



Engineering Standard

SAES-X-700

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Cathodic Protection of Onshore Well Casings

Document Responsibility: Cathodic Protection Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

- 1.1 This standard prescribes the minimum mandatory requirements governing the design and installation of cathodic protection (CP) systems for onshore metallic well casings.

Commentary Notes:

The cathodic protection requirements for offshore well casings are beyond the scope of this standard and are addressed in [SAES-X-300](#). Onshore well casings with anodes installed offshore are within the scope of this standard.

Cathodic protection as addressed in this standard does not provide corrosion protection for the inside surface of the well casing.

- 1.2 Cathodic protection systems for onshore well casings may be dedicated, shared, ICCP and/or galvanic CP systems.
- 1.3 Onshore oil, gas, observation, water injection, and water supply metallic well casings with a predicted life expectancy greater than five years shall be provided with cathodic protection within the time period specified in [Section 7](#) of this standard if:
- The well casing is installed through a corrosive formation, or
 - The well casing is not installed through a corrosive formation, but has a permanent buried metallic flow-line, in which case, sufficient CP shall be provided to maintain the flow-line at an acceptable protection level in accordance with [SAES-X-400](#) without electrical isolation of the well casing from the flow-line.

Commentary Note:

Typically, well casings without flow-lines completed in or above the UER formation do not require cathodic protection.

- 1.4 A metallic well casing that is not installed through a corrosive formation and does not have a permanent flow-line does NOT require cathodic protection. However, if a foreign impressed current anode bed is within 200 meters of this type of well, electrical bonding shall be implemented to minimize the probability of downhole interference.
- 1.5 A metallic well casing that has not been coated with Fusion Bonded Epoxy (FBE) and is installed within a metallic or non-metallic cellar and backfilled shall be provided with two prepackaged 27.5 kg (60 lb) magnesium anodes installed inside the wellhead cellar to provide supplemental cathodic protection for the landing base area.
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Commentary Note:

To provide further clarification for the above statement, supplemental galvanic anodes for permanent protection of the landing base area are not required for well casings that:

- do not have cellars, or*
- are installed in cellars that are not backfilled, or*
- are FBE coated through the cellar area.*

1.6 This standard shall not be attached to, nor made a part of a purchase order.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Company Engineering Standards, Material Specifications, Standard Drawings, or forms shall be resolved in writing by the Design Agency representative through the Company Cathodic Protection (CP) 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](#), “Instructions for Obtaining a Waiver.”

3 References

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

The Saudi Aramco 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-062](#)

Onshore Wellsite Safety

[SAES-P-104](#)

Wiring Methods and Materials

[SAES-X-300](#)*Cathodic Protection of Marine Structures*[SAES-X-400](#)*Cathodic Protection of Buried Pipelines***Saudi Aramco Materials System Specifications**[17-SAMSS-004](#)*Conventional 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](#)*Modular Photovoltaic Power Supply for Cathodic Protection*[17-SAMSS-017](#)*Impressed Current Cathodic Protection Cables*[17-SAMSS-018](#)*Remote Monitoring System (RMS) for Cathodic Protection***Saudi Aramco Standard Drawings**[AA-036385](#)*Cathodic Protection - Deep Anode Bed*[AA-036389](#)*Galvanic Anode Details*[AD-036785](#)*Symbols for Cathodic Protection***Saudi Aramco Best Practice**[SABP-X-003](#)*Cathodic Protection Installation Requirements***Saudi Aramco General Instructions***GI-0002.710**Mechanical Completion and Performance Acceptance of Facilities**GI-0428.001**Cathodic Protection Responsibilities***3.2 Industry Codes and Standards****National Fire Protection Association**[NFPA 70](#)*National Electrical Code (NEC)***National Electrical Manufacturers Association****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.

Coated Casing: The term “coated casing” as used in this engineering standard describes a well casing with an external non-conductive coating (typically Fusion Bond Epoxy or FBE). The coating must be applied to all sections of the casing in contact with soil or formation, from surface to the bottom of the casing or to a depth determined to facilitate external corrosion mitigation with cathodic protection through the relevant down hole corrosive aquifers. Casings that have been coated over the upper two or three joints of casing only are not “coated casings”. Coating applied to well casings is not applied as a corrosion barrier. It is applied to reduce the total amount of CP required or to extend the influence of the applied CP.

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

CP System Operating Circuit Resistance: The total 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 for commissioning.

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 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. 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 storage facility. Scraper traps and launcher areas are not plant areas.

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 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

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.). A surface anode bed may also be referred to as a Shallow Anode Bed.

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.

T/R: Transformer/Rectifier - A cathodic protection power supply that transforms and rectifies AC power into an adjustable output DC power for cathodic protection applications. Typically abbreviated or truncated as “T/R” or “Rectifier”.

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.

Uncoated Casing: The term “uncoated casing” when used in this engineering standard describes a well casing that is either bare (no external coating), or may have an external coating applied to the shallow sections of casing to minimize corrosion in the landing base or surface soils.

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

WIP: Water Injection Plant

5 Design Review and Approval

5.1 Contractor/Designer Qualifications

- 5.1.1 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.
- 5.1.2 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.

Commentary Note:

As noted in GI-0428.001, PMT may request assistance from CSD for the verification of the qualifications of the Design Contractor's engineer responsible for designing the CP systems.

5.2 Design Review

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

5.2.2 The Design Agency shall not issue drawings for construction until the design has been reviewed and approved in writing by CSD and the CP Proponent organization.

5.3 Design Basis Scoping Paper (DBSP)

The DBSP shall specifically state if cathodic protection is required, or is not required, as dictated by SAES-X-700. No other design considerations for cathodic protection are required for the DBSP.

5.4 Project Proposal

5.4.1 Project Proposal packages submitted to CSD for review shall provide all design considerations that can be developed without requiring the measurement of field data or a site visit.

5.4.2 The Project Proposal package shall include a specific statement in the scope of work that clearly identifies any requirement to provide CP for existing well casings, flow-lines or trunk-lines.

5.4.3 The Project Proposal shall provide clear direction on the general design approach with respect to the following:

a. The CP systems shall be designed as:

- single well CP systems, or
- multi-well CP systems

b. The well casings are:

- coated casings, or
- bare casings

c. The CP power supply shall be:

- Photovoltaic, or
- Galvanic, or
- AC powered
 - air cooled, or
 - oil cooled
 - single phase, or
 - three phase

5.4.4 The Project Proposal shall clearly state if remote monitoring equipment will be included with the CP power supplies and if so shall provide the following general design information:

- a. Will the CP power supply be provided with:
 - signal transmitters, or
 - a Remote Monitoring Unit (RMU)?
- b. What operating parameters are going to be monitored (must meet minimum requirements)?
- c. What communication system will be used for the remote monitoring system?
- d. What software will be supplied for the CP Proponent? If the data is not transmitted to the area Saudi Aramco PI data base, then the software shall be provided through the Project.

5.4.5 The Project Proposal shall contain a professionally drafted Index “X” CP layout drawing using the cathodic protection symbols shown on Standard Drawing [AD-036785](#) “Symbols for Cathodic Protection”, illustrating:

- a. All existing and new well casings, flow-lines and trunk-lines associated with or affected by the proposed CP system.
- b. The proposed location of all CP equipment associated with the new CP system with general details for:
 - the proposed anodes and anode bed(s)
 - output ratings for the proposed CP power supply
 - cable locations, lengths, and sizes
 - junction boxes and bond stations

5.5 Detailed Design

5.5.1 Detailed Design packages shall provide all design considerations contained in the Project Proposal further developed based on the collection of relevant field data including:

- a. Soil resistivity measurements for proposed anode beds that will be installed shallower than 15 meters (not mandatory for deep anode beds).
 - b. Site information sufficient to develop a field verified site plan (CP layout drawing) that clearly illustrates all proposed CP equipment and all buried structures within 200 meters of the proposed anode bed and associated well casing(s).
 - c. Field verified operating data for existing CP equipment within 200 meters of the proposed anode bed or associated well casing(s).
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- d. For detailed designs of multi-well CP systems in fields where the casing resistances have not already been determined, site tests on each relevant type of well casing to determine the respective resistance to ground are required.

5.5.2 Detailed Design packages shall contain the **original** completed and signed “Well Casing Design Quality Assurance Check List” attached to the cover letter or transmittal sheet for the design package (See [Appendix 1](#)).

5.5.3 Detailed Design packages shall contain all calculations and applicable field data required to verify design compliance with the Saudi Aramco Cathodic Protection Engineering Standards including an electrical simulation drawing for all multi-well CP systems.

6 Design Technical Requirements

6.1 General

6.1.1 The design shall facilitate an integrated CP system for all associated buried metallic structures, and shall comply with all spacing and access restrictions detailed in [SAES-B-062](#).

6.1.2 CP power sources for an existing CP system shall not be utilized to protect a new well casing without approval from the CP Proponent organization for the existing CP system.

6.1.3 Permanent buried flare lines and blow down lines on a well pad shall be made permanently electrically continuous with the well casing or the negative circuit of the well casing CP system.

6.1.4 The use of a photovoltaic CP power supply shall be assessed from an economic perspective for cathodic protection of new wells located more than 3 kilometers from the nearest 4.16 kV or 13.8 kV power line.

Commentary Notes:

The economic assessment shall include comparative costs for operations and maintenance between the systems being considered. During the DBSP review, the proponent organization can then verify stipulated versus actual costs, and may consider other cost related factors like future expansion and theft/vandalism issues.

For designs where photovoltaic power supplies are determined to be the most cost effective alternative, consideration should be given by PMT to place a request with the Saudi Aramco Drilling Dept. to have the well casings externally coated. Photovoltaic CP for a coated well casing typically has a notable cost advantage over a bare well casing.

- 6.1.5 For uncoated well casings, a dedicated CP power source shall be provided for each well when the surface facilities for the two most distant wells involved are separated by more than 2 km.

Exception:

With written authorization from the CP Proponent organization, uncoated well casings spaced farther apart than 2 km may use a common CP power source.

Commentary Notes:

The above exception addresses areas where theft and vandalism of a solar powered CP system is a concern to the CP Proponent. To avoid theft of long runs of buried cable, the cable should be installed with below grade junction boxes, buried concrete anchors at each cable end, and minimal use of above grade cable identification markers.

Galvanic anodes if viable may be used instead of solar power as a dedicated CP power source.

- 6.1.6 Uncoated well casings separated by less than 2 km may utilize a single CP power source, provided the design protection criteria for each well as stated in Tables [1A](#), [1B](#) and [1C](#) of this standard are met without the use of electrical resistors.

Exception:

Resistors shall not be designed into a multi-well CP system, however, if during commissioning, adequate current distribution is not achieved, resistors may be added if approved by a CP Subject Matter Expert (SME) in CSD and the Supervisor of the CP Proponent organization. If resistors are approved as stated above, they shall be welded tap adjustable or fixed (non-adjustable) resistors and shall be 0.15 ohms or less.

Commentary Note:

Coated well casings do not require a dedicated negative cable and are not restricted by the 2 km separation imposed on CP systems with multiple uncoated well casings.

- 6.1.7 At sites where one CP power source is used to protect multiple well casings, each uncoated well shall have a dedicated negative cable unless approved otherwise by the CP Subject Matter Expert (SME) in CSD. The negative cables shall be terminated in a negative junction box located to optimize the current distribution between casings.

- 6.1.8 If approved by the CP Proponent organization and the CP Subject Matter Expert (SME) in CSD, a CSD approved underground junction box (9COM 6000012080) may be used for an anode bed junction box, splice box, or a negative cable junction box.
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Commentary Note:

Underground junction boxes restrict the ability to measure current distribution to the anodes or the structures and are only recommended for use in areas where cable theft and vandalism or other operating conditions prohibit the use of above ground junction boxes.

6.2 Field Data

Field data and site verification of existing equipment that may affect or be affected by the proposed CP system are required for the detailed design. No field data or site visits are required for the DBSP or project proposal.

The following field investigation and data collection shall be completed and the results included with all detailed design packages submitted for review.

6.2.1 Existing Well Casings and Buried Pipelines

Verification and documentation (illustrate on the CP layout drawing) of all buried pipelines and well casings, or other buried metallic structures within 200 meters of the location of the proposed CP power supply, anode bed, or well casing.

6.2.2 Existing CP Systems

Measurement of all relevant cathodic protection currents in cables and flow-lines, plus all relevant power supply voltages and currents, and all relevant structure potentials.

6.2.3 Soil Resistivity Measurement

6.2.3.1 Shallow Remote Anode Beds

- a. Soil resistivity or soil conductivity measurements shall be taken at 10 meter intervals.
 - b. Measurements shall be taken for at least two soil layers (typically 3 and 6 meter depths) down to the planned installation depth of the anode bed.
 - c. Measurements shall be taken in parallel and perpendicular orientations over the full length of the proposed shallow anode bed location.
 - d. 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.

- e. If the soil resistivities within a proposed shallow 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](#)).
- f. 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.
- g. The proposed location for the shallow anode bed shall be clearly marked with wooden or metal stakes at each end. Show the location on the CP layout drawing.

6.2.3.2 Deep Remote Anode Beds

- a. Soil resistivity or soil conductivity measurements for deep anode beds are recommended but are not mandatory. If site measurements are not taken, contact the CSD SME for well casing CP for typical design resistivities.
- b. Record drill stem and test anode resistance measurements on the form contained in [Appendix 2](#) and submit 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 shall determine the final acceptable borehole depth, and anode distribution.
- c. The proposed location for the deep anode bed shall be clearly marked with a wooden or metal stake. Show the location on the CP layout drawing.

6.2.3.3 Distributed Anode Beds

Distributed anodes are not used for well casing CP.

6.2.3.4 Galvanic Anode Locations

- a. Soil resistivity measurements are not required for galvanic anodes used for supplemental cathodic
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protection of well casings or associated pipelines.

- b. Soil resistivity measurements taken by the design agent, and/or ground water resistivity data supplied by the Saudi Aramco Groundwater Protection organization, shall be used for the design of galvanic anode systems used for the primary source of cathodic protection of well casings.
- c. Drill stem and test anode resistance measurements to validate the initial design parameters are mandatory for deep galvanic anode systems used for the primary source of cathodic protection of well casings.

6.3 Design Life

- 6.3.1 Size ICCP anode beds to discharge the CP power source rated current at the anode consumption rate detailed in Table 2, for a minimum of 20 years.

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

- 6.3.2 Galvanic anode systems used for primary or supplemental CP shall be designed to provide a minimum life of 20 years.

Exception:

Magnesium anodes complying with the requirements of 9COM 6000012790 may be installed offshore to protect onshore well casings and in such cases shall provide a minimum life of 10 years.

- 6.3.3 New Well Added to a CP System Less than 10 Years Old:

Where a new well is being added to a CP system commissioned within the previous 10 years, an anode bed upgrade is NOT required if the existing T/R and anode bed are capable of providing the required current at an output voltage not greater than 90% of the power supply full rated voltage. If the required current for the existing wells and the new well(s) cannot be achieved at 90% or less of full rated voltage, an anode bed upgrade shall be designed to comply on a prorated basis (see 6.3.4).

- 6.3.4 New Well Added to a CP System more than 10 Years Old:

Where a new well is being added to a CP system that is more than 10 years old, the contribution of the existing anode bed to the overall anode bed life and current capacity for the upgraded CP system shall be calculated on a prorated basis using 10 years at full rated output as full

life. The existing anode bed shall be bonded to the new anode bed when practical and in compliance with this standard.

Commentary Notes:

Example: 12 TA-4 anodes operating for 5 years at 23 amps would be given a prorated remaining life contribution calculated as follows:

- *1 TA-4 anode has a capacity of 4.45 Amps x 10 year = 44.5 Amp-yr*
- *12 TA-4 have a 10 year capacity of 44.5 x 12 = 534 Amp-yr*
- *12 TA-4 at 23 Amps for 5 years have consumed 5 x 23 = 115 Amp-yr*
- *Prorated percent consumed = 115/534 x 100 = 21.5%*
- *Remaining prorated capacity = 78.5% x 12 anodes = 9.4 = 9 anodes*

6.4 Design Current Criteria

6.4.1 The cathodic protection system design shall provide the minimum design currents detailed in Tables [1A](#), [1B](#) and [1C](#) of this standard.

Commentary Note:

Galvanic cathodic protection systems used as the primary cathodic protection power source should use the listed commissioning current for the design minimum current output.

6.4.2 The cathodic protection requirements for well casings in fields that are not specifically covered by the information provided in Tables [1A](#), [1B](#) or [1C](#) shall be determined on a case by case basis by the CP Subject Matter Expert (SME) for well casings in CSD.

6.4.3 The protection criteria for commissioning and monitoring are detailed in Tables [1A](#), [1B](#) and [1C](#) of this Standard.

6.4.4 **Multi-well** CP systems shall be designed with CP power supplies sized with a minimum rated output current equaling the sum of:

- a. The commissioning current requirements, plus
- b. the estimated current required for the flow-line, plus
- c. a design current capacity surplus of 30%.

Commentary Note:

Do not use the above method when determining the CP power supply current rating for single well CP systems. The CP power supply current rating for a single well CP system is specifically stated for each field in Tables [1A](#), [1B](#) and [1C](#).

Table 1A – CP Current Requirement for Gas Well Casings⁽⁶⁾

Gas Well Casings Cathodic Protection Current Requirements – Single Well								
Field Designation	Bare Casing				Coated Casing			
	Design		Com- mission	Monitor	Design		Com- mission	Monitor
	Minimum CP Power Supply Rating (amps)	Current Included For Flowline (amps)	Minimum Casing Current (amps)	Optimum Casing Operating Current (amps)	Minimum CP Power Supply Rating (amps)	Current Included For Flowline (amps)	Minimum Casing Current (amps)	Optimum Casing Operating Current (amps)
Abu Jifan, Fazran, Ghazal, Jufayn, Khurais, Mazalij, Midrikah, Midyan, Nuayyim, Shaybah, Tinat, Waqr								
- T/R ⁽²⁾	25	3	20	15-20	10	3	2	1.5-5
- Photovoltaic ⁽¹⁾	25	0 ⁽¹⁾	20	15-20	7.5	0 ⁽¹⁾	2	1.5-5
Haradh, Hawiyah, Harmaliyah, Nujayman, Shedgum, Uthmaniyah								
- T/R ⁽²⁾	50	5	40	35-40	50	5	35	30-35
- Photovoltaic ⁽¹⁾	45	0 ⁽¹⁾	40	35-40	45	0 ⁽¹⁾	35	30-35

Table 1B – CP Current Requirement for Water Injection and Oil Well Casings⁽⁶⁾

Oil Production and Water Injection Well Casings Cathodic Protection Current Requirements – Single Well								
Field Designation	Bare Casing				Coated Casing			
	Design		Com- mission	Monitor	Design		Com- mission	Monitor
	Minimum CP Power Supply Rating (amps)	Current Included For Flowline (amps)	Minimum Casing Current (amps)	Optimum Casing Operating Current (amps)	Minimum CP Power Supply Rating (amps)	Current Included For Flowline (amps)	Minimum Casing Current (amps)	Optimum Casing Operating Current (amps)
Uthmaniyah								
- T/R ⁽²⁾	50	5	35	30-35	15	5	7	5-7
- Photovoltaic ⁽¹⁾	45	0 ⁽¹⁾	35	30-35	10	0 ⁽¹⁾	7	5-7
Abqaiq, Abu Ali, Abu Hadriyah, AinDar, Berri, Dammam, Fadhili, Fazran, Hawiyah, Khursaniyah, Manifa, Qatif, Safaniyah, Shedgum								
- T/R ⁽²⁾	35	5	25	20-25	10	5	3	2-4
- Photovoltaic ⁽¹⁾	25	0 ⁽¹⁾	25	20-25	7.5	0 ⁽¹⁾	3	2-4
Ginah, Haradh, Hawtah, Harmaliyah, Midyan, Nuayyim, Shaybah								
- T/R ⁽²⁾	25	5	15	12-15	10	5	2	1-3
- Photovoltaic ⁽¹⁾	15	0 ⁽¹⁾	15	12-15	7.5	0 ⁽¹⁾	2	1-3
Abu Jifan, Khurais, Mazalij								
- T/R ⁽²⁾	10	1	4	2-5	5	1	1	0.5-5
- Photovoltaic ⁽¹⁾	7.5	0 ⁽¹⁾	4	2-5	3	0 ⁽¹⁾	1	0.5-5

Table 1C – CP Current Requirement for Water Supply Well Casings^(3,4,5,6)

Water Supply Well Casings Deeper than the UER Formation Cathodic Protection Current Requirements – Single Well								
Field Designation	Bare Casing				Coated Casing			
	Design		Com- mission	Monitor	Design		Com- mission	Monitor
	Minimum CP Power Supply Rating (amps)	Current Included For Flowline (amps)	Minimum Casing Current (amps)	Optimum Casing Operating Current (amps)	Minimum CP Power Supply Rating (amps)	Current Included For Flowline (amps)	Minimum Casing Current (amps)	Optimum Casing Operating Current (amps)
Abu Jifan, Khurais, Mazali - T/R ⁽²⁾ - Photovoltaic ⁽¹⁾	10 5	5 0 ⁽¹⁾	2 2	1-3 1-3	10 5	5 0 ⁽¹⁾	0.5 0.5	0.2-0.5 0.2-0.5
All Other Fields - T/R ⁽²⁾ - Photovoltaic ⁽¹⁾	10 7.5	1.5 0 ⁽¹⁾	6 6	5-7 5-7	10 5	1.5 0 ⁽¹⁾	1 1	0.5-1 0.5-1

Notes:

- (1) CP current requirements for the flow-lines and trunk-lines of well casings cathodically protected by **photovoltaic** or galvanic systems shall be determined on a site specific basis. If additional current is necessary it shall be added to the current specified in Tables [1A](#), [1B](#) and [1C](#).
- (2) The current required for the flow-lines and trunk-lines for AC powered well casing CP systems is included in the "CP Power Supply Rating (amps)" for T/Rs. If the flow-line or trunk-line is greater than 15 km long, additional current capacity requirements shall be determined through calculations completed in accordance with [SAES-X-400](#).
- (3) Table 1C applies to water supply wells that extend through the wet UER formation such as typical Wasia water supply wells. Wells that do not extend below the UER (or other known corrosive formation), do not require CP. Wasia water wells drilled in areas where the UER is dry, do not require cathodic protection.
- (4) Regardless of the water well type, associated buried flow-lines must be cathodically protected in accordance with [SAES-X-400](#).
- (5) Water wells without cathodic protection, and within 200 meters of an impressed current CP system anode bed, or cathodically protected well casing must be bonded to the negative circuit of the CP system and supplied with sufficient CP current to ensure down-hole interference does not create an external corrosion problem. In this regard, the ΔV measured between the water well and the other protected structure within 200 meters should be less than 200mV measured with extended lead wires, well head to protected structure.
- (6) Contact the CSD "SME for well casing cathodic protection" for current requirements for wells in fields not listed above.

6.5 Anodes and Anode Beds

6.5.1 Impressed current and galvanic anodes shall be manufactured in accordance with [17-SAMSS-007](#) and [17-SAMSS-006](#) respectively.

Exception:

Where site conditions necessitate the installation of anodes in soil resistivities above 5000 ohm-cm, alternative impressed current anode types (not described by [17-SAMSS-007](#)) may be used if pre-approved in writing by the CP Proponent organization and the CP SME in CSD.

Commentary Note:

Nominal dimensional and weight data as specified in [17-SAMSS-007](#) for HSCI anodes are contained in [Table 3](#) of this standard for ease of reference.

- 6.5.2 Anodes to be installed onshore deeper than 15 meters are classified as “deep” anode beds and as such require the drilling depth to be pre-approved in writing by the Saudi Aramco Groundwater Division, Reservoir Characterization Department.
- 6.5.3 Deep anode beds shall be installed in accordance with the latest revision of Saudi Aramco Standard Drawing [AA-036385](#) “Cathodic Protection Deep Anode Bed”.

Exception:

Where electrolyte resistivities or bore hole conditions are not suited to the conventional installation detailed on [AA-036385](#), alternative material and installation configurations may be used if pre-approved by the CSD SME for well casing cathodic protection.

- 6.5.4 For an anode bed discharging 25 amperes or more, a minimum distance of 150 meters shall be maintained between the nearest anode and the well casing.

Exception:

Where electrolyte resistivities at the anode bed are below 1000 ohm-cm, the distance between the anode bed and the nearest well casing may be less than 150 meters, but must be far enough from the nearest well casing such that the calculated anodic gradient (ΔV) at the well casing is less than 1.0 volt using the resistivity determined at the anode bed. For multiple well casing locations, the calculated difference in the anodic gradient between any two well casings must also be less than 200 mV.

- 6.5.5 For an anode bed discharging less than 25 amperes, a minimum distance of 75 meters shall be maintained between the nearest anode and the well casing.

Exception:

Where electrolyte resistivities at the anode bed are below 1000 ohm-cm, the distance between the anode bed and the nearest well casing may be less than 75 meters, but must be far enough from the nearest well casing such that the calculated anodic gradient (ΔV) at the well casing is less than 1.0 volt using the resistivity determined at the anode bed. For multiple well casing locations, the calculated difference in the anodic gradient between any two well casings must also be less than 200 mV.

- 6.5.6 Design parameters for impressed current anodes shall be as detailed in [Table 2A](#) and [17-SAMSS-007](#). The design parameters for galvanic anodes shall be as detailed in [Table 2B](#), [17-SAMSS-006](#), and Saudi Aramco Standard Drawing [AA-036389](#).
-

**Table 2A – Impressed Current Anode
Consumption Rates and Maximum Design Current Densities**

Anode Material	Consumption Rate (kg/amp-y)	Anode Current Density (mA/cm ²)
High Silicon Cast Iron	0.45	0.7
Mixed Metal Oxide	Per Manufacturer's Specifications	Per Manufacturer's Specifications

Commentary Note:

The consumption rates detailed in [Table 2A](#) include efficiency and the utilization factor for a HSCI tubular anode. Shortening of the effective anode length due to an end cap on the anode shall be neglected in the theoretical calculation of anode current capacity.

**Table 2B – Galvanic Anode
Consumption Rates and Open Circuit Potential**

Anode Material	Consumption Rate (kg/amp-y)	Open Circuit Potential (-mV vs Cu/CuSO ₄)
Aluminum	3.8	-1100
Magnesium	10.3	-1700

Commentary Note:

The consumption rates detailed in [Table 2B](#) include efficiency; however, a utilization factor of 0.85 may be included for design purposes at the designer's discretion.

- 6.5.7 The impressed current anodes most commonly used by Saudi Aramco are listed in [Table 3](#) below. Galvanic anode information is contained on Saudi Aramco Standard Drawing [AA-036389](#) and in [17-SAMSS-006](#).

Table 3 – Impressed Current HSCI Anode Data

Type	Dimensions (nominal)	Weight (minimum)	Maximum Design Current Per Anode	Maximum Commission Current
TA-2	56 mm x 2133 mm	20.5 kg	2.63 amps	4.0 amps
TA-4	95 mm x 2133 mm	38.5 kg	4.45 amps	7.0 amps
TA-5A	121 mm x 2133 mm	79.0 kg	5.67 amps	10.0 amps

Commentary Note:

The maximum acceptable current during commissioning is based on manufacturer's ratings and shall not be used for design. This number shall only be used when determining commissioning acceptance.

- 6.5.8 The ICCP current capacity of an ICCP anode bed shall be equal to or greater than the design current for the associated CP power source and shall be calculated as follows:

$$SA_{AB} \times I_{\phi} \geq I_{\theta}$$

Where:

SA_{AB} = The total surface area of all the anodes in the anode bed

I_{ϕ} = Anode material current density per [Table 2A](#)

I_{θ} = CP power source rated current output

- 6.5.9 Adjacent ICCP anode beds powered from separate CP power sources shall be separated by a minimum distance of 50 meters.
- 6.5.10 Impressed current anodes shall be designed to maintain the minimum clearance detailed in [Table 4](#) from any other cathodically protected structure.
- 6.5.11 Adjacent 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 4](#).

Example:

Two 50 amp deep anode beds placed 75 meters apart in 2500 ohm-cm soil can be installed 75 meters away from a buried pipeline.

Table 4 – Minimum Distance to Nearest Cathodically Protected Structure

Anode Bed Rated Output Current (Amps)	Minimum Distance in Meters as a Function of Average Soil Resistivity at Anode Bed			
	$\rho < 500 \text{ } \Omega\text{-cm}$	$500 \text{ } \Omega\text{-cm} \leq \rho \leq 1000 \text{ } \Omega\text{-cm}$	$1000 \text{ } \Omega\text{-cm} < \rho \leq 3000 \text{ } \Omega\text{-cm}$	$\rho > 3000 \text{ } \Omega\text{-cm}$
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
150+	Calculate the required distance to achieve an anodic gradient to remote earth of less than 1.8 volts using the soil resistivity measured at the anode bed.			

Exception:

The separation distance between an existing anode bed and a new buried structure shall be acceptable if field measurements on the buried structure at the nearest point to the anode bed demonstrate that the polarized (instant off) potential is less than -1.20 volts (w.r.t. Cu/CuSO₄).

Commentary Notes:

- 1) *The distances detailed in [Table 4](#) are provided to limit the structure polarized (instant off) potential to less than 1.20 volts and to minimize the interference effects on other independent cathodically protected structures. Polarized potentials may be measured using a CP Assessment Probe (9COM 6000014643) or a CP potential coupon, as detailed in [SAEP-333](#) Appendix A-2.*
- 2) *For a new ICCP system, the “Anode Bed Output Current” value for [Table 4](#) is the rated current output of the new CP power supply.*

6.6 Circuit Resistance

- 6.6.1 For a **T/R**, the CP system **rated** circuit resistance shall be defined as the T/R rated voltage, divided by the T/R rated current. Rated voltages and currents are as detailed on the manufacturer's data sheet/plate.
- 6.6.2 For a **photovoltaic** CP system, the **rated** circuit resistance shall be defined as the photovoltaic system rated output voltage divided by the CP power source minimum required rated current from Tables [1A](#), [1B](#) and [1C](#).
- 6.6.3 The CP system **operating** circuit resistance for an ICCP system shall be defined as the total effective resistance seen by the output terminals of the respective ICCP power supply, and for calculation purposes shall include:
 - a. Anode bed resistance to ground.
 - b. Positive cable resistance from CP power source to anodes.
 - c. Negative cable resistance from CP power source to structure.
 - d. Resistance of the casing to remote earth. This shall be as shown in Table 5 unless site testing is completed to verify a more accurate value.
 - e. Effective resistance caused by +0.8 volts anode bed back emf (for HSCI in coke breeze) plus the structure back emf per [Table 5](#) (example: -1.2 volts casing back emf + 0.8 volts anode bed back emf = 2.0 volts total between the anode with coke breeze backfill, and a coated steel casing).

$$R_{\text{emf}} = (0.8\text{v} + \text{back emf per Table 5}) / I_{\text{rated}}$$

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

Exceptions:

A back emf of +1.0 volts (Cu/CuSO₄) shall be used for mixed metal oxide anodes in seawater, subkha, or comparable high salinity wet applications without coke breeze. This does not include the back emf associated with the polarized potential of the structure.

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

Table 5 – Resistance of Casings to Remote Earth & Back EMF of Casings

Characteristic	Area	Bare Production Casing	Coated Production Casing	Bare Water Supply Well Casing	Flow-line / Trunk-line Network	Well Site Grounding Network ⁽²⁾
Resistance of Casing to Remote Earth (ohms) ⁽¹⁾	Qatif	0.015	0.07	0.05	0.055	0.20
	Khurais	0.10	0.30	0.15	0.20	0.70
Structure Back EMF (volts) ⁽¹⁾	All Areas	1.17	1.2	1.15	1.2	1.0

Note 1: The values contained in Table 5 are applicable to wells in the listed area. Areas with similar surface formation and casing completion characteristics can be assumed to be similar for design purposes. Field testing is required in other areas to determine the appropriate design parameters for back emf and resistance to ground of the relevant structures.

Note 2: Consideration of the well site grounding network is required where an extensive grounding network affects the current distribution at a well site such as would typically occur where down hole pumps are used, or where the field has been constructed with metallic power poles with an interconnected ground system.

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

- The target commissioning current shall be achieved at a voltage between 30% and 70% of the T/R rated voltage output.
- The normal operating output current shall be achieved with the voltage adjustment set at more than 10% of the available (rated) T/R voltage output.

Commentary Note:

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

6.6.5 The CP system “operating” circuit resistance measured during commissioning of a new CP system shall not be greater than 90% of the CP power supply “rated” circuit resistance unless all of the following are met:

- a. The system can discharge the minimum current required for commissioning listed in Tables [1A](#), [1B](#) and [1C](#) of SAES-X-700.
- b. If the CP system power supply is a tap adjustable T/R, it shall have at least two fine tap setting increments remaining.
- c. Each anode current, for the required minimum number of anodes is at or below the maximum commissioning current rating ([Table 3](#) of SAES-X-700).

6.7 DC Power Supply

6.7.1 Cathodic protection rectifiers and photovoltaic systems shall be manufactured in accordance with [17-SAMSS-004](#) and [17-SAMSS-012](#) respectively.

6.7.2 The maximum allowed output rating for a DC power supply is 100 volts.

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

6.7.4 Rectifiers with NEMA Class 3R enclosures shall NOT be used inside hydrocarbon plant areas, within 30 meters of the plant perimeter fencing (outside), or within 1 km of a coastline.

6.8 Junction Boxes

6.8.1 Junction boxes shall be manufactured in accordance with [17-SAMSS-008](#).

6.8.2 Anode junction boxes used with DC power supplies with a rated output greater than 50 volts and a rated load resistance equal to or greater than 10 ohms shall utilize one of the following alternatives:

- a. Shall use a non-metallic anode junction box, or
 - b. Shall have a protective clear plastic plate mounted in front of the shunts, with holes drilled to facilitate measurement of the current through each shunt.
-

6.9 DC Cables

6.9.1 Cathodic protection DC cables shall be manufactured in accordance with [17-SAMSS-017](#).

6.9.2 DC cables connected to a CP power supply either directly or through a junction box shall be shall be #6 (16 mm²) or larger. Cables larger than 16 mm² shall be optimized in size to compliment the current capacity and resistance requirements of the respective CP system.

6.9.3 DC cables shall comply with the most recent edition of the National Fire Protection Association [NFPA 70](#), National Electric Code (NEC).

6.9.4 Unless otherwise specified by the cable manufacturer, the allowable ampacity of High Molecular Weight Polyethylene (HMWPE) cables manufactured in accordance with [17-SAMSS-017](#) shall be rated for ampacity under the column for insulation rated for 90°C in the [NFPA 70](#), NEC Handbook. Correction shall be made to an operating conductor temperature of 40°C.

6.10 Monitoring

6.10.1 The column titled “Monitor” in Tables [1A](#), [1B](#) and [1C](#) of this standard shall be used as a guideline for adjusting the output of cathodic protection systems to the optimum current output.

6.10.2 Where a remote monitoring system (RMS) is used, the design details for the RMS shall be submitted to the CP SME in CSD and the CP Proponent organization for review and approval. Mandatory design details include:

- a. A description of the existing CP RMS used by the respective CP Proponent in the respective area (if applicable). The description shall detail existing RMS hardware, software, communication connectivity and protocols.
- b. Confirmation of proposed hardware and software compatibility with the existing CP RMS (if applicable), or written authorization by the CP SME in CSD and the CP Proponent organization to use a non-compatible RMS.
- c. A data flowchart that illustrates the data path from the CP power supply to the CP Proponent’s desktop including connectivity details with software requirements and communication protocols.

6.10.3 Remote monitoring systems for well casing cathodic protection power supplies shall be designed and installed at all new CP system installations

where an RTU is located within 500 meters of the CP power supply.

- a. The CP RMS shall at minimum use signal transmitters for DC output voltage and current and a circuit breaker status switch.
- b. The data collected and stored by the CP remote monitoring system shall be accessible by the CP Proponent organization directly from their desktop computer.

6.10.4 At locations where an existing useable RTU is not within 500 meters of the CP power supply, the need for a remote monitoring system shall be determined by the Project Group and the CP Proponent organization at the Project Proposal stage.

Commentary Note:

Remote monitoring is strongly recommended for all Projects that will be installing cathodic protection in a new field, or in an existing field where monitoring of the new cathodic protection systems in accordance with [SAEP-333](#) will not be practical with the existing cathodic protection technical staff.

6.10.5 Remote Monitoring Units (RMUs) for cathodic protection power supplies shall comply with the requirements of [17-SAMSS-018](#).

6.10.6 Cables and field wiring used for the remote monitoring systems shall comply with [SAES-P-104](#).

6.10.7 Signal Transmitter Requirements for CP Remote Monitoring Systems are as follows:

- a. CP remote monitoring systems using signal transmitters shall utilize two (preferably loop powered) 4-20 mA signal transmitters to monitor the DC voltage and current. A third channel (digital) shall be used to monitor the CP power supply AC circuit breaker status.
 - b. The CP power supply shall be supplied with a circuit breaker containing a factory built-in auxiliary status switch to facilitate monitoring the CP power supply AC circuit breaker status. This type of circuit breaker must be clearly and specifically identified as a requirement on the Material Purchase Order.
 - c. The wiring between the circuit breaker auxiliary switch, signal transmitters and the RTU must be sized such that the resistance is within the maximum load tolerance of the signal transmitter (typically 600 ohms maximum).
-

6.11 Bonding

- 6.11.1 Well casings shall be electrically continuous with their associated piping. Resistance bonding is not allowed.

Exception:

If adequate current distribution is not achieved during commissioning of a multi-well cathodic protection system, the use of electrical isolation devices accompanied by a bond station may be added if approved by the CSD CP SME for cathodic protection of onshore well casings and the Supervisor of the CP Proponent organization. If resistors are necessary, they shall be welded tap adjustable or fixed (non-adjustable) resistors and shall be 0.15 ohms or less.

- 6.11.2 Electrically isolated flanged piping sections (spool pieces) installed in a flow-line or trunk-line for use with instrumentation or other applications shall be bonded around using a metal bond strap fabricated to facilitate a reliable bond around the isolated equipment and ease of installation and removal.

6.12 Electrical Isolation

Electrical isolation shall not be installed between a well casing and the associated flow-line.

Exceptions:

If adequate current distribution is not achieved during commissioning of a multi-well cathodic protection system, the use of electrical isolation devices accompanied by a bond station may be added if approved by the CSD CP SME for cathodic protection of onshore well casings and the Supervisor of the CP Proponent organization. If resistors are necessary, they shall be welded tap adjustable or fixed (non-adjustable) resistors and shall be 0.15 ohms or less.

Where an electrical isolating gasket is used to isolate between two flange faces, it shall be installed at a location where the pipe is in a vertical orientation if practical.

7 Installation, Records, Commissioning and Inspection

- 7.1 Where cathodic protection is required as specified in this standard, it shall be installed and pre-commissioned within 2 years after the drilling completion date of the well in all areas except Uthmaniyah. In the Uthmaniyah area cathodic protection shall be installed within 1 year after the drilling completion date of the well.

Exceptions:

- 1) *Installation and pre-commissioning of cathodic protection may be delayed until the flow-line has been installed at well casing locations where the well casing*

meets all of the following criteria:

- a. The well casing has not been externally coated or is a coated well drilled with a total vertical depth greater than 8000 feet.*
- b. AC power of distribution voltage is more than 5 km away.*
- c. Soil or shallow aquifer (within 100 meter depth) resistivities are greater than 500 ohm-cm and not conducive to achieving full CP with galvanic anodes.*

2) *Installation of cathodic protection may be delayed for up to 3 years in Uthmaniyah and 4 years elsewhere for well casings where the associated flow-line or trunk-line has been installed and meets all of the following criteria:*

- a. The trunk-line or flow-line has electrical continuity with the well casing through mechanical connection, or electrical bonding.*
- b. The trunk-line is adequately cathodically protected.*
- c. The flow-line or trunk-line, is adequately protected at a measurement point 1 km away from the well casing.*
- d. AC power of distribution voltage is more than 5 km away.*

7.2 All pre-commissioning and commissioning shall be done according to Tables [1A](#), [1B](#) and [1C](#) of [SAES-X-700](#), GI-0002.710 and [SAEP-332](#).

7.3 Refer to Saudi Aramco Best Practice [SABP-X-003](#) for detailed Installation, Records, and Inspection requirements. [SABP-X-003](#) shall be deemed a mandatory document for this Standard.

7.4 Refer to Saudi Aramco Engineering Procedure [SAEP-332](#) for commissioning requirements. The criteria listed in this standard for commissioning are directly applicable to all precommissioning requirements.

Revision Summary

5 December 2012

Major revision.

- Revised protection criteria for photovoltaic systems for coated gas wells.
- Added an exception for multiple bare well casings spaced more than 2 km apart.
- Introduced statements to allow greater flexibility in the commissioning requirements.
- Added the requirement for NACE certification for design engineers and field technicians.
- Reworded the Scope and revised other relevant sections to allow the use of galvanic anodes for CP of well casings.
- Added Mazalij and Midyan areas to the Tables defining current requirements.
- Modified the statement in the current requirement tables that specified a general current requirement for all fields not listed to stating that fields not listed require the criteria to be determined by the CSD CP SME.
- Updated resistance parameters for coated and bare well casings for Khurais area.
- Revised and restated the time required before cathodic protection installation and pre-commissioning is required.
- Modified anode bed upgrade requirements for a new well at existing multi-well locations.
- Changed the drill stem resistance measurement technique to a four wire method.
- Added observation wells into the scope of this standard.
- Standardized Tables [1A](#), [1B](#) and [1C](#) for flow-line current for photovoltaic CP systems
- Added a statement mandating non-metallic anode junction boxes for rectifiers with a rated voltage above 50 volts and a load resistance of 10 ohms or more.
- Updated the Definitions.
- Added sections to clarify the requirements for the DBSP, Project Proposal, and Detailed Design.
- Added the requirement for a simulation drawing for multi-well CP systems.
- Added sections to clarify the requirements for field testing and data collection for the design.
- Added the requirement to contact the CSD SME for typical resistivity measurements for deep anode holes where measurements haven't been taken.
- Added an exception to allow the installation of deep anode beds in an arrangement different than detailed in the Standard Drawings.
- Added an exception to allow anode beds to be closer to structures in low resistivity environments.

Appendix 1 – Design Quality Assurance Check List

BI- _____ JO- _____ Well Number _____

Item	Done	N/A	Details for the <u>Proposed</u> Anode Bed shown on CP Layout Dwg.
1	☐	☐	The number and type of anodes (TA-2, TA-4 or TA-5)
2	☐	☐	Proposed installation configuration, i.e., shallow or deep, and
3	☐	☐	if deep then confirmation of acceptable depth from Groundwater Protection Division
4	☐	☐	Diameter, depth, and number of holes and,
5	☐	☐	if more than one hole, the spacing of the holes
6	☐	☐	The distance between the oil/gas/water well and the proposed anode bed
7	☐	☐	The location of any buried pipeline within 200 meters of the proposed anode bed. If there are no buried pipelines (flow-line or other lines) within 200 meters of the proposed anode bed, please state this in the notes section of the drawing
Item	Done	N/A	Details for <u>Existing</u> CP equipment shown on CP Layout Dwg.
8	☐	☐	The age of existing anode bed and the number and type of anodes
9	☐	☐	The current distribution to existing wells for a multi-well system
10	☐	☐	Existing CP power supply operating output, or the measured operating resistance to verify correct current balance between new and existing
Item	Done	N/A	Details for <u>Proposed</u> DC Power Supply shown on CP Layout Dwg.
11	☐	☐	Rated DC volts and amps
12	☐	☐	Remote monitoring equipment details or a statement saying, "no remote monitoring"
13	☐	☐	The size and length of all DC cables for the proposed CP system
14	☐	☐	The CP junction boxes and their placement
Item	Done	N/A	Calculations for Anode Beds (on CP Layout Dwg or on separate page)
15	☐	☐	Maximum allowable CP system resistance
16	☐	☐	Maximum allowable anode bed resistance
17	☐	☐	Calculated shallow anode bed resistance based on soil resistivity measurements taken at site (not required for deep anode bed)
Item	Done	N/A	Miscellaneous Requirements (on CP Layout Dwg or on separate page)
18	☐	☐	Simulation sketch showing satisfactory current distribution to each well if more than one well casing is being protected by one rectifier
19	☐	☐	Verification statement that "ALL" buried ground cables on the site are insulated (jacketed)

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

Item _____

Item _____

Designer's Name (Print) _____ Signature and Date _____

Designer's NACE Cert # _____ PMT Engineer Name (Print) _____

Appendix 2 – Drill Stem and Test Anode Resistance Measurements

Field: _____ Well No.: _____ Submitted By: _____ Date: _____

CP Power Supply		Anode Hole(s)				Anodes		
DC Volts	DC Amps	Hole No. ___ of ___	Target Resistance	Maximum Resistance	Max. Depth(m)	Number	Type TA-2, 4 or 5	Other

Existing CP System Data ☐ Not Applicable

Existing CP Power Supply Rated Volts _____ Rated Amps _____			Existing Anode Hole(s)			Existing Anodes		
Operating DC Volts	Operating DC Amps	Manufacture Date	Shallow or Deep?	Number of Holes	Measured Resistance to Well Head ⁽¹⁾	Number	Type TA-2, 4 or 5	Installation Year

Measurement Equipment Data:

Resistance Measurements	Length (meters)	Size (AWG or mm ²)	Resistance (ohms)
Megger Calibration Cable ⁽²⁾	25	Two wire #14AWG	
Cable Connected to Well Head ⁽³⁾	200	Two wire #14AWG	
Cable Connected to Test Anode ⁽⁴⁾	100	16mm ²	
Drill Stem to Drill Truck ⁽⁵⁾			

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

Depth (m)	Drill Stem Resistance (ohms)	Test Anode 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 2 – 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:

- Procedure to measure the “offset resistance” of the test wires and connection resistances:
 - Unspool and connect 25 meters of #14 AWG wire to terminal C1 on the Megger.
 - Unspool and connect 25 meters of #14 AWG wire to terminal P1 on the Megger.
 - Unspool and connect 200 meters of #14 AWG wire to terminal C2 on the Megger.
 - Unspool and connect 200 meters of #14 AWG wire to terminal P2 on the Megger.
 - Tightly twist the open end of the two 25 meter wires together and clamp to a bolt or flange on the wellhead (use vice grips or a “C” clamp – do not use alligator clip, spring clip or spring clamp).
 - Tightly twist the open end of the two 200 meter wires together and clamp to a different bolt or flange on the wellhead (use vice grips or a “C” clamp – do not use alligator clip, spring clip or spring clamp).
 - Measure the resistance with the Megger. If the measurement is other than 0.00 ohms, record the “zero offset” resistance measured as shown on the meter.
- Procedure to measure the resistance of an anode bed or drill stem:
 - Unspool and connect 25 meters of #14 AWG wire to terminal C1 on the Megger.
 - Unspool and connect 25 meters of #14 AWG wire to terminal P1 on the Megger.
 - Unspool and connect 200 meters of #14 AWG wire to terminal C2 on the Megger.
 - Unspool and connect 200 meters of #14 AWG wire to terminal P2 on the Megger.
 - Twist the open ends of the two 25 meter wires together and clamp to the bus bar in the anode junction box for the anode bed measurement, or to the drill stem or drill truck frame for the drill stem measurement (use vice grips or a “C” clamp – do not use alligator clip, spring clip or spring clamp).
 - Twist the open ends of the two 200 meter wires together and clamp to a flange bolt on the well head (use vice grips or a “C” clamp – do not use alligator clip, spring clip or spring clamp)
 - Record the resistance shown on the Megger.
 - Subtract the “zero offset” recorded earlier (Note 1) from the resistance shown on the meter. The resulting value is the resistance of the anode bed or drill stem to ground and assumes the resistance to ground of the well casing is negligible.
- Procedure to measure the resistance of the cable connected to the test anode (including anode connection)
 - Unspool and connect 25 meters of #14 AWG wire to terminal C2 on the Megger.
 - Unspool and connect 25 meters of #14 AWG wire to terminal P2 on the Megger.
 - Uncoil the test anode 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 cable.
 - Twist the open ends of the two 25 meter wires together and clamp to one end of the anode (use vice grips or a “C” clamp – do not use alligator clip, spring clip or spring clamp).

Appendix 3 – Recommended Procedures

A3.1 Minimizing Casing Corrosion near Surface

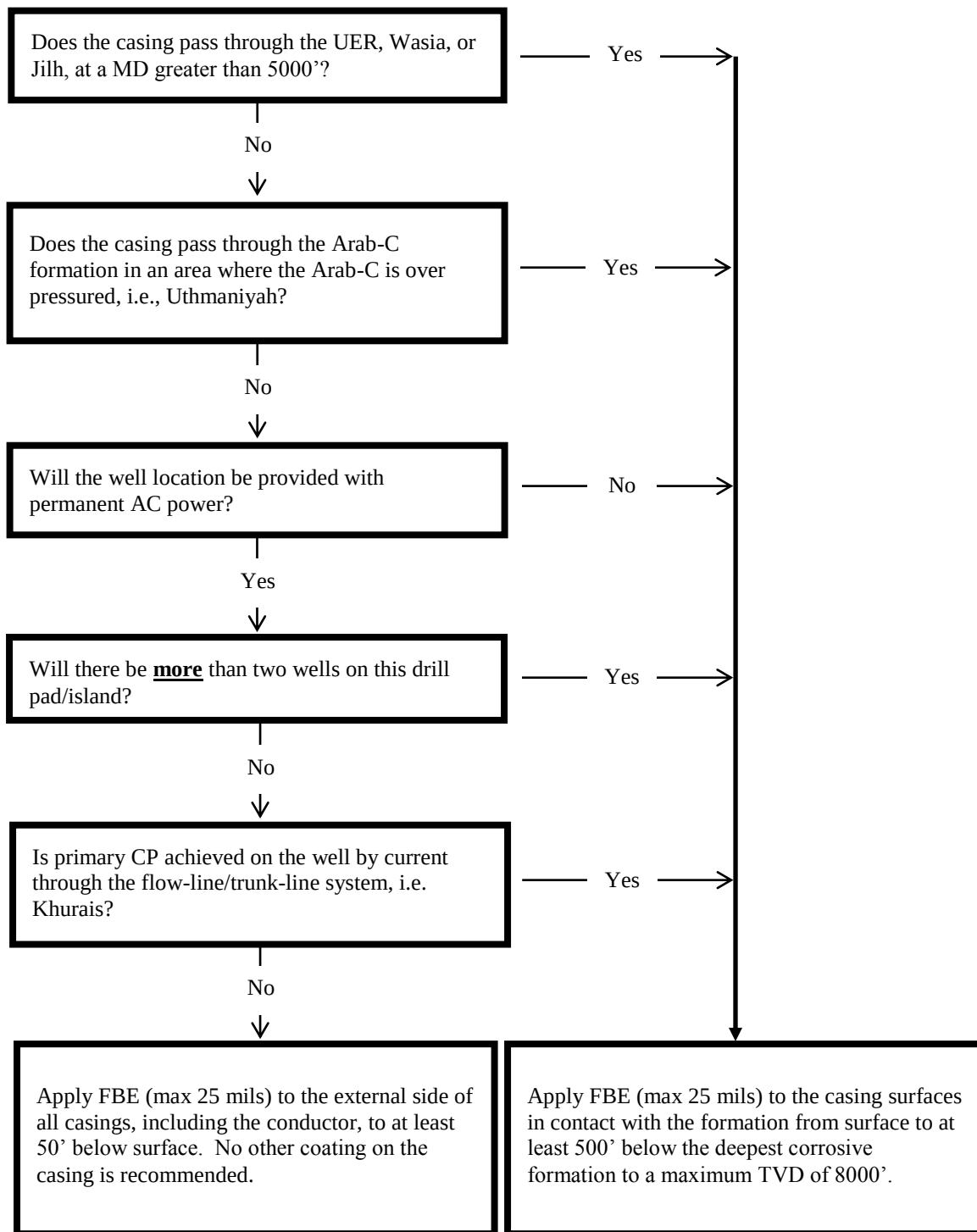
To minimize corrosion of the well casings inside cellars, in the landing base area, or near surface, the following procedures should be implemented:

- Use an external FBE coating on the top two joints of all casings that extend to surface.
- Drilling operations should ensure that all cement is removed from the base of the cellar after each cement job to prevent the formation of a cement floor.
- Fill all annuli near surface with cement to displace air or water in the annuli.
- Seal the annular space between casings in the landing base area by seal welding the casings at surface (including the surface casing or conductor casing) to stop the ingress of air into the annular space between the casings.
- Seal (weld closed) any windows cut in the casings for top jobs, etc.

A3.2 External Coating on Well Casings

- A3.2.1 The application of FBE to the external side of well casings may be used to effectively reduce the current requirement to approximately 10% of the cathodic protection current required for a similar non-coated casing.
- A3.2.2 The application of FBE to the external side of well casings may be used to effectively increase the depth of influence of a cathodic protection system. Nominal attenuation characteristics for 16 mils (400 microns) of FBE coating applied to the external side of the well casing to a depth of 6000 to 8000 feet will typically extend adequate cathodic protection by 3000 to 4000 feet further into the bare casing section.
- A3.2.3 The application of FBE to the external side of well casing tubulars should be restricted to a maximum thickness of 25 mils (625 microns). Additional thickness creates problems due to the tight closing tolerances of the casing installation equipment.
- A3.2.4 Casing with collar can be FBE coated effectively without removal of the collar if a preheat is completed on the collar before running the casing section through the assembly line induction oven, and by manually back spraying into the casing/collar crevice immediately before the collar enters the spray chamber.

A3.3 General Decision Chart for Coating “Onshore” Well Casings



A3.4 Determination of Well Casing Current Requirement

- A3.4.1 Well casing corrosion in the Arabian Gulf area is typically caused by long line corrosion currents that are generated between two or more down-hole formations. The shallowest of the formations with an anodic response are typically more than 1000 feet deep and the area experiencing corrosion typically doesn't affect more than one or two lengths of casing.
- A3.4.2 Corrosion can typically be attributed to poor quality cement in the casing/bore-hole annulus often amplified by the presence of flowing formation conditions or acid gases. Downhole corrosion cannot be detected by surface measurement techniques such as "E Log I", and cannot be reliably modeled using only formation resistivities and casing data.
- A3.4.3 The most reliable method (and arguably the only reliable method) of determining the amount of CP current required to mitigate long line corrosion in a downhole formation is to run a CP evaluation log (**Note:** CP evaluation logs are not effective for localized corrosion cells). Cathodic protection evaluation logs have been run by Saudi Aramco in the following fields; Abqaiq, Abu Ali, Ain Dar, Haradh, Hawiyah, Hawtah, Marjan, Nuayyim, Qatif, Safaniyah, Shaybah, Shedgum, and Uthmaniyah.
- A3.4.4 Before CP is turned on; a cathodic protection evaluation log can be run to identify corrosive formations. However, due to the time delay for polarization of the casing, a log that is run to identify corrosion currents cannot reliably be immediately followed by a second log to determine the quantity of CP current required to overcome the corrosion currents.
- A3.4.5 A CP evaluation log can be run to determine the amount of CP required to mitigate long line corrosion currents but a nominal amount of cathodic protection should be applied two weeks or more prior to running the log.
- When running the log, the actual amount of current going to the casing must be measured with a current clamp placed around the casing. It would be misleading to use the output current of the CP power supply because the flow-line and surface facilities associated with the rig will also take some of the current.
 - The flow-line for the well will typically be physically disconnected during the logging procedures and must be bonded to the well head for the logging to accurately simulate actual operating conditions. This bond should be in place immediately after the flow-line is disconnected from the well head. If the bond is not installed, interference currents from nearby CP systems that would not occur when the flow-line is connected may occur when the flow-line is

disconnected and in such cases would distort conclusions drawn from the logging information.

- For best results, the CP evaluation logging tool should be run at a maximum pull rate of 1500 feet per hour and station stops should be made every 5 feet in areas where higher resolution is desirable, and every 10 feet in areas where lower resolution is acceptable.
- For best results, the cathodic protection logging tool should be left stationary at the lowest depth of the log for a period of 15 to 30 minutes before beginning the calibration part of the log. This delay is required to facilitate temperature stabilization of the tool.
- The cathodic protection evaluation logging tool should be provided with new blades at the beginning of each casing investigation, and should be provided with dielectric or electrically isolated stand-offs/centralizers. These are of particular importance for logging non-vertical casing segments.
- The use of the surface reference electrode (often termed “fish” by the logging vendor) is not required.

A3.5 Drilling Deep Anode Holes

A3.5.1 Drilling Equipment

Drill deep anode holes with rotary type drilling equipment that circulates the cuttings to surface by water (or water/mud mixture) through the hollow center of the drill pipe. Do NOT use equipment that drills a dry hole, or does not circulate drilling fluid to remove cuttings unless the formation characteristics dictate the use of a dry drilling technique such as is required in Khurais.

A3.5.2 Use of Casing

- Case the top 3 to 6 meters as required to maintain hole integrity through poorly consolidated surface soils.
 - Do not install anodes inside any cased section of the hole.
 - Use cement plugs to seal lost circulation areas, or bentonite if necessary. Do not use casing in areas where anodes will be placed (the casing will later corrode and the backfill dissipate into the formation leaving the anodes without complete backfill).
 - 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.
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