                             |           |         |
| 15                                                                                                                               |                                             |                                             |           |         |
| 18                                                                                                                               |                                             |                                             |           |         |
| 21                                                                                                                               |                                             |                                             |           |         |
| 24                                                                                                                               |                                             |                                             |           |         |
| 27                                                                                                                               |                                             |                                             |           |         |
| 30                                                                                                                               |                                             |                                             |           |         |
| 33                                                                                                                               |                                             |                                             |           |         |
| 36                                                                                                                               |                                             |                                             |           |         |
| 39                                                                                                                               |                                             |                                             |           |         |
| 42                                                                                                                               |                                             |                                             |           |         |
| 45                                                                                                                               |                                             |                                             |           |         |
| 48                                                                                                                               |                                             |                                             |           |         |
| 51                                                                                                                               |                                             |                                             |           |         |
| 54                                                                                                                               |                                             |                                             |           |         |
| 57                                                                                                                               |                                             |                                             |           |         |
| 60                                                                                                                               |                                             |                                             |           |         |
| 63                                                                                                                               |                                             |                                             |           |         |
| 66                                                                                                                               |                                             |                                             |           |         |
| 69                                                                                                                               |                                             |                                             |           |         |
| 72                                                                                                                               |                                             |                                             |           |         |
| 75                                                                                                                               |                                             |                                             |           |         |
| Continued on next page.                                                                                                          |                                             |                                             |           |         |

## Appendix 1 – Drill Stem and Test Anode Resistance Measurements (continued)

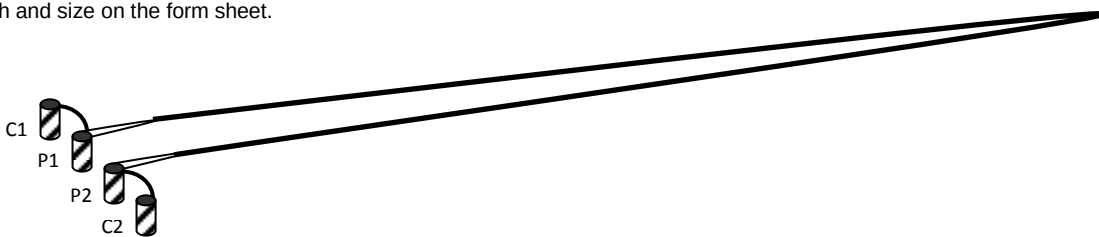
| Depth (m) | Drill Stem Resistance (ohms) | Test Anode Resistance (ohms) | Soil Type | Remarks |
|-----------|------------------------------|------------------------------|-----------|---------|
| 78        |                              |                              |           |         |
| 81        |                              |                              |           |         |
| 84        |                              |                              |           |         |
| 87        |                              |                              |           |         |
| 90        |                              |                              |           |         |
| 93        |                              |                              |           |         |
| 96        |                              |                              |           |         |
| 99        |                              |                              |           |         |
| 102       |                              |                              |           |         |
| 105       |                              |                              |           |         |
| 108       |                              |                              |           |         |
| 111       |                              |                              |           |         |
| 114       |                              |                              |           |         |
| 117       |                              |                              |           |         |
| 120       |                              |                              |           |         |

**Notes:**

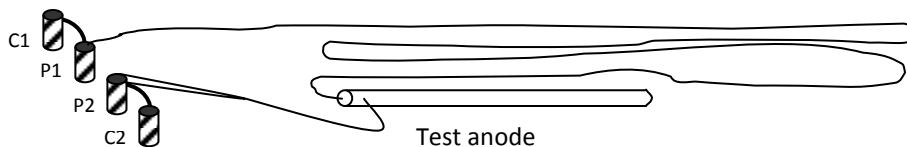
- Measurement of the resistance of the calibration cable:
  - Use the 20 meter 2-wire #14 AWG cable for this measurement.
  - Uncoil** the cable completely.
  - Connect one of the wires to P1 and the other end of this wire to P2.
  - Connect one end of the other wire to P1 and the other end of this wire to P2.
  - Use a small piece of wire to short between C1 and P1.
  - Use a second small piece of wire to short between C2 and P2.
  - Measure the resistance with the Megger
  - This resistance should be less than 0.05 ohms.



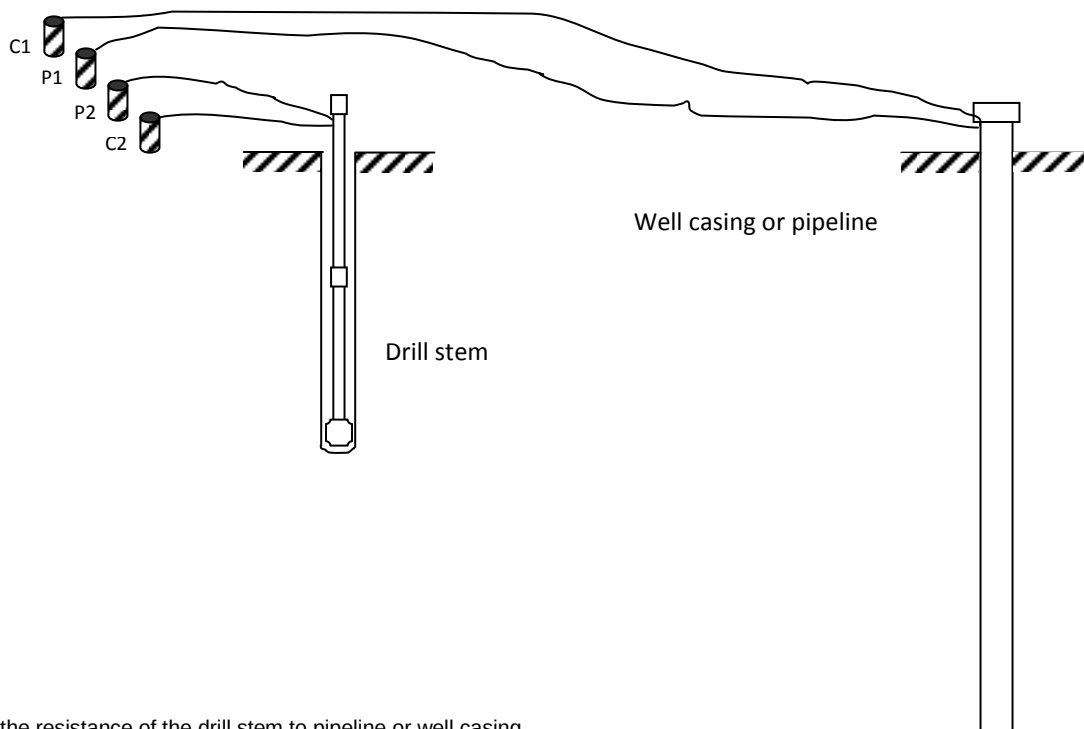
- Measurement of the resistance of the cable used to connect to the pipeline or well casing:
  - Use the 200 meter 2-wire #14 AWG cable for this measurement.
  - Uncoil** the cable completely.
  - Connect one of the wires to P1 and the other end of this wire to P2.
  - Connect one end of the other wire to P1 and the other end of this wire to P2.
  - Use a small piece of wire to short between C1 and P1.
  - Use a second small piece of wire to short between C2 and P2.
  - Measure the resistance with the Megger
  - This resistance should be less than 0.90 ohms.
  - There should be absolutely **NO SPLICES** in this cable. If a longer cable is required, use a longer cable and record the length and size on the form sheet.



3. Measurement of the resistance of the cable connected to the test anode
  - Uncoil the cable and loop the cable end back towards the anode in a single loop
  - Connect terminals C1 and P1 of the Megger to one of the strands of copper from the end of the anode cable.
  - Connect a short wire from terminals C2 and P2 of the Megger to the end of the anode with a clamp.
  - This resistance should be approximately 0.14 to 0.16 ohms depending on the calibration cable resistance and ambient temperature.



4. Measurement of the resistance of the drill stem to pipeline or well casing
  - Use the 200 meter 2-wire #14 AWG cable and the 20 meter 2-wire #14AWG cable for this measurement.
  - **Uncoil** the 200 meter cable completely.
  - Connect one of the wires to P1 and the other end of this wire to the pipeline or well casing.
  - Connect one end of the other wire to C1 and the other end of this wire to the pipeline or well casing.
  - **Uncoil** the 20 meter cable completely.
  - Connect one of the wires to P2 and the other end of this wire to the drill stem.
  - Connect one end of the other wire to C2 and the other end of this wire to the drill stem.
  - Measure the resistance with the Megger
  - There should be absolutely **NO SPLICES** in these cables. If a longer cable is required, use a longer cable and record the length and size on the form sheet.



5. Measurement of the resistance of the drill stem to pipeline or well casing.
  - Connect C1 and P1 to the pipeline or well casing as illustrated above.
  - Short C2 and P2 together
  - Connect the end of the wire from the test anode to C2 and begin measurements in the bore hole.

## **Appendix 2 – Splice Procedure for Damaged Cathodic Protection Cable**

### **1. Purpose**

To provide a quality work instruction for splicing damaged cathodic protection cables that have become damaged after installation.

### **2. Scope**

The scope covers impressed current and galvanic cathodic protection cables that have become damaged after installation, in situations where it would be impractical or it would not be cost effective to replace the entire length of cable. This splice procedure shall not be applied to new construction on cables that have not been installed. Typical cables covered by this Procedure are as follows:

- a. Installed cables connected to the negative or positive circuit of an impressed current cathodic protection system
- b. Installed cables connected to magnesium or other type galvanic anodes
- c. Installed cables connected between junction boxes & pipelines

### **3. References**

#### **3.1. Saudi Aramco References**

- 3.1.1. Saudi Aramco Engineering Standards

[SAES-P-104](#)

*Wiring Methods and Materials*

- 3.1.2. Saudi Aramco Standard Drawings

[AA-036675](#)

*Cathodic Protection Installation Details Direct Buried Cables*

#### **3.2. Industry Codes and Standards**

- 3.2.1. National Fire Protection Association

*NFPA 70*

*National Electrical Code (NEC)*

### **4. Procedure**

#### **4.1. Cable Installation**

- 4.1.1. Prior to cable laying, dimensions of cable trench shall be check against the S.A. Standard Drawing ([AA-036675](#)) for Cathodic Protection (CP). Particular attention will be paid to the requirement for bedding with clean sand, warning tape or/and quality of back filling materials.

- 4.1.2. Where cables are pulled into conduits or ducts these shall be inspected to ensure they are clean and free from foreign debris. Ensure that cable installed in conduits shall be in accordance with [SAES-P-104](#) and [AA-036675](#).
- 4.1.3. Where cables of different voltage levels and /or services are run in parallel; segregation will be in accordance with the specification and drawings.
- 4.1.4. Splicing and termination of low voltage CP cables shall be carried out by experienced and qualified electrical technicians.

#### **4.2. Splice Installation**

- 4.2.1. Strip each conductor end by removing the appropriate amount of insulation determined by the length of the crimp connector.
- 4.2.2. Insert the splicing sleeve (crimp connector) on the conductor:
  - i. Place the splicing sleeve (crimp connector) over the end of the first conductor.
  - ii. Push the splicing sleeve (crimp connector) on the conductor until the insulation is fully butted against the end of the splicing sleeve (crimp connector).
  - iii. While holding the conductor and splicing sleeve in this position, use the crimping tool to press crimps in the splicing sleeve.
  - iv. Crimp the splicing sleeve twice on each end, rotating the conductor 90 degrees between crimps.
  - v. Repeat steps (i – v) for the second conductor to be crimped at the other side of the splicing sleeve.
- 4.2.3. The installed splicing sleeve (crimped connector) shall then be taped:
  - i. Apply three half lap layers (50% overlap) of Scotch 130C rubber tape followed by
  - ii. Three half lap layers of Scotch 33+ electrical tape.

### Appendix 3 – Pre-Commissioning Form for Multi Well Cathodic Protection Site

[illegible]