Engineering Standard

SAES-X-700 31 July, 2004

Cathodic Protection of Onshore Well Casings

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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 well casings.

Commentary Note:

The cathodic protection requirements for offshore well casings are addressed in SAES-X-300, "Cathodic Protection of Marine Structures".

1.2 Onshore oil, gas, and water injection well casings with a life expectancy greater than five years shall be provided with impressed current cathodic protection.

Commentary Note:

The General Supervisor of the Oil Facilities & Projects Division or the General Supervisor of the Gas Facilities & Projects Division determines if the life expectancy of a new well is greater than 5 years. The respective General Supervisor shall also determine if the well is expected to be more than 3 kilometers from the nearest 4.16 kV or 13.8 kV power line in which case, a coated casing and a solar powered CP system becomes more economical.

1.3 Onshore water supply wells shall be evaluated by the Proponent cathodic protection organization and by the Cathodic Protection and Coatings Unit of CSD on a case-by-case basis to determine if cathodic protection is cost effective. Water supply well casings that have been externally coated with factory applied Fusion Bonded Epoxy coating do not require a dedicated impressed current cathodic protection system. Where cathodic protection is deemed necessary, the installation of three prepackaged 27.5 kg (60 lb) magnesium anodes (17-SAMSS-006) at a minimum depth of 3 meters, outside the cellar shall be considered acceptable.

Commentary Note:

In most cases, internal corrosion is more severe than external corrosion in a water source well. Cathodic protection for the external side of the casing in such cases would not be beneficial. However, at locations where external failures are expected to precede internal failures, cathodic protection should be applied.

1.4 Well casings with backfilled cellars made from steel, steel reinforced concrete, or dielectric materials shall be provided with two prepackaged 27.5 kg (60 lb) magnesium anodes (17-SAMSS-006) installed inside each wellhead cellar to mitigate landing base corrosion.

Exception:

Casings that have been factory coated with FBE do not require the installation of the two magnesium anodes in the cellars.

1.5 This standard may not be attached to nor made a part of purchase orders.

2 Conflicts and Deviations

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

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

3 References

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

The Desktop TIC and the Saudi Aramco Engineering Standards intranet web site contain the latest revisions of all standards and a listing of standard drawings. The Drawing Management System (DMS) contains standard drawing listings with the latest revision numbers.

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-107	*Overhead Distribution Systems*
SAES-P-111	*Grounding*

SAES-Q-001	*Criteria For Design and Construction of Concrete Structures*
SAES-Q-005	*Concrete Foundations*

Saudi Aramco Materials System Specifications

17-SAMSS-004	*Tap Adjustable Rectifiers for Cathodic Protection*
17-SAMSS-006	*Galvanic Anodes for Cathodic Protection*
17-SAMSS-007	*Impressed Current Anodes for Cathodic Protection*
17-SAMSS-008	*Junction Boxes for Cathodic Protection*
17-SAMSS-012	*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-036073	*CP Cable Connection to Well Head*
AD-036132	*Termination Detail Cable Identification*
AA-036280	*Photovoltaic Power System*
AA-036346	*Surface Anode Bed Details - Horizontal and Vertical Anodes (Sheets 1 & 2)*
AA-036356	*Deep Anode Bed - Aquifer Penetrating*
AA-036378	*Rectifier Installation Details (Sheets 1 & 2)*
AA-036385	*Deep Anode Bed - Without Anode Support Pipe*
AB-036540	*Mounting Support Details for Junction Boxes*
AA-036675	*Direct Buried Cable - Installation Details*
AB-036677	*An Overview (Architectural) Security and General Purpose Fencing*
AA-036678	*Security and General Purpose Fencing Post and Fabric Details*
AD-036785	*Symbols for Cathodic Protection*

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 Design

4.1 Design Review and Approval

4.1.1 **IT IS MANDATORY** that proposed construction drawings and the related cathodic protection design information for every design package be submitted to the Proponent cathodic protection organization (as defined by GI-0428.001) **and** the Cathodic Protection & Coatings Unit of CSD for review and approval.

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

4.1.2 The Supervisor of CSD/ME&CCD/Cathodic Protection and Coatings Unit and the Supervisor of the Proponent cathodic protection organization shall indicate their review and approval of each Cathodic Protection drawing by signature. The signatures shall be placed in the "Review of Key Drawings" block of each Index X Drawing, or on a Drawing Completion Certificate referencing the specific drawing numbers that have been reviewed.

4.1.3 The design package submitted for review shall contain at minimum:

a) The scope of work

b) Professionally drafted full size Index "X" CP drawings that:

- detail each CP item by description and stock number if applicable;
- detail the proposed location for each piece of CP equipment including but not limited to rectifiers, anodes, junction boxes, bond stations, test stations, and bonds to structures;

- detail and specifically identify all cathodic protection cables including all anode, structure, bond, and rectifier cables;
- clearly identify the specific and individual cable routing and termination points within the respective test stations, junction boxes, bond boxes, and rectifiers;
- detail all cathodic protection equipment using the cathodic protection symbols as shown on standard drawing AD-036785 "Symbols for Cathodic Protection".

c) All calculations and applicable field data required to verify design compliance with the Saudi Aramco Cathodic Protection Engineering Standards.

Commentary Notes:

Cathodic protection design considerations begin at the DBSP stage and should be reasonably developed by the Project Proposal stage. The Project Proposal should include all design considerations that can be developed without acquiring actual field measurement data including proposed anode type(s) and sizing of the cathodic protection rectifier(s).

The 90% Design Package should present a complete and comprehensive cathodic protection system design including all required field measurement data, calculations, a detailed description of the proposed cathodic protection equipment, and a set of detailed drawings that illustrate the proposed placement of all cathodic protection equipment and the associated protected structures.

4.2 General Design Requirements

4.2.1 The design shall consider the complexities of the casing and the operating environment, including:

- cellar shielding;
- bare or coated well casing;
- distance to AC power (solar or AC powered CP system);
- other cathodic protection systems;
- well spacing and multiple casing CP systems;

- nearby buried metallic structures with, or without cathodic protection systems.

4.2.2 Bare well casings completed with casing cellars made from steel, steel reinforced concrete, or dielectric materials shall be provided with prepackaged 27.5 kg (60 lb) magnesium anodes (17-SAMSS-006) installed inside each well head cellar to mitigate landing base corrosion. The anodes shall be installed according to Standard Drawing AA-036073.

4.2.3 Well casing facilities that contain permanent buried flare lines and/or blow down lines do not require magnesium anodes for protection of the line anchors, provided the respective lines are made permanently electrically continuous with the well casing and the negative circuit of the well casing cathodic protection system.

4.2.4 A proposed well that will be located more than 3 kilometers from the nearest 4.16 kV or 13.8 kV power line shall be considered for external coating and a solar powered CP system.

4.2.5 A bare well casing located more than 6 kilometers from the nearest 4.16 kV or 13.8 kV power line shall be considered for a solar powered CP system. The selection of the power supply (rectifier or photovoltaic system) shall be based on an economic analysis using established Saudi Aramco procedures.

4.2.6 Anode beds for photovoltaic CP systems shall be sized to provide the optimum economic combination of CP system circuit resistance and photovoltaic array arrangement.

4.2.7 The design shall facilitate an integrated cathodic protection system for all associated buried metallic structures, and shall comply with all spacing and access restrictions detailed in SAES-B-062.

4.2.8 A dedicated CP power source shall be provided for each well casing when the surface facilities for the two most distant well casings involved are separated by more than 2 km. If the two most distant well casings in a group are separated by less than 2 km, the well casings may utilize a single CP power source provided the design protection criteria for each well as stated in Table 1 is met without the use of electrical resistors.

Commentary Note:

The decision to protect more than one well casing with a common CP power source is a function of cost. The evaluation of the comparative costs is the responsibility of the design agency.

4.2.9 At sites where one CP power source is used to protect multiple casings, each casing shall have a dedicated negative cable unless approved otherwise by the Proponent cathodic protection organization and the Supervisor of the Cathodic Protection and Coatings Unit of CSD. The negative cables shall be terminated in a negative junction box(es) placed at a location selected to optimize the current distribution between casings.

4.2.10 CP power sources designed for an existing CP system shall not be utilized to protect a new well casing without written concurrence from the Proponent cathodic protection organization.

4.3 Design Life

The anode bed shall be sized to discharge the CP power source rated current capacity at the consumption rate detailed in Table 2, for a minimum period of 20 years.

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

4.4 Design Protection Criteria

4.4.1 The cathodic protection system design shall provide the minimum design current as detailed in Table 1. "Exceptions" to the listed design currents shall be based on data from cathodic protection evaluation logs and/or experience with similar well casings in the area and require written concurrence from the Supervisor of CSD/ME&CCD/CP&CU and the Supervisor of the Proponent cathodic protection organization. Contact the Supervisor of CSD/ME&CCD/CP&CU for the required rated current for CP power supplies for areas not listed in Table 1.

Table 1 – Cathodic Protection Power Source Minimum Rated Current

Description	Bare Casing (Amps)	Coated Casing (Amps)
Deep Gas Wells – All Areas		
- Rectifier	50	50
- Photovoltaic*	40	40
Oil Prod. & Water Inj. Wells		
Uthmaniyah		
- Rectifier	50	15
- Photovoltaic*	40	10
Abqaiq, Ain Dar, Qatif, Shedgum		
- Rectifier	35	10
- Photovoltaic*	25	5
Haradh, Hawtah, Harmaliyah, Nuayyim, Shaybah		
- Rectifier	25	10
- Photovoltaic*	15	5
Abu Jifan, Khurais, Mazalij		
- Rectifier	10	**
- Photovoltaic*	5	**
Water Supply Wells – All Areas	See para. 1.3	See para. 1.3

* Additional current shall be added for the flowlines if necessary
** Indicates that a current requirement has not been established.

Exception:

The rated current for a CP power supply for a multiple well drill site shall be sized using the current listed in Table 1 for a photovoltaic system plus the estimated current required for the flowline & trunkline system.

Commentary Notes:

The design currents for rectifier powered cp systems detailed in Table 1 consider protection of the associated flowline and trunkline. Additional current may be required for the flowline and trunkline of the photovoltaic powered cp systems and should be evaluated on a case by case basis.

Deep gas wells require protection through the Jilh formation (greater than 10,000'). To achieve adequate protection, the deep gas well casings must be coated and supplied with a 50 amp CP system (45 amp if solar).

4.4.2 The protection criteria for commissioning and monitoring are detailed in SAEP-332 and SAEP-333 respectively.

4.5 Anodes and Anode Beds

4.5.1 Impressed current and galvanic anodes shall be manufactured in accordance with 17-SAMSS-006 and 17-SAMSS-007 respectively.

4.5.2 Anodes to be installed 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 Chief Hydrologist, Groundwater Division, Reservoir Characterization Department.

4.5.3 A minimum distance of 150 meters for a bare well casing, and 75 meters for a coated well casing, shall be maintained between the nearest anode in an anode bed and the well casing.

Commentary Note:

The minimum separation distance is the distance required to provide satisfactory current distribution on the well casing.

4.5.4 Design parameters for impressed current anode characteristics for soil applications shall be as detailed in Table 2.

Table 2 - Impressed Current Anode Consumption Rates and Nominal Design Current Densities

Anode Material	Consumption Rate (kg/amp-y)	Nominal Current Density (mA/cm²)
High Silicon Cast Iron	0.45	0.7

Commentary Note:

The consumption rates detailed in Table 2 consider efficiency and utilization factor. 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.

4.5.5 The impressed current anodes most commonly used by Saudi Aramco are listed in Table 3 below.

Table 3 – Impressed Current HSCI Anode Data

Type	Dimensions	Weight	Nominal Design Current	Maximum Commission Current
TA-4	95mm x 2133 mm	38.6 kg	4.45 amps	7.0 amps
TA-5A	121mm x 2133 mm	79.4 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.

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

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

Where:

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

I_{φ} = Anode material nominal current density per Table 2

I_{θ} = CP power source minimum rated current per Table 1

4.5.7 Adjacent anode beds powered from separate CP power sources shall be separated by a minimum distance of 50 meters.

4.5.8 Impressed current anodes shall be designed to maintain the minimum clearance detailed in Table 4 from any other cathodically protected structure.

Table 4 – Minimum Allowable Distance From Underground Structures for Soil Resistivities Between 1000 and 3000 ohm-cm

Anode Bed Rated Output Current (Amps)	Minimum Distance (Meters)
0 – 35	35
36 – 50	75
51 – 100	150
100 – 150	225

Exceptions:

Where measured soil resistivities between the anode bed and the structure have been measured and documented to be less than 1000 ohm-cm, the minimum distance can be reduced by 50%.

Where measured soil resistivities between the anode bed and the structure have been measured and documented to be greater than 3000 ohm-cm, the minimum distance shall be increased proportionately.

Commentary Notes:

The distances detailed in Table 4 are provided to limit the structure theoretical potential to 3 volts presuming an average soil resistivity of 3000 ohm-cm, and to minimize the interference effects on other independent cathodically protected structures.

Multiple deep anode beds can be treated as individual anode beds if the separation between the anode beds meets or exceeds the minimum distances detailed in Table 4. Example: Two 50 amp deep anode beds placed 75 meters apart can be installed 75 meters away from a buried pipeline.

4.6 Circuit Resistance

4.6.1 For a "rectifier", the CP system "*rated*" circuit resistance shall be defined as the rectifier rated voltage, divided by the rectifier rated current. Rated voltage and current are as detailed on the manufacturer's data sheet/plate.

4.6.2 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 rated current (Table 1).

4.6.3 The CP system "*operating*" circuit resistance shall be defined as the total effective resistance seen by the output terminals of the respective rectifier or photovoltaic OCC, and for calculation purposes shall include:

- Anode bed resistance to ground
- Positive cable resistance from CP power source to anodes
- Negative cable resistance from CP power source to structure
- Resistance of the casing to ground (0.02 ohms for a bare casings and 0.07 ohms for a coated casing)
- Effective resistance caused by 2.0 volts back EMF (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 the steel casing

R_{emf} = 2.0 volts/I_{rated}

I_{rated} = CP power supply "rated" current

Exception:

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

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

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

Where:

R_{op} = CP system "operating" circuit resistance

R_{rated} = CP power supply "rated" circuit resistance

Commentary Note:

See section "6.1 Commissioning" for operating circuit resistance tolerances allowed during commissioning.

4.6.5 If the soil resistivities within a proposed anode bed vary by more than 100%, either additional anodes shall be added, 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).

4.6.6 **Remote Surface Anode Bed:** Conduct soil resistivity or soil conductivity measurements at 10 meter intervals, and at 3 and 6 meter depths over the full length of the proposed surface anode bed location.

4.6.7 **Remote Deep Anode Bed:** Soil resistivity or soil conductivity measurements for deep anode beds are recommended but not mandatory before the anode hole is drilled. The Supervisor of the Cathodic Protection & Coatings Unit of ME&CCD/CSD will determine the final bore hole depth and anode placement based on the drill stem resistance and test anode resistance measurements measured during drilling of the anode hole.

Commentary Note:

The intent of 4.6.7 is to eliminate the requirement for "Geonics" soil conductivity surveys in areas that have a low probability of being designed with surface anode beds.

4.6.8 For deep anode bed designs, drill stem resistance measurements and test anode resistance measurements shall be taken by the construction contractor and submitted for review and analysis to the Supervisor of the Cathodic Protection & Coatings Unit of ME&CCD/CSD. The drill stem and test anode measurements shall be taken in accordance with the requirements detailed in Standard Drawing AA-036385. CSD in

consultation with the Groundwater Division shall determine the final acceptable borehole depth, and anode distribution.

4.7 DC Power Supply

4.7.1 Cathodic protection rectifier and photovoltaic systems shall be manufactured in accordance with 17-SAMSS-004 and 17-SAMSS-012 respectively.

4.7.2 For hazardous (classified) areas, 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.

4.7.3 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.

4.7.4 DC power supplies shall not be rated for output voltages greater than 100 volts.

Commentary Note:

Photovoltaic arrays are modular 6V-15A assemblies to be coupled together in the most appropriate configuration to provide the optimum voltage and current for the site requirements and conditions.

4.8 DC Cables

4.8.1 Cathodic protection DC cables shall be manufactured in accordance with 17-SAMSS-017.

4.8.2 DC cables connected to the rectifier shall be #4 (25 mm²) or larger.

4.8.3 DC cables shall be sized to comply with the most recent edition of the National Fire Protection Association NFPA 70, National Electric Code (NEC).

Commentary Note:

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 appropriate column for insulation rated for 75°C in the NFPA 70, NEC Handbook.

4.9 Monitoring Facilities

4.9.1 Monitoring and routine maintenance for well casing cathodic protection equipment operation and performance levels shall be conducted in accordance with SAEP-332.

4.9.2 Remote monitoring systems for well casing cathodic protection systems, when used, shall comply with the requirements of 17-SAMSS-018.

Exception:

Where signal transducers are used for remote monitoring, they are NOT required to conform to 17-SAMSS-018, but at minimum shall be loop powered and shall reliably interface the DC output current and voltage of the rectifier to the onsite RTU.

Commentary Note:

Where signal transducers are used, care must be taken to ensure that the wiring between the RTU and the transducers is appropriately sized with consideration given to the distance between the RTU and the CP rectifier.

4.10 Bonding

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

Exception:

Multi-well drill sites may require the use electrical isolation devices accompanied by a bond station, but shall not use resistors in the bond station to restrict current.

4.11 Electrical Isolation

Electrical isolation shall not be installed between a well casing and the associated pipeline or flowline.

Exception:

Electrical isolation devices may be used at multi-well drill sites if accompanied by a bond station and pre- approved in writing by the Proponent cathodic protection organization and the Supervisor of the Cathodic Protection and Coatings Unit of CSD/ME&CCD. Where a site installed 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 possible, and the internal diameter of the pipe shall be coated for at least 0.5 meters on each side of the flange.

5 Installation

5.1 Impressed Current Anodes

5.1.1 General

5.1.1.1 The construction contractor shall only install anode beds at locations that have been pre-marked (staked) by the design agency or its representative.

5.1.1.2 The design agency or its representative shall mark or stake all proposed surface and deep impressed current anode bed locations to correlate with soil 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 anode bed location so as to ensure compliance with the anode bed placement restrictions detailed in this standard.

5.1.1.3 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.

5.1.1.4 Anode cables for below grade usage shall be inspected for insulation damage just before installation.

a) The inspection shall be conducted with a pulse type holiday detector set at 18,000 volts DC, and shall be witnessed by Saudi Aramco or its designated agent. Cables that do not meet the dielectric test shall not be used.

b) A visual and touch inspection of the anode cable insulation immediately adjacent to the head of the anode shall be conducted. Anode leads with noticeable "necking" or an obvious reduction in diameter of the insulation shall not be used.

Commentary Note:

ANODES SHOULD NEVER BE ROLLED, PARTICULARLY WHILE THE ANODE CABLE IS STILL ON THE 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.

5.1.1.5 Repaired anode cables, anodes or anodes with repaired anode-to-cable connections shall not be used.

5.1.1.6 TA-5A anodes shall not be lowered into deep anode beds by their anode lead wires. A rope or pipe support shall be used to lower and support the TA-5A anodes in the borehole.

5.1.2 Surface Anode Beds

5.1.2.1 Surface anode beds shall be installed according to standard drawing AA-036346 at the location and depth determined from the soil resistivity measurements and specified on the project site layout drawing.

5.1.2.2 The number one anode shall be the farthest anode located on the right hand side of the anode lead junction box, when facing the front of the box.

5.1.3 Deep Anode Beds

5.1.3.1 Deep anodes shall be installed according to one of the following standard drawings:

AA-036356	*Aquifer Penetrating Deep Anode Bed*
AA-036385	*Deep Anode Bed without Anode Support Pipe*

5.1.3.2 The number one anode shall be the anode located at the bottom of the hole.

5.1.3.3 All deep anode bed installations shall be pre-approved by the Groundwater Division of the Saudi Aramco Reservoir Characterization Department. The design agency shall be responsible for obtaining the approval and forwarding a copy to the construction contractor.

5.1.3.4 The construction contractor shall not begin the drilling of a deep anode bore hole before receiving a copy of the Groundwater Division's approval forwarded from the design agency.

5.1.3.5 When coupling sections of support pipe, care should be taken to ensure that; cables are not rotated in the well, and

pipe support brackets are aligned with the preceding sections of the pipe support.

5.1.3.6 Calcined petroleum coke (anode bed backfill) shall be mixed with water to form a slurry. All particles that float shall be removed. The slurry shall be pumped from the bottom of the hole at a slow rate, allowing the hole to fill from the bottom up. The amount of backfill required shall be calculated as specified on AA-036385 and the full amount shall be used.

5.2 DC Power Source

5.2.1 The DC power source and associated surface equipment shall not be installed on the well pad area unless:

- located in an area common to other electrical equipment or,
- 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.

5.2.2 Rectifiers and photovoltaic systems shall be installed in accessible locations as far away from sand dunes as practical. The construction contractor shall provide sand stabilization where conditions in the area indicate a high probability for sand dune encroachment, and in areas of probable drifting sand, oil immersed rectifiers shall be mounted a minimum of 300 mm above ground to minimize sand accumulation against the rectifier.

5.2.3 Rectifier

5.2.3.1 The rectifier shall be installed according to standard drawing AA-036378 (Sheets 1 & 2). The installation shall comply with the electrical requirements detailed in SAES-P-111 and SAES-P-107.

5.2.3.2 AC power input to the rectifier shall be through a fused disconnect switch or circuit breaker device, and shall be:

a) supplied with an externally operable handle mechanism, and

b) enclosed in a NEMA 3, 4 or 4X enclosure as required by NEC, with the exception that NEMA 4X enclosures shall be used for all locations within 1 km of a coast line, and

c) mounted in an accessible location approximately 1.8 meters above grade, and within 3 meters of the rectifier, and

d) current rated at 125% of the rectifier input current at rectifier rated load, or the nearest rating to 125% commercially available.

5.2.4 Photovoltaic Power Supplies

5.2.4.1 The photovoltaic power supply shall be installed according to Saudi Aramco standard drawing AA-036280.

5.2.4.2 At installations where more than one module is used, the individual modules shall be placed with all panels facing due south and shall be physically configured such that shadows from any module do not affect any other module.

5.3 DC Cables

5.3.1 All buried DC cables shall be installed according to standard drawing AA-036675.

5.3.2 All buried DC cables (anode, bond, positive, and negative) shall be identified by cable route markers according to standard drawing AA-036378 unless requested otherwise in writing by the Proponent cathodic protection organization.

5.3.3 Positive cables for burial shall be inspected for insulation damage immediately prior to installation. The inspection shall be conducted with a pulse type holiday detector set at 18,000 volts DC. Repair of the positive cable insulation by any method is prohibited. Repair of above grade sections of a positive cable using above grade splice boxes is acceptable.

5.3.4 Negative cables and bond cables for below grade usage shall be visually checked for obvious insulation damage or defects. Cable with visible insulation damage shall either be rejected or repaired with 3 half lap layers of plastic vinyl tape over 3 half lap layers of rubber tape.

5.3.5 A negative drain cable shall be mechanically connected directly to the well head. This shall be done by means of a bolted connection to the lowest above grade flange according to Standard Drawing AA-036073.

5.3.6 Encase above-grade cables in either steel conduit, armored cable, or covered cable trays. Negative cables attached to above-grade structures may extend out of the conduit for up to 500 mm between the conduit and the structure connection.

5.4 Junction Boxes

5.4.1 Junction boxes shall be manufactured in accordance with 17-SAMSS-008, and installed according to standard drawing AB-036540.

5.4.2 All cables inside junction boxes shall be identified with durable tags, according to standard drawing AD-036132. The cable and the terminals shall be labeled to indicate the structures to which they are connected.

5.4.3 Junction boxes shall have both an outside and an inside nameplate indicating the structure and the identification number of the rectifier unit or well number to which they are connected.

5.4.4 Multiple positive or negative cables shall have individual shunts installed for each circuit in the respective junction box.

5.5 Concrete Foundations and Footings

Concrete foundations, footings and supports shall be constructed according to Saudi Aramco Engineering Standard SAES-Q-001 and SAES-Q-005.

5.6 Fencing & Guardrails

5.6.1 Unless written authorization is received from the Proponent organization, a type IV fence shall be installed around rectifiers and photovoltaic power supplies that are located outside existing plant security fences. Details of type IV fencing are shown on standard drawings AB-036677 and AA-036678.

5.6.2 Rectifiers shall not be located inside an electrical substation or any other fenced area that is not normally accessible to CP operating and maintenance personal unless the fencing around the area is modified with a separate entry to allow access to the rectifier.

5.6.3 The design agency or construction agency shall include guardrail facilities for anode bed junction boxes and watering pipes at sites

where vehicular traffic or other conditions in the area indicate a high probability for damage.

6 Commissioning and Inspection

6.1 Commissioning

6.1.1 CP systems for well casings shall be commissioned within 6 months after the completion date of the well. All pre-commissioning and commissioning shall be done according to GI-0002.710 and SAEP-332.

6.1.2 The commissioned "operating" circuit resistance of a newly installed CP system must be less than or equal to 90% of the CP system "rated" circuit resistance, or must comply with 6.1.3.

For commissioning: $R_{op} < 0.9 \times R_{rated}$ (exception 6.1.3)

Where: R_{op} = CP system "operating" circuit resistance

R_{rated} = CP power supply "rated" circuit resistance

6.1.3 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 the CP Proponent organization provides written confirmation that:

a) The system can discharge the CP power supply rated current (Table 1), and for a CP system with a rectifier shall have at least 3 fine tap setting increments remaining; and

b) each anode current, for the required minimum number of anodes, is at or below the maximum commissioning current rating (Table 3); and

c) the required operating conditions indicate that the CP system will be able to provide the required cathodic protection for the lesser of 20 years or the predicted life of the structure.

6.2 Inspection

The Project Management Team (PMT) shall notify Project Inspection before 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 set up and procedure, and
b) during anode cable insulation holiday detection, and
c) during loading of the anodes into surface or deep holes.

7 Records

All Construction drawings shall be updated to show the "as-built" cathodic protection system. Copies of the updated "as-built" drawings and pre-commissioning data shall be submitted to the cathodic protection Proponent department and to the Cathodic Protection and Coatings Unit of Consulting Services Department within 60 days of project completion.

Revision Summary

28 April, 2004	Updated Table 1 to include new areas and clarified to more easily distinguish between well types and areas. Modified, paragraphs 1.4 and 4.2.2 to omit the requirement for galvanic anodes in the cellars of externally coated well casings. Modified and added the appropriate exceptions to allow the design and installation of single CP systems for multi-well drill sites Added an Index of Contents and completed numerous editorial revisions. Revised the "Next Planned Update."
31 July, 2004	Updated Table 1 to include new areas and corrected Qatif requirements. Clarification of the use of CP system back EMF in calculating the design parameters for the CP system operating resistance.