

Engineering Procedure

SAEP-333

31 July, 2004

Cathodic Protection Monitoring

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Saudi Aramco DeskTop Standards

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1 Scope

Monitoring of the CP systems is required to ensure that the CP systems perform satisfactorily and the structures receive adequate protection. This procedure provides the instructions and establishes the responsibilities to monitor cathodic protection (CP) systems for onshore and offshore facilities.

Commentary Note:

Cathodic Protection is essential to protect the underground steel structure from corrosion and it is proven to prolong its life expectancy. For this reason it is cost effective that the proponent corrects deficiencies at the earliest possible time".

2 Applicable Documents

Saudi Aramco Engineering Procedure

[SAEP-332](#)

Cathodic Protection Commissioning

Saudi Aramco General Instructions

GI-0002.100

Work Permit System

GI-0428.001

Cathodic Protection Responsibilities

Supply Chain Management Manual

Topic CU 22.03

3 Safety

Cathodic protection personnel are responsible for obtaining appropriate work permits and associated gas test results from the operations foreman before starting any job. Inspect excavations and confined spaces and ensure they are in a safe condition prior to entering. This includes testing for gas, as discussed above.

Appropriate personal protective equipment (PPE), such as safety glasses, safety shoes with electrically insulated soles, etc., shall be worn. Fall restraining devices shall be used when working on top of structures such as storage tanks.

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

- a. Personnel must be knowledgeable and qualified in electrical safety precautions prior to installing, adjusting, repairing or removing impressed current protection equipment.
- 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 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. 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.
- f. Testing should be avoided when there are thunderstorms or rain 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.

4 Monitoring Procedures

4.1 Rectifier Periodic Check and Monitoring Procedures:

4.1.1 Rectifier Monthly Checks

Check rectifiers on a monthly basis to determine if they are operating. This can be done by Operations or Maintenance personnel who visit the site on a regular basis for purposes other than those relating to cathodic protection. If the checks are done by non-cathodic protection personnel, they shall report any abnormality in rectifier operation to the cathodic protection personnel who operate the system.

Exception:

Rectifiers fitted with remote monitoring systems do not need to have the monthly checks performed through field personnel visits. The monthly rectifier checks requirement also does not apply to Northern Area Producing Offshore platforms.

4.1.2 Rectifier Quarterly Checks

Cathodic protection personnel shall visit rectifier sites on a quarterly basis and immediately prior to the annual survey, to read and record rectifier output volts and amps. Verify these readings with a portable meter and calibrate rectifier meters accordingly. Also check and record oil level and oil temperature on oil-immersed units.

Exception:

Rectifiers fitted with remote monitoring systems do not need to have the quarterly checks performed through field personnel visits. However, Proponents may decide to perform these site visits anyway, if required due to particular operational needs of specific sites.

4.1.3 Rectifier Annual Checks

4.1.3.1 Visual Inspection

Annually, visually inspect the cabinet, terminals and components for mechanical damage, continued serviceability, access, and safety.

4.1.3.2 Transformer Oil Checks

For oil-immersed units, sample and check the transformer oil as follows:

- a. Open the rectifier drain spout to collect approximately one (1) liter of the oil in a clear glass container. If sediment, sludge, or water drains with the oil during sampling, continue draining until the contaminant has been flushed out, and then collect approximately 1 liter of oil. If the sediment has not been flushed out after 4 liters of oil have drained, completely drain and fill the rectifier with new oil. Top up with new oil, if required, to make-up for oil drained for testing.
- b. Replace the oil if it is dark or cloudy and difficult to see through, or if the oil appears to be full of suspended particles. It is much easier to visually judge the quality

of used oil if compared to a sample of new oil. If required by the operating department, transformer oil may be lab-tested for dielectric characteristics and contamination if oil quality is questionable.

- c. Dispose used oil following procedures outlined in Supply Chain Management Manual, Topic CU 22.03. Call Hazardous Materials Advisor for Form 112H approval.

4.1.3.3 Remote Monitoring

For rectifiers equipped with remote monitoring units (RMUs), verify the accuracy of the data being transmitted by the RMU, and the alarm functions. This could be done either by connecting a laptop computer to the RMU in the rectifier, or by comparing the data monitored at the rectifier with that being transmitted to the host computer.

4.1.3.4 Rectifier Negative Junction Box

If there is a multiple negative current return junction box connected to the rectifier, determine the current in each cable by measuring the voltage drops across the shunts, and applying Ohms Law. If no shunts are available, measure the anode current output levels using a D.C. clamp-on ammeter

4.1.4 Periodic Rectifier Check Data

Record all data taken during the annual check on a data sheet similar to and containing all the information shown on the example in Appendix J.

Exceptions:

- 1) *While the annual rectifier check is the preferred and appropriate course of action to ensure rectifier functionality, proponents may elect to conduct the first annual periodic check 12 months after commissioning, and then every 24 months, if the system is operating normally. Revert to the 12/24 month cycle if system malfunctions are found, repaired, and the system re-commissioned.*
- 2) *Remote monitoring system data may be printed out in the report format for the system software, or as required by the proponent.*

4.2 Anode Bed Monitoring and Periodic Maintenance Procedures

4.2.1 Anode Bed Annual Checks

Evaluate the performance of each anode bed annually. Perform this evaluation prior to the annual cathodic protection survey, as indicated in the following steps:

- a) Measure current output levels of impressed current anodes and/or galvanic anodes prior to the scheduled potential survey. For the impressed-current anode beds, the current output levels are monitored and recorded quarterly by reading the CP system current at the rectifier.
- b) If shunts are installed at the anode cable terminals inside the anode junction boxes, determine the anode current output by measuring the voltage drops across the shunts, and applying Ohms Law. If no shunts are available, measure the anode current output levels using a D.C. clamp-on ammeter. Calculate the estimated service life of the anode beds using this data.

4.2.2 Anode Junction Box Annual Check

Annually, individually check all anode junction box connections and fittings for cleanliness and tightness. Any required maintenance shall be conducted as follows:

- a) Take apart and clean all connections and bolted fittings, using wire brush or emery paper.
- b) Apply Burndy "Penetrox E©" oxide inhibiting compound (or equivalent) to all cables and connections, then reinstall all cables and connections.
- c) Seal or reseal all conduit openings with "Duxseal©" compound.
- d) Inspect, and if required, repair or replace the door seals.
- e) Check grounding cable connection to junction box (if applicable), and tighten connection if required.

4.2.3 Periodic Anode Bed Check Data

Record all data taken during the annual check on a data sheet similar to, and containing all the information shown on, the example in Appendix J.

Commentary Note:

Based on operational needs, proponents may elect to conduct the first annual periodic check 12 months after commissioning, and then every

24 months, if the system is operating normally. Revert to the 12/24 month cycle if system malfunctions are found, repaired, and the system re-commissioned.

4.3 Solar Power System Periodic Maintenance and Monitoring Procedures

4.3.1 Solar System Quarterly Checks

Quarterly, thoroughly clean and check the solar system(s), as follows:

- a) Clean the panel glass to be free of dust, sand and salt spray.
- b) Top up batteries with distilled water and flush clean of dust and debris.
- c) Check and adjust solar array performance and regulator operation as per the manufacturer's instructions.
- d) Record all data taken during the quarterly check on a data sheet similar to, and containing all the information shown on, the examples in Appendices C, D and E.

Commentary Note:

The frequency for the battery checkup shall be increased, if required, to ensure that the electrolyte in the battery cells can be maintained at the levels recommended by the manufacturer.

4.3.2 Solar System Annual Check

Annually, in addition to the quarterly checks listed in 4.3.1 above, carry out the following tests:

- a) Disconnect the batteries from the load and solar panels, and check the battery voltage. If the battery voltage is lower than 25% of the average, replace the battery.
- b) If further evaluation is required, use a data logger to verify battery performance over a 4 day period.

4.4 Cathodic Protection System Surveys

4.4.1 General

- 4.4.1.1 Perform structure-to-electrolyte potential measurements at the locations where the structure-to-electrolyte potentials were measured during the CP commissioning survey, or

subsequent monitoring surveys. The locations of the potential measurements can be changed or the quantity increased to ensure that the structure-to-electrolyte levels in the critical areas are adequately monitored.

- 4.4.1.2 Cathodic protection pipe-to-electrolyte potentials are usually measured by connecting the instrument negative (Common) terminal to the structure and the positive terminal to the reference electrode which is in contact with the electrolyte. With this connection the instrument indicates the reference electrode is positive with respect to the structure. Since the reference electrode has a positive value, the structure voltage is a negative value. This connection arrangement as well as the polarity of the potential readings shall be properly recorded.
- 4.4.1.3 Use a portable copper/copper sulfate reference electrode for onshore structures, and a portable silver/silver chloride reference for offshore structures and water storage tanks.
- 4.4.1.4 Where stationary reference electrodes have been installed, measure and record the structure-to-electrolyte potentials using these stationary electrodes.
- 4.4.1.5 Place the portable reference electrode as close as possible to the structure. In dry soil, pour a sufficient amount of water on the soil around the electrode to minimize the contact resistance and to obtain valid readings.
- 4.4.1.6 A good low resistance metallic contact between the voltmeter and the structure is required. If connecting above-grade to a coated structure, make a small cut through the coating layer to ensure a good metallic contact.
- 4.4.1.7 Measure structure-to-electrolyte potentials with a multiple/selectable input impedance voltmeter. At each onshore test location, take the measurement at two values of input impedance to validate the measured value. If the measured value changes by more than 5 mV, the measured value is unreliable and water should be poured on the ground before re-measurement.
- 4.4.1.8 When taking potential measurements on offshore structures or tank internals, add an additional weight to the reference

electrode, to overcome buoyancy and drift from the structure. If using metallic weights, do not install near the "read" end of the reference electrode.

4.4.1.9 When taking structure-to-electrolyte potential measurements, on both onshore and offshore structures, place the reference cell as far from the anode or anode bed as possible.

4.4.1.10 Check all bond and junction boxes associated with the pipeline during a CP system survey. Bond stations require both a pipe-to-soil survey potential and a shunt current measurement. Junction boxes only require a shunt current measurements, if there are shunts installed in the box.

Commentary Note:

Cathodic Protection is essential to protect buried and submerged steel structures from corrosion and it is proven to prolong its life expectancy. For this reason it is cost effective that the proponent correct CP system deficiencies at the earliest possible time.

4.4.2 Offshore

4.4.2.1 Fixed Structures

4.4.2.1.1 Conduct a comprehensive structure-to-water potential survey annually. This survey shall include readings at the water surface, every 10 meters thereafter, and one at the sea bed, with a minimum of two readings on each jacket leg and pipeline riser. Check all bonding cables prior to reading structure-to-electrolyte potentials.

4.4.2.1.2 Measure the voltage difference between accessible well casings, conductors, etc., to check for complete continuity. The difference in voltage between all casings, on the same well (including the conductor pipe) should be less than 5 mV.

4.4.2.1.3 The structure-to-electrolyte potentials shall meet the criteria listed in Appendix B.

Commentary Notes:

- a) *For structures protected by impressed current systems, measure and record the output of each anode or anode string.*
- b) *For underwater surveys conducted by divers, other work such as removal of excessive marine growth, debris removal, and taking photographs, etc., should be added to the diver's tasks, if required by the proponent.*

4.4.2.2 Well Casings

Take current (amperes) readings on each well casing on offshore well platforms with impressed current systems by divers using a Swain[®] Sea Clip. Clip is to be installed around the conductor under water on the seabed or at any location above the water where accurate reading of the return current can be obtained. CP personnel will monitor and record the readings at the surface. This shall be done at least once in the life of the structure at the time of commissioning.

4.4.2.3 Pipelines

- 4.4.2.3.1 Annually measure structure-to-water potentials at each end of each submarine pipeline. Record the potential survey data on a data sheet similar to Appendix H of [SAEP-332](#), or other appropriate data forms. The structure-to-electrolyte potential shall comply with the criteria listed in Appendix B.
- 4.4.2.3.2 Perform pipe-to-water potential surveys every ten years. The underwater survey can either be done by diver teams or by a towed electrode.
- 4.4.2.3.3 Diver team surveys shall include inspection of all bracelet anodes, and structure-to-water potential readings shall be taken midway between bracelet anodes or at 150 m intervals where no anodes exist.

4.4.3 Onshore

4.4.3.1 General

Perform a comprehensive cathodic protection potential survey within 12 months of commissioning and annually thereafter. Prior to the survey, check all power sources and bonds for proper operation. The survey shall include an evaluation of CP systems and measurements of the level of protection on all structures which receive cathodic protection. After the survey, complete all repair or upgrade requirements and conduct spot checks in affected areas.

4.4.3.2 Buried Pipelines

- 4.4.3.2.1 Measure structure-to-electrolyte potentials with all CP systems energized, at all KM markers, at pipeline transition points, road crossings, valves, appurtenances and other locations where there are test points, bond stations or above/below ground transitions. These measurements shall be made with the portable copper/copper sulfate reference electrode placed directly above the pipeline.
- 4.4.3.2.2 If there are stationary reference electrodes, also measure the pipe-to-soil potentials with reference to these electrodes.
- 4.4.3.2.3 Record the structure-to-electrolyte potential on a data sheet similar to Appendix G of [SAEP-332](#), or other suitable form. The measured structure-to-electrolyte potentials shall comply with the criteria listed in Appendix A-1.
- 4.4.3.2.4 CP Coupon Test stations can be used to monitor FBE coated pipelines in Subkha soils. The potential measured is the "Off" potential of the CP coupon, and shall be made using a portable copper/copper sulfate reference electrode placed inside the Coupon Test Station reference tube. The acceptable potential criteria shall be a CP Coupon "Off" potential of -850 mV. See Appendix A-2 for CP coupons installation and monitoring details.
- 4.4.3.2.5 Soil corrosion probes (SCPs) measurements may be used as an alternative to the potential criterion to assess the effectiveness of cathodic protection,

by measuring the mils per year (mpy) corrosion rate of the SCP. The measured corrosion rate of the SCP shall be less than 0.1 mpy, for the pipeline to be considered as having effective cathodic protection. See Appendix A-3 for details regarding suitability of using these probes and the installation and monitoring details. It is preferable to dig up the probe after the first 12 months of service, to visually confirm that the corrosion rates measured from the probes are actually those being experienced on the probe and the pipeline.

- 4.4.3.2.6 3-pin galvanic anode test station monitoring requires checking the pipe-to-soil potential, and current output of the galvanic anode. Measure the potential by connect the voltmeter negative to the terminal labeled "P/S", and the voltmeter positive to a reference electrode. The galvanic anode current is measuring the voltage drop across the 0.01 ohm shunt, using a millivoltmeter. Connect the meter positive to the "P" terminal and the negative lead to the "A" terminal on the test station. The measured voltage will have positive polarity if the anode is providing protective current to the pipe. For the 0.01 ohm shunt, 1 mV = 100 mA of current flow.

4.4.3.3 Buried Plant Piping

Measure the structure-to-electrolyte potentials when all plant CP systems are energized. The measurements shall be taken on the straight run pipelines and on sections buried in the areas within the plant boundary. These include the structures and piping sections buried under SSD fences, in areas where buried piping anchors are present, at pipeline transition points, at all soil access test holes, and in areas where equipment or other buried structures are congested. Record all data taken during the survey on a data sheet similar to and containing all the information shown on the example in Appendix F. The measured structure-to-electrolyte potentials shall comply with the criteria and spacing listed in Appendix A-1.

4.4.3.4 Above Ground Storage Tanks

4.4.3.4.1 Tank Bottoms

- a) Measure the structure-to-electrolyte potentials at the same locations where they were measured during the commissioning survey.
- b) Take a minimum of four (4) potential measurements at equal intervals around each tank bottom. The spacing of the readings shall not be greater than 20 meters.
- c) Measure and record the potential difference between any stationary reference electrodes (usually buried under the tank) and the tank. Measure and record the current output of the anodes (galvanic or impressed current). Record all data taken during the survey on a data sheet similar to and containing all the information shown on the example in Appendix G. The potentials shall meet the criteria listed in Appendix A-1
- d) If soil access holes (outside the ring wall) 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 of the tank shell and at least one meter from any buried bare copper grounding cables.
- e) Where anodes are installed around the tank periphery, measure the potentials at locations midway between the anodes to minimize anode gradient effects.
- f) Where tank bottom access tubes are installed through the tank concrete ring wall, measure the tank-to-soil potentials through these access tubes using a portable copper/copper sulfate reference electrode.
- g) Where slotted monitoring tubes are installed under the tank bottom, pull a portable

reference electrode through the tube and take readings at 1-meter intervals over the length of the tube under the tank. A wet cotton cloth may be wrapped around the tip of the electrode to improve electrical contact of the electrode with the soil surrounding the slotted tube.

- h) Where the 100 mV depolarization criterion is to be utilized, then follow procedures given below:
- Record the "instant off" potential within one second of interrupting the rectifier. If more than one rectifier is connected to the structure being monitored, all the rectifiers should be synchronized to be turned off at the same time.
 - Allow the structure to depolarize for a period of 24 hours.
 - Record the potential after 24 hours. The system is considered protected if the difference between the "instant off" potential and the depolarized potential is more than 100 mV.
 - If the 100 mV depolarization is not achieved within 24 hours, the structure can be allowed to depolarize up to a maximum of 7 days.
 - If the 100mV depolarization is still not achieved after 7 days of depolarization, corrective action shall be implemented to increase Cathodic Protection.
- i. Tanks having second bottoms (two bottoms), rather than replacement bottoms, may have stationary reference electrodes installed between the two bottoms. Measure the structure-to-electrolyte potentials of the bottoms with reference to these electrodes.
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Measure and record the current output of any anodes installed between the two bottoms.

- j. Tanks having secondary containment may have stationary reference electrodes installed between the bottom and the containment lining. Measure the structure-to-electrolyte potentials of the bottom with reference to these electrodes. Measure and record the current output of any anodes installed between the bottom and the containment liner.

4.4.3.4.2 Water Storage Tank Internals

Annually perform a comprehensive tank-to-water potential survey. Measure and record tank-to-water potentials at the upper water level, midway between the upper level and the bottom and at the bottom of the tank. Measure and record the current output of each anode or anode string. Record all data on a data sheet similar to Appendix H, or other suitable form. The potentials shall meet the criteria listed in Appendix A-1.

4.4.3.5 Well Casings

4.4.3.5.1 Annually conduct a comprehensive well casing and flowline survey on well casings. Conduct the survey with all rectifiers turned on. Use the following procedure for conducting this survey:

- a) For all new well casings, determine if the casing is:
 - 1) bare, or
 - 2) FBE coated for the top two joints, or
 - 3) FBE coated beyond the top two joints.

This should be noted, and the current required determined accordingly.

- b) If galvanic anodes are present, measure the current output of the galvanic anodes using a clip-on ammeter. Record the measurement, including the direction of the current flow. This current may be too small to measure in some cases.
 - c) Measure the well casing current and the flowline current using a clip-on ammeter. Adjust the rectifier(s) as required, to achieve the minimum casing current drain, as specified in Appendix A-1.
 - d) Measure the flowline potential at the transition point. If the potential is greater than -3.0 volts, reduce the rectifier output(s) appropriately.
- 4.4.3.5.2 Plant water supply well casings shall be electrically continuous with impressed current protected buried pipe and impressed current protected tank bottoms. Verify the continuity annually.
- 4.4.3.5.3 Conduct the structure-to-electrolyte potential measurements for the flowlines at a minimum of three locations, which shall include at the well head, the mid-point of the flowline and the termination point. A flowline can terminate at the GOSP or at a trunkline. Measure potentials with all CP systems turned ON. Take additional readings at the road crossings for the above-ground flowlines.
- 4.4.3.5.4 Record all data taken during the survey on a data sheet similar to and containing all the information shown on the example in Appendix I. The currents drains for well casings and the flowline potentials shall meet the criteria listed in Appendix A-1.
- 4.4.3.5.4 Well Casing CP System Downtime Criteria: The following table details the downtime criteria for single well casing cathodic protection systems:
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Field	Maximum Downtime Duration	Cumulative "Off Days" Per 12-Month Period	Minimum "ON" Duration Between Two Consecutive Downtimes
Abqaiq and Uthmaniyah*	<14 days	60	2 x No. of "Off" days
Others	<30 days	60	2 x No. of "Off" days but not less than 30 days

* All efforts should be exerted to minimize the downtime period in Uthmaniyah to less than 14 days.

Deviations from these specified durations requires the processing of an Engineering Standards Waiver Request.

4.4.4 Sheet Pilings, Trestles and Piers

Measure structure-to-electrolyte potentials on the soil sides of sheet piling, and on-shore trestle and pier pilings using a copper/copper sulfate reference electrode. Measure the potential measurements on the water sides of the sheet piling, and off-shore trestle and pier pilings, using a silver/silver chloride reference electrode. The measured structure-to-electrolyte potentials shall comply with the criteria as listed in Appendix A-1 and B.

4.4.5 Isolating Devices

4.4.5.1 Isolating devices, e.g., isolating spools, joints and flanges, are sometimes used in cathodic protection systems to isolate buried protected structures from above grade unprotected structures. Test the integrity of all isolating devices with an RF isolation checker instrument. Inspect and test these isolation devices at least annually to ensure their effectiveness.

4.4.5.2 When faulty insulation in a flange is suspected, measure insulation efficiency between each bolt and the flange. If one or more faulty bolt insulators are found, mark these for repair. If all the bolts show they are isolated, then the flange gasket is faulty.

4.4.6 Hydrocarbon Vessels and Tanks Internals

4.4.6.1 Monitor hydrocarbon vessel internals using the installed galvanic anode-monitoring shunts, or permanent reference electrodes, as applicable.

- 4.4.6.2 Crude or product tank CP system effectiveness is determined by visual inspection when the tank is opened for T&I or other maintenance. Galvanic anode consumption rates should be calculated from the remaining dimensions of the anodes.

4.4.7 Underground Storage Tanks

Measure structure-to-soil potentials at 1-meter intervals over the length of the underground storage tank, reservoir or oil-sumps. These potentials should be taken over the centerline of the tank and also at a 1-meter distance along the sides of the structure.

4.5 Foreign Pipeline Crossings Interference Monitoring

- 4.5.1 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 line.
- 4.5.2 Measure potentials on both structures with the nearest Saudi Aramco rectifier cycled "On" and "Off". If the measurements indicate that the Saudi Aramco C.P. system is depressing the protection level on the foreign pipeline, when "On", by 50 mV or more, forward written notification to the owner of the foreign line.
- 4.5.3 If the protection level on the Saudi Aramco line is less than acceptable per Appendix A-1, then conduct a close interval survey in the vicinity of the crossing for approximately 50 meters in each direction over the Saudi Aramco line. If the close interval survey indicates that interference is occurring on the Saudi Aramco line, notify the owner of the foreign pipeline and implement additional cooperative testing with corrective action.

4.6 Cathodic Protection Monitoring Equipment and Maintenance of Voltmeters, Ammeters and Reference Electrodes

- 4.6.1 Use voltmeters, ammeters and reference electrodes suitable for CP monitoring. These meters are operated by batteries. Check meter batteries before each survey to ensure they function properly.
 - 4.6.2 Annually, verify accuracy of digital voltmeters using a device similar to "Tinker&Rasor VC-1 Verifier", and if required have the meter calibrated/repared.
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- 4.6.3 Use high input impedance meters for structure-to-electrolyte potential measurements, especially in areas of high soil resistivity. Input impedance should be in the 20+ megohm range. Multimeters with various setting levels of input impedance are preferred, for example, Miller model LC-4.
- 4.6.4 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 the appropriate factor for the clamps. Currently, the clamp-on ammeters made by William H. Swain company are widely used in Saudi Aramco facilities.
- 4.6.5 Properly maintain copper/copper sulfate and silver/silver chloride reference electrodes, as follows:
 - 4.6.5.1 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. Rinse the copper rod thoroughly after sanding, before reinstalling in the electrode casing. 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.
 - 4.6.5.2 Inspect and test silver/silver chloride electrodes one against another or against a standard voltage source, periodically. If the voltage difference is larger than 10 mV, a replacement is required.
- 4.6.6 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.

4.7 Records and Reports

The responsible proponent organization shall collect and record all field data on the appropriate forms (see data recording forms attached as Appendices to this Procedure), and issue survey reports. The report for the annual CP survey shall summarize the CP status of all protected structures and the performance of all CP systems. It shall also include recommendations to eliminate deficiencies. The annual cathodic protection survey report will be reviewed by CSD at the request of the proponent organization.

5 Responsibilities

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

5.2 Certification Requirement for CP Monitoring Personnel

Each operating proponent of CP shall maintain at all times qualified personnel to conduct the survey and at least one of these personnel should have NACE International CP level 1 certification."

Revision Summary

31 July, 2004 Major revision.

Appendix A-1

FACILITY – ONSHORE (All readings taken with Cu-CuSO ₄ reference electrode, unless otherwise noted)	PROTECTION CRITERIA	
PIPELINES Non-Subkha In Subkha In Subkha, FBE Coated, CP Coupon "Off" Potential Mothballed with Uncertain Future Utilization Mothballed with Known Future Utilization Buried Crossovers & Bypasses Non-Subkha or Subkha, using Soil Corrosion Probe (Corrosion Rate)	-1100 mV -1000 mV -850 mV "Off" ⁽⁶⁾ -850 mV -1100 mV -1000 mV ⁽¹⁾ Less than 0.1 mpy ⁽¹⁰⁾	
VALVE SITES Motor Operated Valves Gas & Hand Operated Valves	-1000 mV ⁽¹⁾ -1000 mV ⁽¹⁾	
PLANTS (including Pipeline Junctions & Pump Stations, GOSPs and Bulk Plants) Hydrocarbon Lines Metallic Fire Water Lines	-850 mV ⁽¹⁾ -850 mV ⁽²⁾	
WELL CASINGS Deep Gas Wells – All Areas - Rectifier - Photovoltaic Oil Prod. & Water Injection Wells Uthmaniyah ^(7, 8) - Rectifier - Photovoltaic Abqaiq, AinDar, Shedgum, Hawiyah, Nuayyim, Qaif - Rectifier - Photovoltaic Haradh, Hawtah, Harmaliyah, Shaybah - Rectifier - Photovoltaic Abu Jifan, Khurais & Mazalij - Rectifier - Photovoltaic Water Supply Wells – All Areas ⁽⁹⁾ - Rectifier - Photovoltaic	Minimum Casing Current Drain (amps)	
	Bare Casing	Coated Casing
	25 25 40 35 20 20 12 12 5 5 5 5	35 30 10 5 5 4 4 4 - - - -

Appendix A-1 (Cont'd)

TANKS	
Internals	-900 mV ⁽³⁾
Bottom Underside (as applicable)⁽⁴⁾	
Stationary Zinc Reference Electrodes Installed Under Tank Bottom	+200 mV
Stationary Cu-CuSO ₄ Reference Electrodes Installed Under Tank Bottom	-900 mV
Portable Cu-CuSO ₄ Reference Electrodes in Soil Access Holes Outside Ring Wall	-1000 mV
Portable Cu-CuSO ₄ Reference Electrodes through Ring Wall Access Tubes	-900 mV
Portable Cu-CuSO ₄ Reference Electrode in Monitoring Tube Under Tank Bottom	-900 mV
Depolarization criterion: Minimum depolarization after 24 hours or max. 7 days	100 mV
TRESTLES AND SHEET PILING (Soil Side)	-850 mV
UNDERGROUND TANKS	
Underground tanks, sumps and reservoirs	-850 mV

- 1) Measured at intervals not to exceed 30 meters over all piping.
- 2) Measured at all above-ground appurtenances.
- 3) Measured against a Ag-AgCl reference electrode.
- 4) CP systems for tanks with oil sand pad or asphalt foundations shall be operated based on the design output of the rectifier. Dedicated CP systems for such tank foundations shall not be upgraded.
- 5) Applies only to tanks which do not have ring wall access tubes or under-bottom stationary electrodes.
- 6) Applies only to FBE coated pipelines in subkhya soils. "Off" potentials are measured using a CP Coupon Test Station.
- 7) 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.
- 8) Rectifier output should be reduced if nearby pipeline potentials exceed 3.0 volts, provided that the minimum current drain is 20 amperes.
- 9) 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.
- 10) Corrosion rate criterion, in mils per year, is for the metal loss experienced by the soil corrosion probe.

Appendix A-2

Cathodic Protection Coupon Test Stations

A. Background

A CP coupon is used to simulate coating defects (holidays) on the structure being evaluated. The CP coupon test station (CTS) is installed near the pipeline and then connected to it through the wiring in the CTS head. This allows the CP coupon to be connected to the CP system on the pipeline, thus simulating a holiday in the coating. The CP coupon can then be disconnected from the circuit during periodic testing, and an instant-off potential measured. The CP coupon can then continue to be monitored and the depolarization measured.

These measurements approximate the polarized or "off potential" and the depolarized potential of the structure in the vicinity of the CP coupon and allow the operator to calculate the IR drop. A second "free-corroding" native coupon is also installed in the CTS coupon to measure the native potential of the coupon.

CTSs are not a substitute for:

- Low cathodic protection potential levels due to poor coating quality
- Ineffective or malfunctioning CP systems
- Other abnormal conditions resulting in poor protection.

In these cases, the cause of the poor protection should be identified, and suitable remedial measures taken to resolve the problem.

B. Conditions for Using CP Coupon Test Stations (CTSs) as CP Monitoring Tools

CP coupons been approved in Saudi Aramco for use in low resistivity (subkha type) soils, on cross-country FBE coated pipelines, with "excellent" coating, and no history of corrosion in the area where the CTS is being installed. An -850 mV "off" potential measurement of the CP coupon is considered to indicate adequate protection. (See Section 4.4.3.2 and Appendix A-1 above).

C. Monitoring Procedures

CTS potentials are measured using a CU/CuSO₄ reference electrode and a high impedance voltmeter. Measure the CP Coupon and Native Coupon "off" potentials by interrupting the current flow to the CP coupon using the On/Off switch in the test station head. The potential reading must be taken with 1 second of interrupting the current to the coupon. If using a digital voltmeter, the

second reading that flashes on the screen after the current is switched off is usually accepted as a valid "off potential reading. A specialized recording voltmeter or data logger can also be used to measure the off-potential 200 milliseconds after the coupon current has been interrupted.

D. Monitoring Schedules

Measure and record the potentials at least once a month for the first 12 months. Thereafter, the monitoring frequency can be reduced to once every 3 months.

E. Installation Guidelines

See Installation Instructions below for details. A permanent reference cell can be installed inside the test station tube for monitoring. Alternatively potentials are measured using a portable reference cell with an extension to lower it down inside the test station tube.

CP coupon should not be connected to the CP circuit for at least 4 weeks after installation, to allow the coupon to freely corrode and essentially be comparable to the condition of the pipe in this same soil environment.

F. CP Coupon Test Station Installation Instructions

Pre-Installation Checks

Refer to the list below for the materials required for the CTS installation for each site. Ensure that all materials for the particular site are on-hand, prior to starting the excavation work.

Check CP Coupon TS to see if the two coupons at the bottom of the tube are fixed firmly (not loose), and extend out of the bottom of the tube for the full length of the metal coupon.

Installation Steps

- CTS is to be installed to the side of the pipeline, at pipe mid-line depth, about 25 cm (10 inches) from the pipeline
- Excavate to top of pipe. This will locate pipe center, as well as to allow for thermite welding of wire connection for the CTS (if required).
- Excavate 25 cm to the side of the pipe up to the mid line of the pipe. Try to leave undisturbed soil between the CTS and the pipe.

- Drill hole in the side of the CTS tube, just below the approximate grade level. Insert the test lead wire (from the pipe, or existing KM CP test Station) through this hole, and bring it to the top of the CTS tube.
- Install CTS next to the pipe, as specified above, and backfill.
- Add "native" soil to the CTS tube (approximately 0.25 meter)
- Leave enough slack in the test head wires so that the head can easily be removed and moved aside.
- Complete backfilling of the excavated area around the CTS and the pipeline.

Typical Installation Sketch

The **CP Coupon** test station consists of a 3 in. diameter PVC tube, a test head (Figure 1), and two 9 sq. cm cylindrical carbon steel coupons. One of these coupons is connected to the pipeline CP circuit (and is therefore called the "CP Coupon"), through an "on/off" switch. The other remains unconnected and is used to monitor the native potential of the coupon in the soil ("Native Coupon"). The "connection for reference electrode" is used only if a permanent reference electrode is installed inside the test station tube.

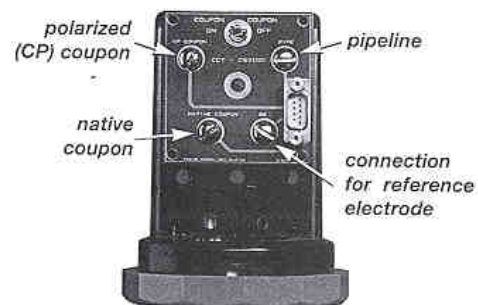


Figure 1 – CP Coupon Test Station Head

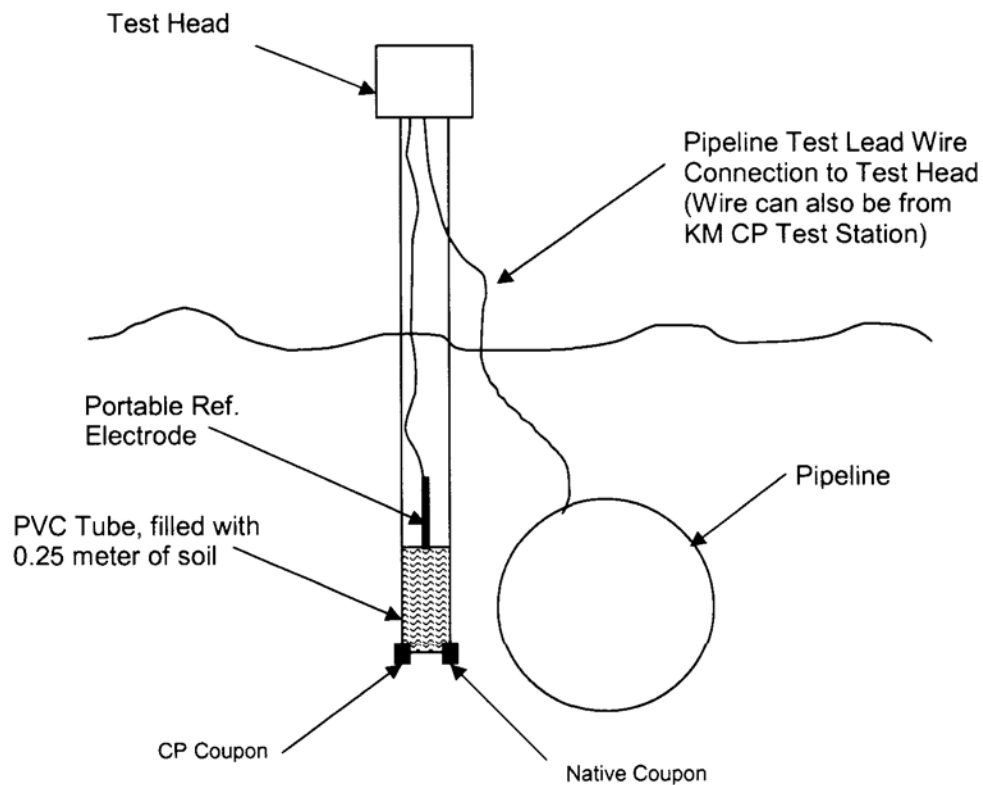


Figure 2 – CP Coupon Test Station Installation

CTS Monitoring Procedure and Records

The potential measurements for the CTS are done as follows:

- 1) Data is recorded with the portable electrode at grade level as well as inside the test station tube. This is done to see if there is any significant interference effect on the readings taken at grade level outside the test station tube. The reading taken inside the tube is considered to be one which is more accurate, as it is not influenced by any stray currents in the area.
- 2) The portable reference electrode must be lowered down into the test station tube, and should make contact with the soil in the tube at the bottom. This can be done by temporarily removing the test head from the tube, and lowering the reference cell attached to an extension rod.
- 3) The "off" potential measurements are made by using the on/off switch in the test head.
- 4) The potential reading must be taken with 1 second of interrupting the current to the coupon. If using a digital voltmeter, the second reading that flashes on the screen after the current is switched off is usually accepted as a valid "off potential reading. A specialized recording voltmeter or data logger can also be used to measure the off-potential 200 milliseconds after the coupon current has been interrupted.
- 5) All "off" potential readings (for the pipeline, CP coupon, and the native coupon) are taken using the on/off switch in the test station head.

Record the CP potentials as follows:

Portable Ref. Cell at Grade Level	Date	Date	Date	Date
Pipeline Potential - Coupon CP "On"				
Pipeline Potential - Coupon CP "Off"				
Coupon Potential – Coupon CP "On"				
Coupon Potential – Coupon CP "Off"				
Native Coupon Potential - Coupon CP "On"				
Native Coupon Potential - Coupon CP "Off"				
Portable Ref. Cell inside Test Station Tube				
Pipeline Potential - Coupon CP "On"				
Pipeline Potential - Coupon CP "Off"				
Coupon Potential – Coupon CP "On"				
Coupon Potential – Coupon CP "Off"				
Native Coupon Potential - Coupon CP "On"				
Native Coupon Potential - Coupon CP "Off"				

Material Requirements

No.	Description	Qty	Comments
1	CP Coupon Test Station Tube	1	
2	CP Coupon Test Station Head	1	Connect separate wire from pipeline to this CTS
3	#10 AWG, STR Wire for Pipe Connection		Quantity as required
4	Thermite Weld Equipment		Quantity as required
5	2" PVC Pipe, 3 meter long (Soil Access Tube), if required	1	For portable reference cell measurement

Appendix A-3

Electrical Resistance Soil Corrosion Probes

A. Background

The use of electrical resistance (ER) soil corrosion probes (SCPs) to determine actual corrosion rates can assist in determining the effectiveness of cathodic protection (CP) in high resistivity soils. This technique is especially useful in cases of:

- Poor reference cell soil contact resulting in erroneous CP potential measurements, or
- When "Off" potential measurements cannot be practically taken on complex, interconnected pipeline systems.

CP potential measurement errors can occur in:

- Very dry, high resistivity desert soils or in sand dune areas, and
- On pipelines with berms which have been sprayed with oil for soil consolidation.

In such situations, the measured potentials may not meet the minimum operating criterion requirement, even if the CP system output is raised, or supplemental galvanic anode "hot spot" protection is provided at such locations.

SCPs are not a substitute for:

- Low cathodic protection potential levels due to poor coating quality.
- Ineffective or malfunctioning CP systems.
- Other abnormal conditions resulting in poor protection.

In these cases, the cause of the poor protection should be identified, and suitable remedial measures taken to resolve the problem.

B. Conditions for Using ER Soil Corrosion Probes (SCPs) as CP Monitoring Tools

The following should be used as a guide for selecting locations where SCPs can be used to measure the effectiveness of cathodic protection:

- Pipeline with potentials lower than the minimum acceptable criterion for the soil conditions, where remediation measures such as installing additional CP system capacity are not practical or cost effective.

- Pipe coating must be FBE, in good/excellent condition (no blistering bare patches or other obvious coating damage). This can be verified by bell hole inspection.
- Pipe coating for short buried sections/road crossings which have been reconditioned using high performance ACPS-113 coatings may also be monitored using SCPs.
- The existing piping must have no documented history of corrosion, or inspection records showing any leaks, ruptures or corrosion damage in the vicinity of the location where the SCP is proposed to be installed.
- Instrument scraper records, where available, should also be used to determine that there is no history of corrosion for the selected installation location.
- The soil must be homogenous over the length of pipe section that the probe data will be used for determination of CP effectiveness. Install one SCP test station for at least every 1 kilometer of pipe section with uniform soil conditions.
- The SCP shall be monitored monthly for the first 12 months, and at quarterly intervals thereafter.
- A visual examination of the probe should be conducted 12 months after installation, by excavating up the SCP, to verify the measured corrosion rates by visual examination of the probe and pipe surface.

C. Monitoring Procedures

Use a "CK-4 Corrosometer" instrument to measure the metal loss on the corrosion probe. The Corrosometer data has to be converted to metal loss (mils), and then plotted as an Excel X-Y graph, to determine the corrosion rate in mils per year (mpy) from the slope of the trendline of the plotted data.

For potential measurements, measure the Probe and Native Coupon "off" potentials by interrupting the current flow to the probe using the On/Off switch in the test station head.

D. Monitoring Schedules

Measure the SCP at least once a month for the first 12 months. Thereafter, the monitoring frequency can be reduced to once every 3 months.

E. Installation Guidelines

See Installation Instructions below for details. A "Soil Access Tube" (see Figure 3 below for details) may be required in high resistivity soils, if probe/coupon potentials are also desired to be measured.

The probe should not be connected to the CP circuit for at least 4 weeks after installation, to allow the probe to freely corrode and essentially be comparable to the condition of the pipe in the same soil environment.

F. Soil Corrosion Probe Test Station Installation Instructions

Pre-Installation Checks

Refer to the check list below for materials required for the Soil Corrosion Probe (SCP) installation for each site. Ensure that all materials for the particular site are on-hand, prior to starting the excavation work.

Installation Steps

- 1) SCP should be installed to the side of the pipeline, at pipe mid-line depth, (3 o'clock, or 9 o'clock) about 25 cm (10 inches) from the pipeline
- 2) Excavate to top of pipe. This will locate pipe center, as well as to allow for thermite welding of wire connection for the SCP (if required).
- 3) If there is no adjacent existing CP test station, thermite weld a #10 WAG test lead wire to the pipe and bring it to grade level.
- 4) Excavate 25 cm to the side of the pipe up to the mid line of the pipe.
- 5) Drill hole in the side of the SCP tube, just below the approximate grade level. Insert the test lead wire (from the pipe, or existing KM CP test Station) through this hole, and bring it to the top of the SCP tube. Leave enough slack in the test lead wire so that the head can easily be removed and moved aside.
- 6) Install SCP next to the pipe, and backfill.
- 7) Complete backfilling of the excavated area around the SCP and the pipeline.

Typical Installation

The general installation layout of the SCP test station is shown in Figure 1 below.

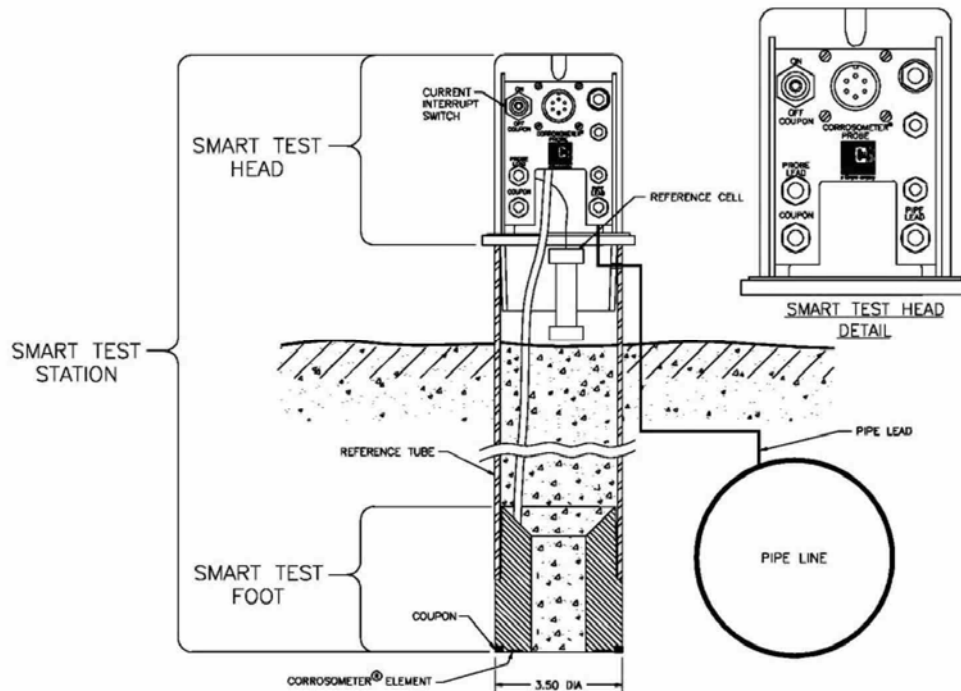


Figure 1 – SCP test Station Installation Detail

SCP Test Head Connections

The wiring arrangement for the **Soil Corrosion Probe (SCP)** test head is shown in Figure 2 below. The "Probe" in the SCP is connected to the pipeline CP circuit through an on/off switch, and is thus cathodically protected. All test head and internal probe and coupon connections in the SCP are pre-wired by the manufacturer, except the "probe" terminal to the on/switch terminal connection, which has to be done at the time of test station installation in the field.

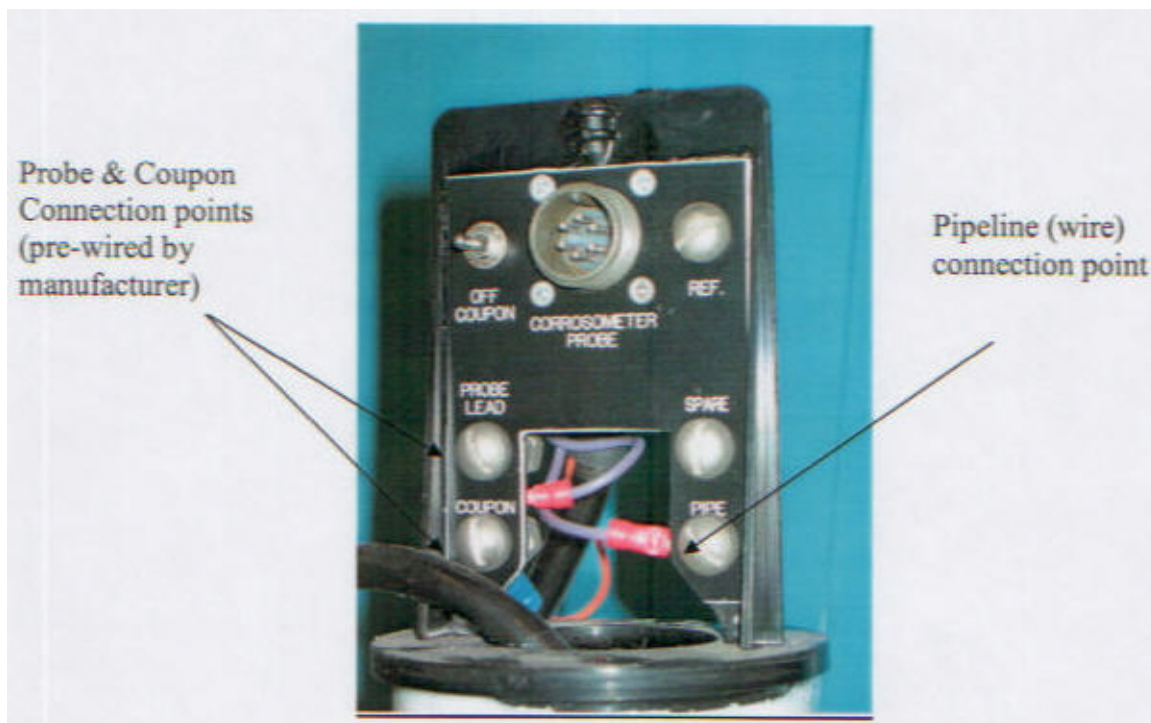


Figure 2 – Detail of SCP Test Station Head

Use of Soil Access Tubes

In some cases (*very dry soils*) an *additional* soil access tube may also be installed for use in measuring potentials using a portable reference electrode, as shown in Figure 3 below:

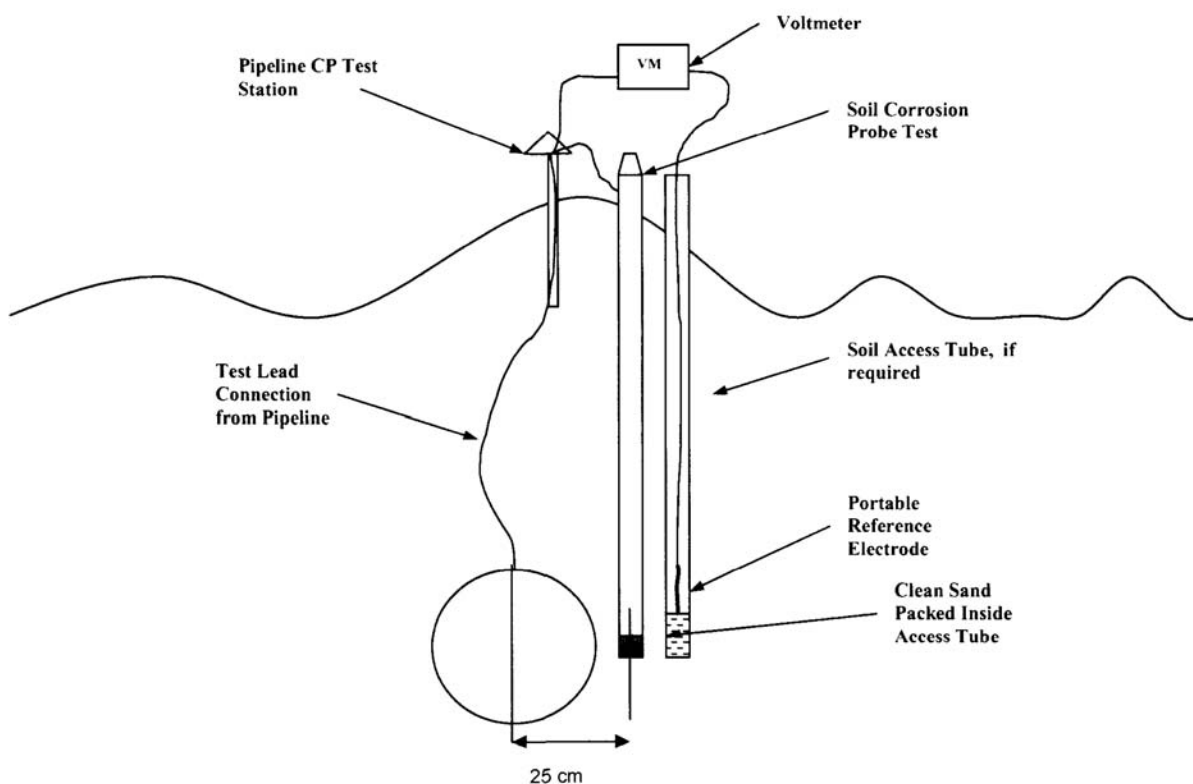


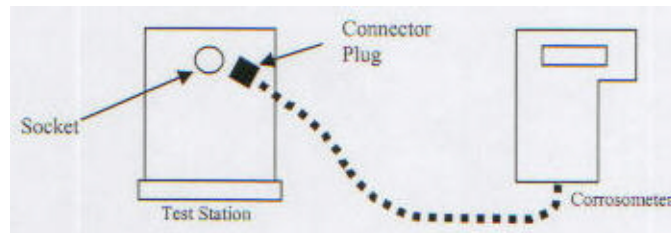
Figure 3 – SCP Installation with Soil Access Tube

Material Requirements

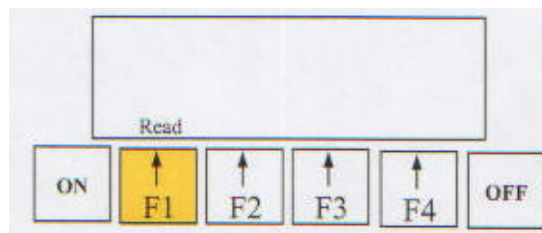
No.	Description	Qty	Comments
1	Soil Corrosion Probe Test Station	1	Connect separate wire from pipeline to this SCP
2	#10 AWG, STR Wire for Pipe Connection		Quantity as required
3	Thermite Weld Equipment		Quantity as required
4	2" dia, PVC pipe (soil access tube), if required		For reference cell access

Corrosometer Monitoring Procedure

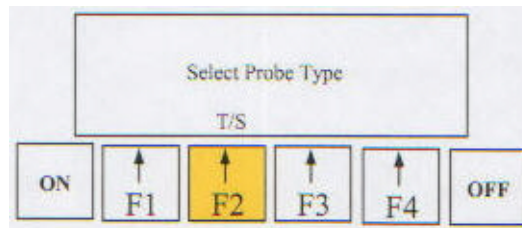
1. Turn meter "OFF". Connect the Corrosometer connector to the plug in the test station.



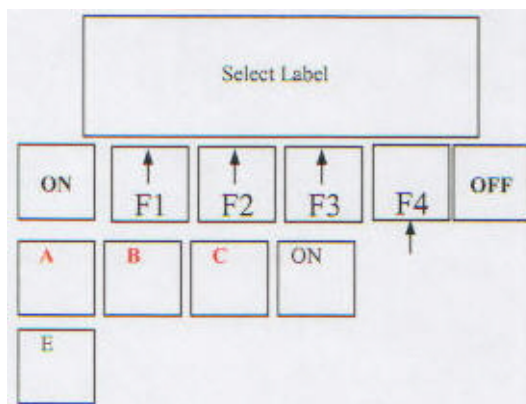
2. Turn on the meter by pressing "ON".
3. Confirm that the "Span" (F4) is set to 25 for the label you want to record data for (Step 6 below).
4. From the displayed menu choices, select "Read" (Press F1).



5. "Select Probe Type" will be displayed, Select "T/S" (Press F2).



6. "Select Label" will be displayed.



Choose:

- "A" for Location 1,
- "B" for Location 2,
- "C" for Location 3, etc.

(each test station location will have it's own label assigned to it.)

7. The meter will start reading. Wait until the flashing in the display stops and the reading are displayed. (This usually takes about 2 minutes, 45 seconds).

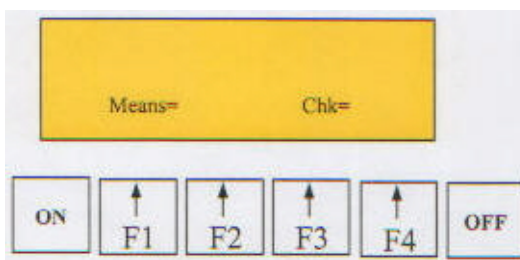
SCP Monitoring Records

Record the Corrosometer data in the following Table format:

CK-4 Corrosometer Data

	Date	Date	Date	Date
Check				
Measure				
mpy*				

* This reading is displayed using "DISP, F2" from the initial menu, if the consecutive probe readings are more than 14 days apart.



The recorded data can be displayed by selecting "**DISP, F2**" from the initial menu and pressing the correct label no.

Record the CP potentials as follows:

Portable Ref. Cell at Grade Level	Date	Date	Date	Date
Pipeline Potential - Probe CP "On"				
Pipeline Potential - Probe CP "Off"				
Probe Potential – Probe CP "On"				
Probe Potential – Probe CP "Off"				
Coupon Potential - Probe CP "On"				
Coupon Potential - Probe CP "Off"				

Appendix B

FACILITY – OFFSHORE (All readings taken with Ag-AgCl reference electrode)	Protection Criteria
Fixed Platforms	-900 mV
Pipelines	-900 mV
Trestles and Sheet Piling (Water Side)	-900 mV

Attachments to SAEP-333

- Double click here => [SAEP-333A](#) to view the Appendices C-K.