

Engineering Procedure

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Cathodic Protection Commissioning

Document Responsibility: Cathodic Protection

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1 Scope

This procedure provides instructions and establishes responsibilities for commissioning a new cathodic protection (CP) system or to reactivate an existing system that has been inoperative for more than 30 days. Following this Engineering Procedure will ensure that (a) all CP system components are operating within manufacturer's and design parameters, and (b) detrimental effects on other structures caused by the operation of the CP system are minimized and within acceptable tolerance levels.

2 Applicable Documents

2.1 Saudi Aramco References

Saudi Aramco Engineering Standards

<u>SAES-X-300</u>	<i>Cathodic Protection of Marine Structures</i>
<u>SAES-X-400</u>	<i>Cathodic Protection of Buried Pipelines</i>
<u>SAES-X-500</u>	<i>Cathodic Protection Vessel and Tank Internals</i>
<u>SAES-X-600</u>	<i>Cathodic Protection of Plant Facilities</i>
<u>SAES-X-700</u>	<i>Cathodic Protection of Onshore Well Casings</i>

Saudi Aramco Standard Drawings

<u>AA-036353</u>	<i>Water Storage Tanks, Internal Impressed Current Cathodic Protection</i>
<u>AA-036354</u>	<i>Water Storage Tanks, Interior Galvanic Anode Installation</i>
<u>AA-036762</u>	<i>Crude & Product Tank Bottom, Internal Galvanic Anode Installation</i>

Saudi Aramco General Instruction

<i>GI-0002.100</i>	<i>Work Permit System</i>
<i>GI-0428.001</i>	<i>Cathodic Protection Responsibilities</i>

2.2 Industry Codes and Standards

Institute of Electrical and Electronic Engineers, Inc.

<i>IEEE STD 450</i>	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications</i>
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3 Safety

Cathodic protection personnel are responsible for obtaining appropriate work permits and associated gas test results from the operations foreman in all classified areas before starting any job.

Appropriate personal protective equipment (PPE), such as safety glasses, safety shoes with electrically insulated soles, etc., shall be worn. Use rubber mats, rubber gloves, or both, when test leads are used near high voltage AC power lines. Fall restraining devices shall be used when working on the top of structures such as storage tanks.

Appropriate safety precautions must be followed when making electrical measurements, and include:

- a. Use properly insulated test lead clips and terminals to avoid contact with unexpected hazardous voltages. Test clips should be attached one at a time each time a connection is made. A single hand should be used to make the connection, in a well balanced body position, while the other hand should be free from resting on any surface.
- b. Use caution when long test leads (100 meters or longer) are extended near overhead high voltage AC power lines, since hazardous voltages can be induced into the test leads. Use rubber mats, rubber gloves, or both, when making measurements if induced AC potentials over 15 volts are measured on pipelines near high voltage AC power lines.
- c. Use caution when stringing test leads across streets, roads and other locations subject to vehicular traffic.
- d. Use caution when making tests at electrical isolation devices. Appropriate voltage detection instruments or voltmeters with insulated test leads should be used to determine if hazardous voltages exist before proceeding with tests.
- e. Personnel must be knowledgeable and qualified in electrical safety precautions prior to installing, adjusting, repairing or removing impressed current protection equipment.
- f. Testing should be avoided when thunderstorms are in the area. Remote lightning strikes can create hazardous voltage surges that travel along the pipe under test.
- g. Inspect excavations and confined spaces and ensure they are in a safe condition prior to entering. This includes testing for gas, as discussed above. Follow all appropriate Saudi Aramco Work Permit procedures (See GI-0002.100).

4 Instructions

4.1 Commissioning Survey

4.1.1 General

The commissioning of a cathodic protection system involves the following:

- a. A performance evaluation of rectifier(s) or solar power supply(ies)
- b. An evaluation of current distribution in anode bed(s)
- c. Measurements of structure-to-electrolyte potentials to determine the protection status of the structure(s). The potential measurements shall take place before the CP system is energized ("As-Found" potential) and when the CP system is turned On and Off ("On" and "Off" potentials).

An evaluation of current distribution in the negative circuits, if applicable

Commentary Note:

The Saudi Aramco Project Management Team (SAPMT) shall be notified of the deficiencies detected during the commissioning to ensure corrective action is taken.

4.1.2 Rectifier System

Inspect and energize the rectifier in accordance with the Appendix A Commissioning Report.

4.1.3 Solar Power System

Inspect and energize the solar systems in accordance with the Appendix B Commissioning Report. Conduct a baseline Battery Discharge Capacity Test according to the procedure outlined in IEEE STD 450, Section 6. Attach the results of this test to the commissioning report.

4.1.4 Anode Bed Evaluation

- 4.1.4.1 For each impressed current anode bed, set the power source to discharge the rated current of the CP system. Measure the current output of individual anodes, and record on the Appendix J Commissioning Report for an onshore anode bed, or on the Appendix K Commissioning Report for an offshore anode bed. If one or more of the anodes is discharging more

than their rated output, note the fact on the commissioning report data form, and refer it to the appropriate personnel, for further evaluation and resolution with SAPMT.

- 4.1.4.2 When multiple negatives are utilized, measure and record return current on each negative cable.

4.1.5 Bond Adjustment

Generally, at the bonding stations, resistors are not required and direct bonding connections shall be applied. Measure the magnitude and direction of the CP current flowing through the direct bonds. However, if resistors are utilized, also record the magnitude and direction of CP currents flowing through the resistors. Measure the potentials on the bonded piping sections, and record these on the appropriate commissioning report.

4.1.6 Electrical Isolating Devices

Test the integrity of all isolating devices with an RF isolation checker instrument and/or a clamp-on ammeter. If an isolating flange is found to be defective, test the isolating sleeves and washers on each bolt. Faulty isolating devices shall be corrected by identification as exception items, but shall not delay commissioning unless the cathodic protection system is rendered ineffective. If shorted, measure the current flow through the isolating device using a clamp-on ammeter, where possible.

4.1.7 Potential and Current Measurements

4.1.7.1 General

For structures surrounded by soil, measure the structure potential with a portable copper-copper sulfate reference electrode. With the exception of well casing potential measurements, place the reference electrode in close proximity to the structure to minimize measurement error associated with voltage (IR) drop in soil. Avoid placement of the reference electrode near buried anodes, bare copper grounding cables, or steel reinforced concrete pilings or foundations as this may generate erroneous readings and should be avoided. For structures surrounded by water, measure the structure-to-water potentials with a portable silver-silver chloride reference electrode. During the potential measurements, keep the reference electrode as close as possible to the structures. If there are anodes in the area of the potential measurement,

locate the reference electrode midway between the anodes. Measure potentials at well-defined locations to allow for future monitoring.

If stationary reference electrodes are installed to monitor the protection levels on a structure, measure the structure potentials with reference to these electrodes. However, the potentials of the stationary electrodes shall be compared with the potential of the portable reference electrode used in the commissioning survey to validate the potential values measured by these stationary electrodes.

For the structures where galvanic anodes are installed prior to their construction, the "As-Found" potential measurements are not required.

4.1.7.2 Submarine Pipelines

Measure potentials at both ends of the submarine pipe, at the anodes, and at midpoint between two anodes. The measured potentials shall comply with the CP potential criterion as stated in [SAES-X-300](#). If the pipeline starts from or terminates at an onshore facility, measure the potentials on the section(s) buried in this facility to ensure that the protection levels meet the CP criterion for plant buried pipelines, as stated in [SAES-X-600](#). Record the potential survey data on the Appendix H Commissioning Report.

4.1.7.3 Offshore Platforms

If the structures are protected by an impressed-current anode system(s), set the current output to operate at approximately 90% of the design current requirement, prior to taking the potential measurements. For the structures protected by galvanic anode systems, no adjustment is required prior to the potential measurements. Measure potentials on each main platform jacket leg, on each pipeline riser, and on each well conductor. The minimum required number of potential measurements are as follows:

- a) In water depths of 15 meters or less, take potential measurements at three locations: the sea bed, one meter below the surface, and the midpoint.
- b) In water depths of 15 to 30 meters, take potential measurements at four locations: the sea bed, three meters

above the sea bed, one meter below the surface, and the midpoint.

- c) In water depths of 30 meters or more, take potential measurements at five locations: the sea bed, three meters above the sea bed, one meter below the surface, and two intermediate depths.

Record the potential survey data on the Appendix I Commissioning Report.

Commentary Notes:

- a) *Make sure that each well head is electrically connected to the platform jacket through a bond cable or a welded continuity bar.*
- b) *For structures protected by galvanic anodes, take potential measurements at 1) the sea bed, 2) one meter below the surface, and 3) sections between the anodes. Note that CP potential levels at sections between anodes usually are less than those near the anodes.*

4.1.7.4 Onshore Buried Pipelines

For buried cross-country pipelines, flow lines, trunk lines, and test lines, measure potentials at all KM markers, road crossings, valves, and other locations containing test points and/or bond stations. For the potential measurements, place the portable copper-copper sulfate reference electrode directly above the pipelines. After the "As-Found" potentials are measured, energize the CP system, and set the current output of the impressed-current anode system(s) to operate at approximately 90% of the design current requirement.

During this "On" potential survey, take the first potential measurement at the negative drain point to ensure that potentials do not exceed the maximum potential allowed per [SAES-X-400](#). If the pipe potentials exceed the maximum allowable value in any area, measure the "Off" potentials of the pipe(s) in these areas, switch off the respective CP system, and immediately notify SAPMT of this deficiency.

Record both "As-Found" and "On" potentials on the Appendix G Commissioning Report. The measured potentials shall comply with the CP potential criteria, as stated in [SAES-X-400](#). If all the pipe potentials meet these potential criteria, fine

tune the rectifier current output to maintain the protection levels within the allowable range. Report the results of the potential measurements together with any deficiencies found during commissioning.

Commentary Note:

For buried pipelines, cathodic protection must be achieved within 30 days of pipeline burial.

4.1.7.5 Tank Internals

After recording the "As-Found" potential measurements, set the current output of the impressed current anode system to operate at approximately 90% of the design current requirement. For the galvanic anode systems, no adjustment is required.

For tanks with access holes from the tank roof, measure the "On" potential measurements at three depths: 1) the tank bottom, 2) the midpoint, and 3) one foot below the water level. Do not place the reference electrode close to the anodes on an anode string but rather between anodes.

For both the impressed current and galvanic anode CP systems, measure the current output of the anodes associated with each tank, and record these on the Appendix E Commissioning Report. The measured potentials shall meet the CP potential criteria, as stated in [SAES-X-500](#). The potential survey data shall also be recorded on the Appendix E Commissioning Report.

Commentary Notes:

- a) *Stringent adherence to all required safety precautions, including the use of fall prevention devices, is required when personnel are taking measurements through tank roof access holes.*
- b) *Tank internal CP system commissioning for water tanks should only be done when the tank is 100% full. This will ensure that the CP system is set to provide protection for the full wetted surface area of the tank.*
- c) *Measure potentials through the reference cell access holes that are installed 150 mm from the tank shell (as shown on Standard Drawing No. [AA-036353](#) or [AA-036354](#)). For existing*

tanks that do not have these access holes, take the potentials as close to the shell as practical.

- d) *Galvanic anodes installed/bolted directly to the tank bottom internals (as shown on Standard Drawing [AA-036762](#)) can be checked for electrical continuity/zero-resistance to the tank, using an ohm-meter or a Megger® type insulation tester, prior to filling the tank with product. Do not scratch or damage the coating inside the tank. Measure the resistance between any two anodes, or between an anode and the tank shell external surfaces (e.g., at an uncoated flange face).*

4.1.7.6 In-Plant Buried Pipelines

After the "As-Found" potential measurements are recorded, set the current output of the impressed current anode system(s) to operate at approximately 90% of the system design current requirement and measure the "On" potentials on the pipeline(s). For horizontal pipeline(s), place the reference electrode directly above the buried piping section. For vertical pipe(s), locate the reference electrode within 300 mm from the pipe. In asphalt or concrete paved areas, place the reference electrode inside soil-access test holes to achieve adequate soil contact. The "On" potentials shall meet the CP potential criterion, as stated in [SAES-X-600](#). Record the commissioning data on Appendix A and Appendix C Commissioning Reports. Adjust the CP system output after the potential survey to maintain the protection levels at or above the minimum potential criterion specified in [SAES-X-600](#).

Commentary Notes:

- a) *Plant Buried Piping Commissioning Report - Appendix C p.2 Survey Data:*

Most soil access boxes do not have structure connections. The structure that the portable meter is connected to must be identified and recorded on Appendix C p. 2. Record the structure connection description under the column "Test Point Connection Location". Record the soil access box number (reference cell location) under the column "Soil Access/Test Point Number". The structure connected to must be the structure that the soil access box is over and the structure that is nearest the soil access box. This procedure will verify if the bond is connected to the structure being tested.

- b) *Plant Buried Piping Commissioning Report - Appendix C p.3 Bond Drain Data:*

For the bond drains, record the bond drain cable number or the structure connected label under column "Bond Cable No. or Structure". Record the structure name that the bond current is flowing from under the "Name of Structure Current Flowing From" column and the structure the current is flowing to under the "To" column. Record the (-mV) potential of the structure the bond current is flowing from under the "Potential (-mV) of Structure Current Flowing From" column and the (-mV) potential of the structure the bond current is flowing to under the "To" column. Record the bond current in amps under the "Bond Current" column. Record the as-found or off potential of the structure the bond current is flowing from under the "As-Found/Off Potential (-mV) From" column and the as-found or off potential of the structure the bond current is flowing to under the "To" column.

4.1.7.7 Tank Bottoms

After measuring the "As-Found" potentials, set the current output of the impressed-current anode system(s) to operate at approximately 90% of the system design capacity. Take a minimum of four (4) potential measurements at equal intervals around each tank bottom.

If the anodes are installed around the tank periphery, the potential measurement locations should be midway between the anodes to minimize anode gradient effects. If test access holes are available, measure the tank-to-soil potentials at these test access holes. If there are no test access holes, take the tank potential measurements at locations within two meters from the tank bottom and at least one meter from any buried bare copper grounding cables.

If tank bottom access tubes are installed at the tank concrete ring wall, measure the tank-to-soil potentials through the access tubes. If stationary reference electrodes are installed between the two bottoms of tanks with replacement bottoms, measure the CP potentials of the bottoms with reference to these electrodes. If a slotted plastic monitoring pipe is installed under the tank bottom, measure the CP potentials of the tank bottom by pulling a portable reference electrode through this monitoring pipe.

If possible, measure and record the current output of the anodes. Record the potential survey data on the Appendix D Commissioning Report. After the potential survey, adjust the

CP system output to meet or exceed the applicable minimum criteria specified in [SAES-X-600](#).

Commentary Note:

Tank bottom CP system commissioning should only be done when the tank is at least 75% full of product. This is to ensure that the bottom plates are in maximum contact with the soil. If the tank is not this full, the measured potentials will not be indicative of overall protective potentials, or the adequacy of protection, on the whole external surface of the tank bottom.

4.1.7.8 Onshore Well Casings

For the measurements of the potentials of the well casing, place the portable copper-copper sulfate reference electrode inside the cellar, immediately next to the casing, and also outside the cellar within 1 meter of the cellar.

After recording the "As-Found" potential measurements, set the current output of the well casing CP system to operate at approximately 90% of the design current capacity for the well casing, according to [SAES-X-700](#). Re-measure the potentials inside and outside the cellar, and record the measurements. The "On" potential both inside the cellar and outside the cellar should be greater than -0.90 volts, and should not decrease from the "As-Found" measurements.

The protection criteria for the well casing shall be a "minimum current drain" from the well casing, as detailed in Table 1 below. Decrease the system output (from 90%) to match the applicable criterion and measure the current drain with the power source(s) on.

Table 1

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WELL CASINGS	Minimum Casing Current Drain (amps)	
	Bare Casing	Coated Casing
Deep Gas Wells – All Areas		
- Rectifier	25	35
- Photovoltaic	25	30
Oil Prod. & Water Injection Wells		
Uthmaniyah ^(1, 2)		
- Rectifier	40	10
- Photovoltaic	35	5
Abqaiq, AinDar, Shedgum, Hawiyah, Nuayyim, Qaif		
- Rectifier	20	5
- Photovoltaic	20	4
Haradh, Hawtah, Harmaliyah, Shaybah		
- Rectifier	12	4
- Photovoltaic	12	4
Abu Jifan, Khurais & Mazalij		
- Rectifier	5	-
- Photovoltaic	5	-
Water Supply Wells – All Areas ⁽³⁾		
- Rectifier	5	-
- Photovoltaic	5	-

Notes:

- 1) In the Uthmaniyah field, operate 25 and 35 amp rectifiers (pre-1990) at maximum allowable output, provided that the minimum current drain is 20 amperes.
- 2) Rectifier output should be reduced if nearby pipeline potentials exceed 3.0 volts, provided that the minimum current drain is 20 amperes.
- 3) The 5 amp criterion is for water wells with dedicated CP systems, and which are less than 2000 ft. deep. For wells deeper than 2000 ft., operating current will be the same as specified above for the oil producing and water injection wells for the various fields.

If the flow line is connected to the well, measure the "On" potentials of the nearest buried section of the flow line. If these "On" potentials exceed the maximum potential allowed for the pipelines, adjust the current output of the well casing CP system power source(s) to reduce these potentials to a level below this maximum criterion. Also measure and record the magnitude and direction of the DC current flow in the flow line.

Record the current and potential data, and associated measurements, on the Appendix F Commissioning Report for each well casing. The commissioning team shall report the

results of the potential survey as well as the deficiencies found during the commissioning.

4.1.8 Interference

- 4.1.8.1 Measure structure-to-electrolyte readings at locations where a known foreign pipeline crosses or comes within 75 meters of a Saudi Aramco pipeline. Place the reference cell directly over the crossing, or over the foreign pipeline at the closest point to the Saudi Aramco pipeline.
- 4.1.8.2 Measure potentials on both structures with the nearest Saudi Aramco rectifier cycled "on" and "off". If the measurements indicate that the Saudi Aramco CP system is depressing the protection level on the foreign pipeline by 50 mV or more, forward written notification to the owner of the foreign pipeline.
- 4.1.8.3 If the protection level on the Saudi Aramco pipeline is less than acceptable per [SAES-X-400](#), then complete a close interval survey in the vicinity of the crossing for approximately 150 meters in each direction over the Saudi Aramco pipeline. If the close interval survey indicates that interference is occurring on the Saudi Aramco pipeline, then notify the owner of the foreign pipeline and implement additional cooperative testing with corrective action.

4.2 Evaluation of the Surveys

Forward the detailed data including raw data and as-built data obtained during the commissioning surveys, to the appropriate department for review. Determine the anomalies, discrepancies, and recommendations for upgrading or improving the cathodic protection system (if any), and notify the appropriate agencies.

4.3 Cathodic Protection Test Equipment and Maintenance of Voltmeters, Ammeters and Reference Electrodes

- 4.3.1 Use proper voltmeters and ammeters and suitable reference electrodes for CP testing. These meters are operated by batteries. Check meter batteries periodically to ensure they still function properly. Generally, they should be replaced every year.
- 4.3.2 Calibrate all meters annually.

- 4.3.3 Use high input impedance meters for structure-to-electrolyte potential measurements, especially in areas of high soil resistivity. Input impedance should be 20 megohms or greater. Multimeters with various setting levels of input impedance are preferred, for example, Miller model LC-4[®].
- 4.3.4 Use a clamp-on-ammeter for the direct measurements of DC currents. Meters having current measuring capacity up to 200 amps and a variety of clamp sizes are preferred. When changing clamp sizes for the same meter, refer to the manufacturer's instructions for adjusting the readings. Currently, the clamp-on ammeters made by William H. Swain company are widely used in Saudi Aramco facilities.
- 4.3.5 Properly maintain copper-copper sulfate and silver-silver chloride reference electrodes, as follows:
 - 4.3.5.1 Clean the tips of the copper-copper sulfate electrodes, and ensure that the electrodes contain an adequate volume of electrolyte with an excess of copper sulfate crystals. Inspect and test the electrodes one against another or against a standard voltage source, periodically. The voltage difference shall not exceed a maximum differential of 10 mV. If this maximum is exceeded, a complete clean-up is needed. In the clean-up, remove the oxide layer on the copper rod by using fine sand paper, and renew the copper sulfate electrolyte. Fill the electrode half full, as a minimum, with a saturated water solution of copper sulfate. Use only distilled water and chemically pure copper sulfate. Also add an excess of copper sulfate crystals, equal to approximately 10% (by weight) of the saturated solution in the cell.
 - 4.3.5.2 Inspect and test silver-silver chloride electrodes, one against another or against a standard voltage source, periodically. A replacement is required if the voltage difference is larger than 10 mV.
- 4.3.6 Check test leads of voltmeters used for structure-to-electrolyte measurements periodically, for continuity and integrity. Repair or replace faulty leads or connections before making measurements.

Commentary Note:

To verify the continuity of the leads, short the leads and measure their resistance. It should be close to zero.

5 Report Forms

Record all data relative to the commissioning and/or re-commissioning of cathodic protection systems on the Commissioning Report forms attached in Appendix A through K of this Engineering Procedure. They are listed as follows:

<i>Appendix A</i>	<i>Cathodic Protection, Rectifier Commissioning Report</i>
<i>Appendix B</i>	<i>Cathodic Protection, Solar System Commissioning Report</i>
<i>Appendix C</i>	<i>Cathodic Protection, Plant Buried Piping Commissioning Report</i>
<i>Appendix D</i>	<i>Cathodic Protection, External Tank Bottom Commissioning Report</i>
<i>Appendix E</i>	<i>Cathodic Protection, Tank Internal Commissioning Report</i>
<i>Appendix F</i>	<i>Cathodic Protection, Well Casing/Flowline Commissioning Report</i>
<i>Appendix G</i>	<i>Cathodic Protection, Pipeline Commissioning Report</i>
<i>Appendix H</i>	<i>Cathodic Protection, Submarine Pipeline Commissioning Report</i>
<i>Appendix I</i>	<i>Cathodic Protection, Offshore Well Casing/Platform Commissioning Report</i>
<i>Appendix J</i>	<i>Cathodic Protection, Onshore Anode Bed Commissioning Report</i>
<i>Appendix K</i>	<i>Cathodic Protection, Offshore Anode Bed Commissioning Report</i>

6 Responsibilities

Commissioning a New CP system, or re-activating an existing CP system is the responsibility of the proponent organization in charge of the CP system. The Consulting Services Department can provide specialist assistance in interpreting the commissioning data, or assist with system troubleshooting for problems encountered during commissioning, if requested by the operating organization.

Refer to GI-0428.001, "Cathodic Protection Responsibilities", for details of the organizational responsibilities for implementing this Engineering Procedure. SAPMT

shall ensure that the pre-commissioning checks have made for the CP system, and all pre-commissioning data forms have been transmitted to the proponent.

Revision Summary

31 May 2005

Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with editorial changes.

Attachments to SAEP-332

- Double click here => [SAEP-332A](#) to view the Appendices.