**COMMONWEALTH OF VIRGINIA**
**DEPARTMENT OF ENVIRONMENTAL QUALITY**
**DIVISION OF WATER QUALITY PROGRAMS**
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**Subject:** **Guidance Memorandum No. 06-2006**
**DEQ's "Guidelines for Underground Storage Tank Cathodic Protection Evaluation"**

**To:** Regional Directors

**From:** Ellen Gilinsky, Ph.D., Director

**Date:** May 26, 2006

**Copies**: Rick Weeks, Regional Groundwater Managers, Fred Cunningham, Russ Ellison, Sam Lillard, Renee Hooper, Elizabeth Lamp

**Summary**: In response to the need for statewide consistency for the required recording of Underground Storage Tank (UST) Cathodic Protection (CP) Evaluations, the attached comprehensive guidance document was developed. The Virginia UST Regulations require that all in use and temporarily out of use UST systems that have metallic product tanks and/or metallic product piping be cathodically protected and tested for compliance every three years. Virginia currently has over 7,150 such CP protected UST systems at some 2,278 UST facilities within the Commonwealth. This guidance establishes DEQ proper CP testing procedures for UST CP evaluations. A very similar guidance document was first developed by the State of Mississippi in 2002 and has been adopted and successfully used by several southeastern states. This Virginia version has been reviewed by the National Association of Corrosion Engineers, Steel Tank Institute, EPA's Office of Underground Storage Tanks, DEQ tank staff, and corrosion experts and specialists.

**Electronic Copy:**
An electronic copy of this guidance in PDF format is available for staff internally on DEQNET, and for the general public on DEQ's website at: http://www.deq.virginia.gov.

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Disclaimer:

**This document is provided as guidance and, as such, sets forth standard operating procedures for the agency. However, it does not mandate any particular method nor does it prohibit any particular method for the analysis of data, establishment of a wasteload allocation, or establishment of a permit limit. If alternative proposals are made, such proposals should be reviewed and accepted or denied based on their technical adequacy and compliance with appropriate laws and regulations.**

*COMMONWEALTH of VIRGINIA*

*DEPARTMENT OF ENVIRONMENTAL QUALITY*

# *GUIDELINES FOR UNDERGROUND STORAGE TANK CATHODIC PROTECTION EVALUATION*

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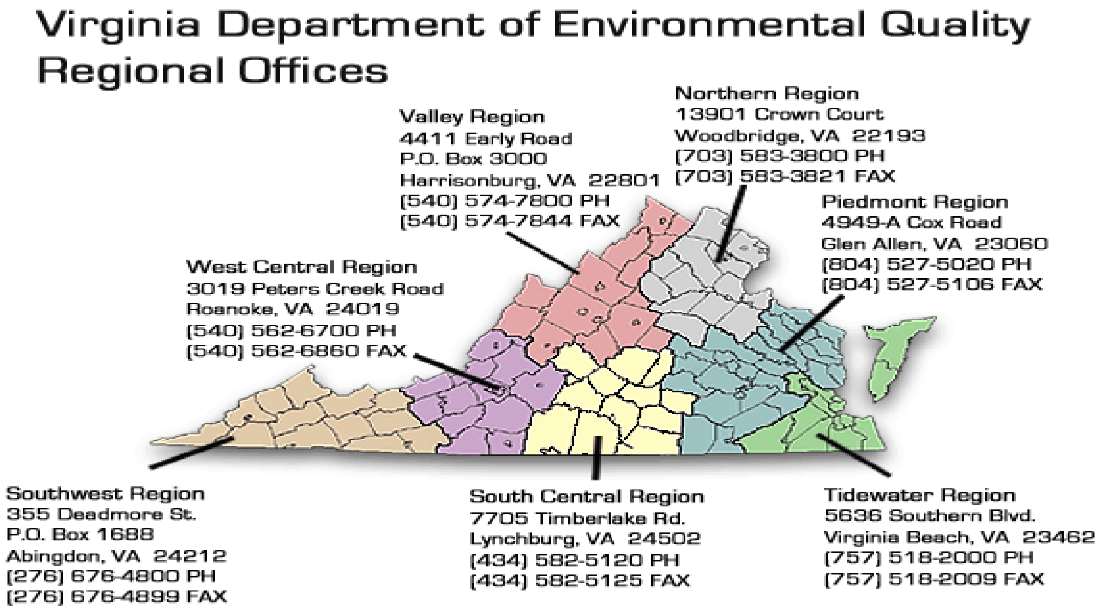
MAY, 2006

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# SECTION 1 - GENERAL

## 1.1 Introduction

The purpose of this document is to establish general guidelines regarding the evaluation of cathodic protection (CP) systems operating on underground storage tank (UST) systems in the Commonwealth of Virginia in concert with the National Association of Corrosion Engineers (NACE) and other national standards. While conducting structure-to-soil potential surveys is the primary means of testing cathodic protection systems, other aspects related to the evaluation, installation, operation and repair of cathodic protection systems are also addressed in this document where necessary.

Evaluation of cathodic protection systems to ensure they are functioning as intended has proven to be one of the more problematic areas of UST regulation and has led to a great deal of confusion and various practices among individuals engaged in the field of cathodic protection. The applicable UST regulations contain no specific criteria and instead defer to industry standards. Also, a large degree of latitude has historically been provided for interpretation of what constitutes an acceptable evaluation.

Since there are many factors that can affect cathodic protection, there is understandably no standard test method or simple approach that will work at every site that has a cathodic protection system in operation. Therefore, the primary intent of this guideline is to create a level playing field in which everyone, who is engaged in the business of UST system cathodic protection in the Commonwealth of Virginia, understands generally what is expected. The second focus of this guideline is to establish sufficient documentation in order to evaluate the results generated by a qualified cathodic protection tester/expert. To this end, a form for evaluating cathodic protection is included in Appendix K of this document. Only qualified cathodic protection testers/experts can perform CP testing to comply with UST regulations in Virginia.

It is further necessary to understand that the creation of this guideline has necessitated a compromise of what is acceptable to some degree. Every effort has been made so as not to place an unduly harsh burden on the tank owners and contractors who operate in the Commonwealth of Virginia. At the same time, it is necessary to be protective of human health and the environment to the degree required to achieve the charge of the Virginia Department of Environmental Quality (VADEQ). This document represents the best efforts of the VADEQ to assure that cathodic protection systems operate as intended and effectively mitigate corrosion while being mindful of the economic constraints that must be considered.

Some of the more important points established with this guidance document are:

- Access to the soil directly over the structure that is being tested must be provided.
- Voltage drops must be considered and "instant off" potentials obtained on all impressed current systems.
- Continuity/isolation should be established whenever a cathodic protection survey is conducted.
- Under certain conditions a "corrosion expert" must evaluate the cathodic protection survey.
- A person must meet certain minimum qualifications in order to perform CP testing.

Simply conducting a structure-to-soil potential survey does not adequately evaluate a cathodic protection system. Other considerations that may need to be addressed are outlined in the text of this document and include: review of previous cathodic protection inspection/testing; continuity measurements; evaluation of rectifier operation; current distribution among an impressed current anode ground bed; consideration of voltage drops; assurance of wiring integrity; continuity bonds; as built drawings and others.

This guideline is not intended to replace any statute, regulatory requirement, nor national standard concerning the installation, repair, operation or testing of UST cathodic protection systems. Rather, it is intended to state the general interpretation of the VADEQ with regard to the implementation of those rules and regulations applicable to UST cathodic protection systems. The Virginia regulation 9 VAC 25-580 requires a national standard be followed for meeting cathodic protection in all cases.

# SECTION 2 - REGULATIONS

## 2.1 Rules

The 1988 Federal and subsequent Virginia UST regulations require that tanks and piping that routinely contain product and are in contact with the ground must be protected from corrosion. If the UST system (tank/pipe) in question is of metallic construction and it is in contact with the ground, it must be cathodically protected or isolated from being in contact with the ground. Metallic product piping installed after December 22, 1988 that is in contact with the ground must be coated with a suitable dielectric material and cathodically protected.

The rules also require that all cathodic protection systems must be evaluated within six months of installation/repair and at least once every three years thereafter. The two general types of cathodic protection that are typically installed on UST systems are galvanic (sacrificial anode) and impressed current (rectifier) systems. Although not a regulatory requirement, consideration should be given to evaluating impressed current systems on an annual basis since these types of systems are more susceptible to failure or may be in need of adjustment on a more frequent basis than a galvanic system.

The VADEQ adopted almost verbatim the federal UST rules found under Subtitle I of the Resource Conservation and Recovery Act (RCRA) with respect to UST cathodic protection. The federal rules are published in Chapter 40 Part 280 of the Code of Federal Regulation ("Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tank Systems"). See 9 VAC 25-580 for the Virginia UST regulation. The regulations reference several industry codes and practices and a listing of these may be found in Appendix A of this document. Following are the pertinent paragraphs of 40 CFR 280 that are related to cathodic protection (9 VAC 25-580 section in parentheses):

280.12 Definitions
(State Regulation 9 VAC 25-580-10)

"Cathodic Protection" is a technique to prevent corrosion of a metal surface by making that surface the cathode of an electrochemical cell. For example, a tank system can be cathodically protected through the application of either galvanic anodes or impressed current.

"Cathodic protection tester" means a person who can demonstrate an understanding of the principles and measurements of all common types of cathodic protection systems as applied to buried or submerged metal piping and tank systems. At a minimum, such persons must have education and experience in soil resistivity, stray current, structure-to-soil potential, and component electrical isolation measurements of buried metal piping and tank systems.

"Corrosion expert" means a person who, by reason of thorough knowledge of the physical sciences and the principles of engineering and mathematics acquired by a professional education and related practical experience, is qualified to engage in the practice of corrosion control on buried or submerged metal piping systems and metal tanks. Such a person must be accredited or certified as being qualified by the National Association of Corrosion Engineers (NACE) or be a registered professional engineer who has certification or licensing that includes education and experience in corrosion control of buried or submerged metal piping systems and metal tanks.

280.20 Performance Standards for New UST Systems
(State Regulation 9 VAC 25-580-50)

(a) Tanks

(2) The tank is constructed of steel and cathodically protected in the following manner:

(i) The tank is coated with a suitable dielectric material;

(ii) Field-installed cathodic protection systems are designed by a corrosion expert;

(iii) Impressed current systems are designed to allow determination of current operating status as required in 280.31 (c); and

(iv) Cathodic protection systems are operated and maintained in accordance with 280.31 or according to guidelines established by the implementing agency; or (various industry codes and standards are referenced here – see Appendix A).

280.20 Performance Standards for New UST Systems
(State Regulation 9 VAC 25-580-50)

(b) Piping

(2) The piping is constructed of steel and cathodically protected in the following manner:

(i) The piping is coated with a suitable dielectric material;

(ii) Field-installed cathodic protection systems are designed by a corrosion expert;

(iii) Impressed current systems are designed to allow determination of current operating status as required in 280.31 (c) and

(iv) Cathodic protection systems are operated and maintained in accordance with 280.31 or guidelines established by the implementing agency.

280.21 Upgrading of existing UST Systems
(State Regulation 9 VAC 25-580-60)

(b) Tank upgrading requirements.

Steel tanks must be upgraded to meet one of the following requirements in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory:

(2) Cathodic protection. A tank may be upgraded by cathodic protection if the cathodic protection system meets the requirements of 280.20(a)(2)(ii), (iii), and (iv) and the integrity of the tank is ensured using one of the following methods:

(i) The tank is internally inspected and assessed to ensure that the tank is structurally sound and free of corrosion holes prior to installing the cathodic protection system; or

(ii) The tank has been installed for less than 10 years and is monitored monthly for releases in accordance with 280.43(d) through (h); or

(iii) The tank has been installed for less than 10 years and is assessed for corrosion holes by conducting two (2) tightness tests that meet the requirements of 280.43(c). The first tightness test must be conducted prior to installing the cathodic protection system. The second tightness test must be conducted between three (3) and six (6) months following the first operation of the cathodic protection system; or

(iv) The tank is assessed for corrosion holes by a method that is determined by the implementing agency to prevent releases in a manner that is no less protective of human health and the environment than paragraphs (b)(2)(i) through (iii) of this section.

(c) Piping upgrading requirements. Metal piping that routinely contains regulated substances and is in contact with the ground must be cathodically protected in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory and must meet the requirements of 280.20(b)(2)(ii),(iii), and (iv).

280.31 Operation and Maintenance of Corrosion Protection
(State Regulation 9 VAC 25-580-90)

(a) All corrosion protection systems must be operated and maintained to continuously provide corrosion protection to the metal components of that portion of the tank and piping that routinely contain regulated substances and are in contact with the ground.

(b) All UST systems equipped with cathodic protection systems must be inspected for proper operation by a qualified cathodic protection tester in accordance with the following requirements:

(1) Frequency. All cathodic protection systems must be tested within 6 months of installation and at least every 3 years thereafter.

(2) Inspection Criteria. The criteria that are used to determine that cathodic protection is adequate as required by this section must be in

accordance with a code of practice developed by a nationally recognized association.

(c) UST systems with impressed current cathodic protection systems must also be inspected every 60 days to ensure the equipment is running properly.

(d) For UST systems using cathodic protection, records of the operation of the cathodic protection must be maintained (in accordance with 280.34 or 9 VAC 25-580-120) to demonstrate compliance with the performance standards in this section. These records must provide the following:

(1) The results of the last three inspections required in paragraph (c) above;

(2) The results of testing from the last two inspections required in paragraph (b) above.

280.33 Repairs Allowed
(State Regulation 9 VAC 25-580-110)

(e) Within 6 months following the repair of any cathodically protected UST system, the cathodic protection system must be tested in accordance with 280.31 (b) and (c) (or 9 VAC 25-580-90.2 and 3) to ensure that it is operating properly.

NOTE:
(1) See APPENDIX M for the VA-DEQ's "Alternatives to Closure for Upgrading Violations - Decision Matrix" for guidance on properly upgrading tanks now that the national UST 1998 Upgrading deadline has passed.
(2) Records of all previous 3-year CP test results should be maintained by the UST owner to assist with CP system trend analysis.

# SECTION 3 - TYPES OF CATHODIC PROTECTION

## 3.1 General

The two general types of cathodic protection that are typically installed on UST systems are galvanic (sacrificial anode) and impressed current (rectifier) systems. There are two types of galvanic installations: factory-installed and field-installed. An attempt to explain the principles involved in the theory of cathodic protection is beyond the scope of this document and it is assumed the reader has a basic understanding of the subject. However, stated in the simplest terms, both of these types of cathodic protection systems attempt to reverse the flow of electric current away from the metal that is intended to be protected from corrosion. Both types of cathodic protection systems prevent electric current from leaving the protected structure by supplying an electrical charge in the form of DC power sufficient to overcome any current that would otherwise leave the structure, thus reducing corrosion. The way in which the required electrical current is provided is what differentiates the two types of cathodic protection systems.

## 3.2 Galvanic Systems

Galvanic systems are also known as sacrificial anode systems because an anode (typically zinc or magnesium) corrodes instead of the protected metal (usually steel). Because the anode corrodes instead of the metal that it is protecting, the anode is said to sacrifice itself. Factory installed sacrificial anodes are usually welded directly to well-coated (with dielectric material) and isolated USTs (e.g., sti-$P_3$®.) Field installed or retrofitted sacrificial anode systems should be mechanically connected to the tank through a test station that allows taking interrupted potential readings and measuring the current output of each anode.

Galvanic systems are generally limited to those tank(s) and piping that are well coated with a dielectric material (e.g., sti-$P_3$® epoxy/aliphatic urethane coated tanks or fusion bonded epoxy coated steel piping) because the available current output of sacrificial anode systems is low and cannot protect large metallic surface areas. Attempts to protect long runs of uncoated piping or uncoated tanks generally are not practical because the useful life of the anodes is too short or the number and cost of anodes needed is too great. For example, it can take 40 or more 17 to 32 pound magnesium sacrificial anodes to protect a poorly coated or bare steel 1,000-gallon UST (for 45 years.)

### 3.3 Impressed Current Systems

Impressed current systems are sometimes called rectifier systems because they utilize an electrical device (a rectifier) to convert an external AC power source to the required DC power source. In this type of system, anodes are installed in the soil around the structure to be protected and the DC power is supplied to the anodes through buried wires. The power to the rectifier should not be interrupted except when conducting maintenance or testing activities. A dedicated and protected circuit should be provided for the impressed current system so that the power cannot be inadvertently cut off.

In impressed current systems the protected structure is bonded/wired to the DC power system to complete the electrical circuit. <u>It is critical that the anodes are connected to the positive terminal and the protected structure to the negative terminal of the rectifier. Reversal of the lead wires will make the components of the tank system anodic and can cause a rapid failure of the tank system due to increased corrosion induced by the rectifier.</u> In addition, it is critical that all wire connections and splices are well insulated. Any breaks in the wiring insulation will allow current to leave the wire at that point and cause a rapid failure of the wire due to corrosion.

Impressed current systems are generally installed on those bare steel tank systems that were installed prior to the effective date of the federal UST regulations (December 22, 1988) since these tanks usually did not have a dielectric coating (not sti-$P_3$®). The level of cathodic protection provided by an impressed current system can be changed since the current produced by the rectifier can be adjusted. Because conditions that affect the level of cathodic protection needed are likely to change over time, adjustment of the rectifier is frequently necessary but only by a corrosion expert.

## SECTION 4 - QUALIFICATIONS TO TEST CATHODIC PROTECTION SYSTEMS

### 4.1 Qualifications

In order to test cathodic protection systems in the Commonwealth of Virginia, an individual must meet certain minimum qualifications. It is the intent of the VADEQ that only those individuals who meet the minimum qualifications may perform testing in a manner that is consistent with the policies of this guidance document. Should an individual who meets the minimum qualifications as described below not possess the knowledge and expertise needed to properly evaluate a cathodic protection system, that individual is not acceptable to DEQ to perform such an evaluation.

While it is not necessary to be an “expert” to test cathodic protection systems in most cases, it should be recognized that the proper evaluation of the two types of cathodic protection systems may require differing levels of expertise. Impressed current systems are inherently more involved and require a higher level of understanding than galvanic systems. In addition, certain circumstances and conditions may exist that would preclude an individual from making an effective evaluation of a cathodic protection system without the assistance of someone who is more qualified.

Because the testing of impressed current systems is inherently more complicated, someone who is only minimally qualified as a “tester” should recognize that they may or may not be able to properly evaluate all such systems. Galvanic cathodic protection systems that are operating as designed are normally straightforward and a lesser degree of expertise is needed to properly evaluate such systems. However, troubleshooting and/or repair of such systems may require someone who has a higher level of expertise than a person who is only minimally qualified as a tester.

Scenarios that require an expert to either conduct or evaluate the cathodic protection survey are listed in Section 7.2 of this document. It should be recognized that there might be other circumstances that require an expert although they may not be specifically listed. A listing of those individuals who meet the qualifications of an expert (certified as either as a “corrosion specialist” or a “cathodic protection specialist”) can be found at the web site of NACE International (http://www.nace.org).

Listed below are the minimum qualifications necessary for a CP contractor to "test" cathodic protection systems:

- Anyone who meets the definition of “cathodic protection tester” as found in 40 CFR 280.12 (9 VAC 25-580-10) is recognized as qualified to test cathodic protection systems. (see section 2.1 above.)

- Anyone who holds a certification from a national association (e.g., NACE International, Steel Tank Institute, etc.) or organization that recognizes at a minimum as qualifying that person as a cathodic protection tester. (e.g., see www.steeltank.com for a complete list of Steel Tank Institute’s (STI) certified testers.)

- See http://www.epa.gov/OUST/compend/adn30lh2.pdf for EPA's more thorough discussion on minimum qualifications for CP testers and experts or APPENDIX N of this guideline.

# SECTION 5 - INSTALLATION / REPAIR OF CATHODIC PROTECTION SYSTEMS

## 5.1 Galvanic Systems

### 5.1.1 sti-$P_3$® Tanks

Anyone who is a UST CP contractor (tester or expert) may repair the cathodic protection system of a sti-$P_3$® tank provided that the repair meets all of the requirements of the tank manufacturer and a corrosion expert. Procedures and calculations such as the current requirement test should be documented and available for review when requested by the Department. The addition of supplemental sacrificial anodes to a sti-$P_3$® tank is allowed without the need for a corrosion expert to design such, provided the provisions of the Steel Tank Institute “Recommended Practice for the Installation of Supplemental Anodes for sti-$P_3$® UST’s R-972-01” are followed. See:

http://www.steeltank.com/library/pubs/recprac/R972-06.pdf An evaluation of the cathodic protection system must be conducted within six months of the installation/repair in accordance with the requirements of this VA-DEQ guidance document.

NOTE: Galvanic CP systems are not recommended for bare (poorly coated) steel tanks due to the higher current required for protecting them (an impressed current system is usually needed.) However, if a galvanic system is installed in the field on a bare steel tank, a CP expert must design that system and all CP testing must include "remote" readings to ensure the entire tank is being protected.

### 5.1.2 Factory Coated Metallic Piping

Installation of sacrificial anodes to factory coated (fusion bonded epoxy) metallic piping may be accomplished without the design of a corrosion expert provided the provisions of the Steel Tank Institute "Recommended Practice for Corrosion Protection of Underground Piping Networks Associated with Liquid Storage and Dispensing Systems R892-91" are followed. As an alternative, the practices as described in the Petroleum Equipment Institute "RP 100–2000 Recommended Practices for the Installation of Underground Liquid Storage Systems" may also be followed when installing sacrificial anodes on factory coated piping.

### 5.1.3 Non-factory Coated Metallic Piping

The installation and/or repair of a galvanic cathodic protection system installed on metallic piping that is not factory coated with a dielectric material may be accomplished by anyone who is a UST CP contractor. However, the design of the galvanic cathodic protection system must be accomplished by a corrosion expert. In addition, an evaluation of the cathodic protection system must be conducted within six months of the installation/repair in accordance with the requirements of this document.

### 5.1.4 Metallic Piping Repair/Installation

Provided below are some general observations that are commonly applicable to questions that arise when attempting to meet the corrosion protection requirements on metallic piping and other metallic components of a typical UST system.

**Protected Components -** Any metallic component of the product piping system, including all metallic nipples, ells, tees, couplings, unions, ball valves, etc. must be protected from corrosion if they are in contact with the ground. Corrosion protection may be accomplished by either: a) isolating the component in question from contact with the ground; or, b) using suitably factory-coated components and adding cathodic protection. Any isolation boot or containment sump designed to isolate the metallic component from contact with the ground must also prevent water from contacting the component in question in order to prevent corrosion of the component. If the metallic piping in question is cathodically protected, it must also be factory coated with a suitable dielectric material if it was installed after December 22, 1988 and in contact with the ground. Product piping installed on or before December 22, 1988 and in contact with the ground does not have to comply with this coating requirement, but does have to have cathodic protection.

**Unprotected Components -** Metallic components of the UST system that do not require corrosion protection include: tank vent lines; any type of tank riser pipe; tank hold down straps (unless manufacturer/local code requires it); remote tank fill lines; and, submersible turbine pump (STP) heads. Although the pump head "routinely contains product", it is not required to meet the corrosion protection requirements and may be in contact with the ground or submerged in water without the need for cathodic protection as long as the manufacturer indicates those conditions are acceptable. However, the pump head should remain visible (not buried) so that any obvious corrosion problems or leaks that may be present can be observed and appropriate action taken to prevent or repair any leaks. Even though it is not required, it is recommended that in damp applications the pump head be protected from corrosion/water due to a noted and likely-related increase in functional element failures. DEQ recognizes the benefit of protecting these components from corrosion, despite the fact that there is no regulatory requirement, and recommends that the owner consider including these items in their corrosion protection system and survey.

**Repair -** Some confusion exists over whether or not buried metallic product piping that has failed can be repaired or must be replaced. "Repaired" as related to steel pipe involves the replacement of the section of pipe that has failed. The entire run of steel piping does not have to be replaced but the repair must consist of replacing the section of pipe that has failed. If the repair pipe used is steel, only steel pipe that is factory coated/wrapped with a dielectric material (e.g., fusion bonded epoxy or extruded polyethylene) can be used to replace the failed section of pipe regardless of whether the existing pipe is galvanized or coated steel. Under no circumstances is it allowable to install galvanized piping when it is intended to serve as a product transfer line. Because of the complexities that may be involved in the cathodic protection of galvanized steel piping, a corrosion expert must evaluate and/or conduct the cathodic protection survey after the repair. Replacement of a steel section of pipe with fiberglass pipe may require the CP system to be re-designed by a CP expert and the CP system re-tested to ensure it functions properly and maintains proper continuity/isolation. (With the many pipe material options available today, field wrapping of metallic pipe (and the addition of anodes) is not suggested even though the existing standards allow it. Factory coated or factory wrapped pipe is always preferable to field wrapping designs.)

**Electrical Continuity -** Dielectric unions are normally not installed if the piping is protected by an impressed current system. For these impressed current systems, it is essential that all buried metallic piping, as well as all other buried metallic components that are within the field of influence of the "impressed current" CP system be bonded to the negative circuit of the impressed current system if it is buried. It is better to electrically isolate any metallic portion of the UST system that is not buried or submerged in water from that portion that is buried/submerged.

**Electrical Isolation -** If metallic piping is galvanically protected, it is critical that effective electrical isolation be provided. Failure to isolate the protected piping will result in premature consumption of the sacrificial anodes. Isolation can be difficult to achieve where cathodically protected piping is present under dispensers that have shear valves present. This is due to the requirement that the shear valve must be properly anchored to the island form. Particular care should be exercised in these instances to assure proper isolation. If possible, the dielectric union should be installed below the shear valve so that anchoring does not cause a continuity problem.

**Screw Joints -** Particular care should be taken when dealing with metallic piping that is mechanically coupled with threaded screw joints. Any threaded joint in a metallic piping material can serve as a break in the electrical continuity of the piping system. It has been established that threaded couple pipe joints can develop enough electrical resistivity over time to effectively isolate each section of a piping system, especially when joint tape or joint compounds are used. For obvious reasons, this is highly undesirable in a cathodic protection system and you should ensure that electrical continuity is present between any sections of piping that are intended to be protected. In some cases, jumper wires or welding may be necessary across each pipe couple in order to assure electrical continuity between each section of piping.

**Flex Connectors -** Any metallic flexible connector (including stainless steel) that is utilized on a piping system must be protected from corrosion if it is in contact with the ground. The best method to achieve this is to ensure the flex connector is isolated from contact with the ground (e.g., soil moved away, booted, etc.). A less desirable option is to cathodically protect it with bag/pencil anodes. If the flex connector was installed after December 22, 1988 and in contact with the ground, it should have been installed with cathodic protection and coated with a dielectric material or wrapped/isolated (booted). Post 1988 installed flex connectors in contact with the ground may be brought back into compliance with DEQ regional UST inspector approval by booting/wrapping or with the addition of anodes designed and approved by a CP expert.. Components installed on or before December 22, 1988 and in contact with the ground do not have to comply with the coating requirement, but do have to have cathodic protection or be isolated/booted. Existing DEQ approved CP (pencil anode) upgrades to flex connectors in contact with soil may be allowed on a case-by-case basis, but any new field-installed CP systems on piping must have a disconnect-switch due to the need to use the -850 mV instant off test method to avoid dissimilar metals effects when CP testing.

**Containment Sumps –** Sumps that cannot be maintained liquid tight should be repaired or replaced. If metallic components of a piping system are installed in a containment sump, the sump should be maintained dry. Metallic components are protected from corrosion by the removal of water on a regular basis. Water in sumps can be highly corrosive due to winter road salt applications. The metallic sump components may also be protected by installing appropriate isolation boots (in the case of flex connectors) or sacrificial anodes. It is noted that in some situations where it is difficult to maintain a dry sump, cathodic protection may be necessary. One means to achieve cathodic protection of metallic components within a wet sump environment is to add clean sand to a depth adequate to bury the added galvanic anode(s) in accordance with the recommendations of a CP expert. Burial of the anode(s) may help prevent an oxidation film from forming on the anode (and causing passivation) in the event that standing water is not always present in the sump. In either case, it is critical that the anode be installed within the containment sump to establish continuity for CP protection. Note that any cathodically protected component installed after December 22, 1988 and in contact with the ground must also be coated with a suitable dielectric material (coating/wrapped) or booted. Past CP (pencil anode) upgrades to flex connectors in contact with soil may be allowed on a case-by-case basis, but any new field-installed CP systems on piping must have a disconnect-switch due to the need to use the -850 mV instant off test method to avoid dissimilar metals effects when CP testing.

**"Mixed" Piping -** In those instances where fiberglass reinforced plastic or flexible piping is connected to an existing metallic pipe (e.g. to extend a fueling island), a cathodic protection test station or access to the soil where the two dissimilar materials are joined must be provided. This is necessary to effectively test the adequacy of cathodic protection operating on the metallic piping.

## 5.2 Impressed Current Systems

Anyone who is a UST CP contractor may install and/or repair an impressed current cathodic protection system. However, the design of an impressed current system must be accomplished by a corrosion expert. If the repair of an impressed current cathodic protection system results in the reconfiguration of any of the components or protective current/voltage values of the system, then a corrosion expert must also design the reconfiguration.
Note: Some UST facilities contain mixed systems such as impressed current systems for some tanks/components alongside other sti-$P_3$® and/or composite tank systems at the facility. This makes "bonding" and "continuity" a critical issue. A CP expert must review all such complex site designs.

If a repair only involves the like-kind replacement of existing components, a corrosion expert does not need to "sign-off" on such work. However, after any repair/alteration of the impressed current system is made, it must be tested for proper operation within six months of the repair. If the repair/alteration results in any of the conditions found in Section 7.2 of this document, then a cathodic protection survey must be conducted/evaluated by a corrosion expert.

### 5.2.1 Rectifier Adjustment

Anyone who is considered qualified as a cathodic protection tester may, if properly trained (see 4.1), adjust the rectifier output/voltage of an impressed current cathodic protection system as long as it remains within the values set by the CP expert who designed the system and with the owner's permission. An evaluation of the cathodic protection system must be conducted whenever an adjustment to the rectifier is made. Before making any adjustments to the rectifier, the power must be turned off by opening both the AC and the DC circuit breakers/fuses.

It should be recognized that increasing the rectifier output could cause an increase in the potential for "stray" current to be generated that may have a detrimental effect on other buried metallic structures at the facility. Excessive rectifier output can also significantly shorten the life of the anode ground bed since the anodes will be consumed more quickly than necessary. Excessive current must be corrected primarily because it may disbond the coating off the tanks and piping. In addition, care should also be taken to ensure that components of the rectifier do not become overheated (causing a potential fire hazard) as a result of increasing the output.

When evaluating the operation and output of a rectifier, it is important to make all measurements with a good quality and accurate portable multimeter. Do not rely on the output indicated by the voltmeter and/or ammeter that may be installed on the rectifier. Most rectifier meters are adjustable and any recalibration/adjustment made should be with an accurate portable multimeter.

The meters that are commonly built into rectifiers are usually not accurate and may even be frozen in a fixed position. If the indicator needle is frozen on the rectifier voltmeter/ammeter and cannot be freed, the owner should repair/replace the meter. If repair/replacement is not accomplished immediately, it should be noted that the meter is not functioning so that an observer will be able to discern that the meter is inoperable.

For the reasons given above and other considerations, a person qualified as a corrosion expert should be consulted whenever the output is adjusted or repairs are made to the rectifier.

# SECTION 6 - CATHODIC PROTECTION TESTING

## 6.1 Equipment

Although the equipment required to test cathodic protection systems is relatively simple, it is very important that the equipment be maintained in good working order and is free of corrosion and contamination. The basic equipment includes an accurate portable voltmeter/ammeter (multimeter), reference electrode, wires, clips and test probes.

It may also be necessary to have a current interrupter for impressed current systems when the power cannot be easily cut on and off at the rectifier. A clamp-on type ammeter can be useful when troubleshooting impressed current systems. Wire locators can help determine the location of buried anode lead wires and header cables. Hand tools to clean corrosion or dielectric coatings from the surface of the structure being tested at the point of contact with lead wires/probes may also be necessary.

### 6.1.1 Voltmeter/Ammeter/Multimeter

A good quality voltmeter/ammeter/multimeter that has an adequate degree of accuracy is essential for testing cathodic protection systems due to the low voltage/current involved. Most "low end" voltmeters/ammeters are not capable of achieving results accurate enough to ensure reliable results and therefore should not be used. **Note—always take safety precautions when working with electrical equipment.**

All testing of cathodic protection systems must be accomplished with a high internal resistance (impedance of 10 meg-ohms or greater) voltmeter that is properly maintained and periodically calibrated in accordance with the manufacturer's recommendations. It is important that the voltmeter has a high internal resistance in order to avoid introducing a large error when measuring structure-to-soil potentials. The voltmeter should be calibrated at least on an annual basis.

The voltmeter must have a high degree of sensitivity and must be placed in as low a scale as possible (normally the 2 volt DC scale works well) in order to accurately measure the small voltages associated with cathodic protection systems. All voltage measurements obtained should be recorded as millivolts (mV). For example, a reading of -1.23 volts should be recorded as -1230 mV; a reading of -.85 volts should be recorded as -850 mV.

Voltmeters that have a variable input resistance can be utilized to ensure that contact resistance between the reference electrode and the electrolyte has been evaluated as a source of error (voltage drop) in the observed structure-to-soil potential. This is accomplished by changing the input resistance and noting whether or not the voltage observed changes significantly. If no voltage change is observed when the input resistance is changed, it can be assumed that contact resistance is not causing an error in the structure-to-soil potential measurement.

An ammeter that has a very low internal resistance is necessary when testing impressed current systems in order to accurately determine the current output of the rectifier and/or individual circuits in the system. Generally, amperage should only be measured where calibrated measurement shunts are present. Alternatively, a "clamp-on" type ammeter may be utilized in those cases where shunts are not present.

The batteries in the portable voltmeter/ammeter/multimeter must also be in good condition. Batteries that are in poor condition can cause unintended errors. If there is any question about the condition of the batteries in any multimeter, they must be replaced. Battery contacts should be free of corrosion.

### 6.1.2 Reference Electrode

A standard copper/copper sulfate reference electrode (also known as a half cell or reference cell) must be utilized in order to obtain structure-to-soil potentials. The reference electrode must be maintained in good working condition and must be placed in the soil in a vertical position when conducting a test.

On those sti-$P_3$® tanks that have a CP test station (e.g., PP2®, PP4®, etc.), a reference electrode is permanently buried in the tank pit. Since it is generally not possible to determine where the permanent reference electrode was installed on these types of systems, or the calibration accuracy or the degree the reference electrode has been affected by soil chlorides, a CP tester may have questions about the integrity of a structure-to-soil potential obtained with a PP4® (local) test station. Additional local and any remote potentials should be obtained in the conventional manner to indicate that adequate cathodic protection has been provided regardless of what the PP4® test station results indicate.

Maintenance of the reference electrode is important for accurate results and includes the following:

a. The copper-sulfate solution inside the reference electrode should be clear. If the solution appears cloudy, this may indicate that the solution has become contaminated and the reference electrode should be compared with the known standard as described in paragraph e below. Should it be necessary to replace the solution, only distilled water and new copper-sulfate crystals should be used. Copper-sulfate crystals must be added to the distilled water until an excessive amount of crystals are present in order to assure a saturated solution. Under average conditions, it is usually a good idea to empty and replace the solution every 2 or 3 months.

b. The porous ceramic tip must be maintained moist at all times. If the tip is allowed to dry out, it may lose its porosity and a good low resistivity contact with the soil will not be possible. Periodic replacement of the tip may be necessary.

c. The copper rod inside the reference electrode should periodically be cleaned with non-metallic sandpaper. Do not use black metal oxide sandpaper, steel wool or any other metallic abrasive as this can cause the copper rod to become contaminated. If the copper rod becomes contaminated, clean the copper rod and replace the copper sulfate crystals.

d. The copper-sulfate solution must be free of contamination or errors will be introduced in the readings you observe. If the reference electrode is submerged in water or placed in moist soils that are contaminated, it is likely that the solution will become contaminated.

e. The reference electrode that is used in the field must be periodically calibrated. How often the reference electrode needs to be calibrated depends upon several different factors. Among the more important factors that should be considered are the frequency of use and the exposure of the reference electrode to contaminants. As a general rule, calibration should be checked once every week if the reference electrode is used daily. If the reference electrode is only periodically used, calibration should be checked prior to each use.

Calibration of the reference electrode is accomplished by comparing it with another reference electrode that has never been used in the field. This new reference electrode that is used only to act as the calibration standard should be properly set up with new copper sulfate solution. This reference electrode must not ever be used in the field in order to prevent it from being contaminated. Consideration should be given to obtaining a reference electrode that is certified by the manufacturer to be properly calibrated.

To calibrate the field electrode:

1. Place the voltmeter on the 2 volt DC scale (or lower) and connect the leads to the reference electrodes. (See Figure 1 below)

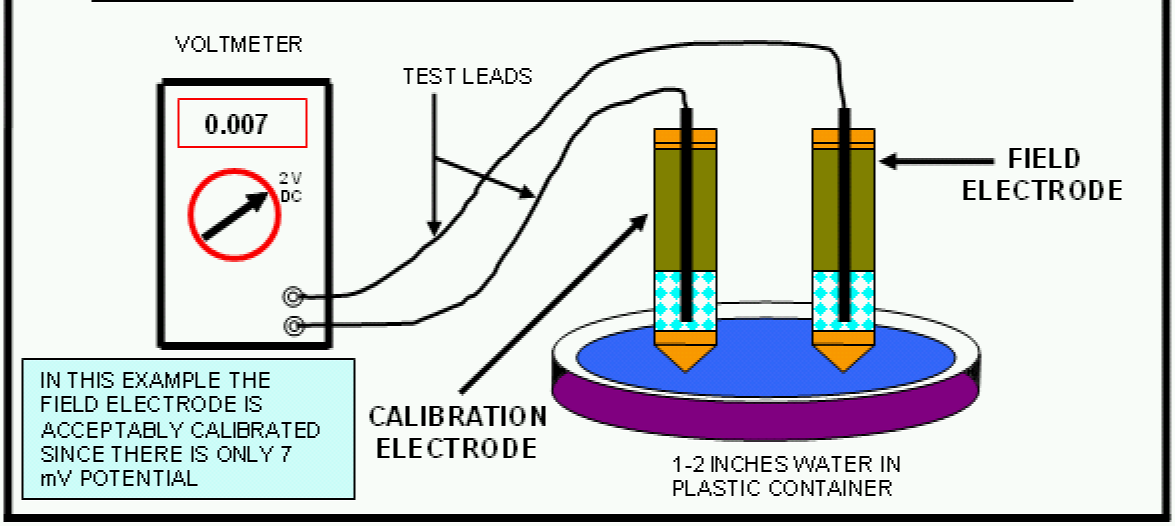
2. Place both the field electrode and the new (never used in the field) standard calibration electrode in a shallow nonmetallic container that has one to two inches of

tap water in the bottom of it. Do not use distilled water. The reference electrodes must be placed vertically in the container with the ceramic tip of each submerged in the water.

3. Observe the potential measurement displayed on the voltmeter. If more than 10 mV potential exists between the two reference electrodes, the field reference electrode should be properly cleaned and refilled with new solution until the potential difference is 10 mV or less. If you are unable to achieve a 10 mV or less potential difference after cleaning/reconditioning, the field electrode must be discarded and a new one obtained.

4. In order to lessen the chance of cross contaminating the calibration electrode, you should leave the calibration electrode in the water for the shortest time necessary to complete the test.

FIGURE 1 - ILLUSTRATION OF REFERENCE ELECTRODE CALIBRATION




### 6.1.3 Lead Wires/Test Probes/Miscellaneous

You should ensure that the insulation material of any lead wires is in good condition. Any clips or probes used to make contact with the structure to be tested must be clean and free of corrosion. A spool of suitable wire of sufficient length is necessary to conduct continuity and/or "remote earth" testing. It is usually necessary to have a probe (lead wire or magnet lead wire) that can be attached to the end of a tank gauging stick in order to contact the tank bottom since it is not uncommon for the test lead on sti-$P_3^{®}$ tanks to either be missing or discontinuous with the tank shell. The magnet will not damage the inside of the tank. A pair of locking pliers can sometimes be useful when attempting to get a solid connection by clamping.

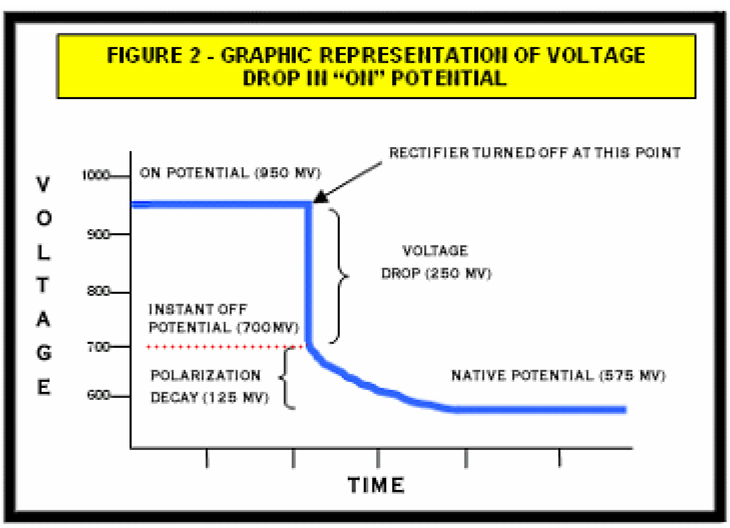
## 6.2 Test Criteria

There are three test criteria that can be utilized to indicate if adequate cathodic protection is being provided to the structure being evaluated:

**-850 mV On -** A structure-to-soil potential of –850 mV or more negative with the protective current applied. This is commonly referred to as "850 on" or the "on potential". This criterion is normally the only one available for factory installed galvanic anode systems (sti-$P_3$®) since the protective current usually cannot be interrupted to conduct the other tests. Voltage drops (see Section 6.3) other than those across the structure to electrolyte boundary must be taken into consideration whenever this criterion is applied. Voltage drops may have a significant impact on the potentials observed when testing impressed current systems with the protective current applied. Therefore, the "850 on" criterion is not applicable to impressed current systems.

**-850 mV (Instant) Off -** A structure-to-soil potential of –850 mV or more negative with the protective current temporarily interrupted. This is often referred to as "850 off", "polarized potential" or "instant off potential". This criterion is applicable to impressed current and field installed or retrofitted galvanic anode systems. Current interruption is not typical for factory installed galvanic systems (sti-$P_3$®). Both impressed current CP and retrofit or field installed galvanic systems must have their protective current interrupted so that IR drop free protection readings are obtained. Caution must be exercised when testing impressed current systems to ensure that no active sacrificial anodes are also installed near the protected structure. If there are active retrofitted or field installed galvanic anodes influencing the observed potential, the "850 off" criterion is not applicable unless the output current of these supplementary anodes is interrupted (e.g., use of an isolating test station).

In general, the instant off potential is the 2nd value that is observed on a digital voltmeter the instant the power is interrupted. The first number that appears immediately after power interruption must be disregarded. After the second number appears, a rapid decay (depolarization) of the structure will normally occur. In order to obtain instant off potentials, a current interrupter or a 2nd person is necessary. If a current interrupter is not available, have the second person throw the power switch at the rectifier off for 3 seconds and then back on for 15 seconds. Repeat and plot this procedure until you are sure an accurate instant off reading has been obtained (see Figure 2).




Note: The sampling rate of the test instrument; recording of readings; capacitance effects from pipelines; and, a choked rectifier, are some of the variables that can affect the analysis of the test results. All of these variables need to be taken into account by the tester as well as the plot of the data obtained. If the characteristic depolarization curve is not obtained, the tester/expert must find out why and retest.

This criterion is considered by most to be the best indicator that adequate cathodic protection has been provided. Therefore, consideration should be given to adjusting the rectifier output upward until the "850 instant off" criterion has been met if this is feasible.

**100 mV Polarization -** A polarization voltage shift of at least 100 mV is commonly referred to as "100 mV polarization" or "100 mV shift". This criterion is applicable to galvanic and impressed current systems where the protective current can be temporarily interrupted and where the steel

UST is not connected to a more noble metal such as copper or stainless steel or passivated steel in concrete. (Current interruption is not typical for factory installed galvanic systems.) Either the formation or the decay of at least 100 mV polarization may be used to evaluate adequate cathodic protection so long as they are not connected to these more noble metals.

The "true" polarized potential may take a considerable length of time to effectively form on a structure that has had cathodic protection newly applied. If the protective current is interrupted on a metallic structure that has been under cathodic protection, the polarization will begin to decay nearly instantaneously. For this reason, it is important that the protective current not be interrupted for any significant length of time. For testing purposes, not more than 24 hours should be allowed for the 100 mV depolarization to occur. On a well-coated structure complete depolarization will usually occur within 48 hours although it could take as long as 30 days. Complete depolarization of uncoated structures may take as long as 60-90 days.

The base reading from which to begin the measurement of the voltage shift is the instant off potential. For example, a structure exhibits an on voltage of –835 mV. The instant off voltage is -720 mV. In order to meet the 100 mV polarization criteria, the structure-to-soil potential must decay to at least –620 mV (final voltage).

The use of native potentials to demonstrate the formation of 100 mV polarization is generally only applicable when a system is initially energized or is re-energized after a complete depolarization has occurred. This is because it is necessary to leave the reference electrode undisturbed (or returned to the exact position) between the time the native and the final voltage are obtained.

## 6.3 Voltage (IR) Drops

The effect that voltage drops have must be considered whenever structure-to-soil potentials are obtained during the survey of a cathodic protection system. The concept of voltage drops is a difficult and controversial subject and a full discussion is beyond the scope of this document. However, stated in the simplest terms, a voltage drop may be thought of as any component of the total voltage measurement (potential) that causes an error.

The term IR drop is sometimes used and it is equivalent to voltage drop. IR drop is derived from Ohm's Law which states that V = I x R. In this equation, V stands for voltage; I represents current (amperage); and, R stands for resistance. Because the observed voltage is equal to the amperage (I) multiplied by the resistance (R) a voltage drop is commonly referred to as an IR drop. There are various sources of voltage drops and two of the more common are discussed below.

**Current Flow -** Whenever a current flows through a resistance, a voltage drop is necessarily created and will be included whenever a measurement of the electrical circuit is conducted. In order to effectively eliminate this voltage drop when testing impressed current systems, it is necessary to interrupt the protective current. The magnitude of the voltage drop obtained on impressed current systems is evaluated by conducting both on and instant off potential measurements.

To illustrate how this type of voltage drop contributes to the potential observed when measuring impressed current systems consider the following example. A potential of -950 mV is observed when the rectifier is on. A potential of -700 mV is observed when the power is interrupted. Taking the absolute values (negative is dropped), the voltage drop component of the on potential is 250 mV (950 - 700 = 250). Figure 2 is a graphical representation of this voltage drop and also shows how the instant off potential will degrade over time until the native potential is reached.

**Raised Earth -** All active anodes will have a voltage gradient present in the soil around them producing a "raised earth effect". An abnormally high (more negative) potential will be observed if the reference electrode is within the voltage gradient of an active anode. The magnitude or area of influence of the voltage gradient is dependent predominantly on the voltage output of the anode and the resistance of the soil. Unfortunately, there is no "rule of thumb" guidance that can be given to determine how far away a reading must be from an anode in order to be outside the voltage gradient. If the potential is suspected to be affected by raised earth, it should be compared to a remote reading.

Because of the raised earth effect, it is necessary to place the reference electrode as far away from any active anode (and still be directly over the structure) when obtaining local potentials on galvanic systems. Since the protective current can not typically be interrupted in galvanic systems, any effect this type of voltage drop may have is evaluated by placing the reference electrode in a "remote" location. Placement of the reference electrode remote ensures that the reference electrode is not within the voltage gradient of an active anode. Since it is desirable to eliminate any effect voltage drops may have, it may be helpful to obtain both local and remote structure-to-soil potentials on galvanic systems. Any effect raised earth may have when testing impressed current systems is eliminated by temporarily interrupting the power. Reference electrode placement locations must always be included on the site sketch of the CP evaluation form.

## 6.4 Stray Current

An unintended current that is affecting the structure being protected is referred to as a stray current. Stray currents can cause rapid corrosion failure of a buried metallic structure and are caused by an electric current flowing through the earth in an unintended path. If the metallic object being cathodically protected is buried near the path of the stray current, the current may "jump-on" the protected structure because it offers a lower resistance path for the current to flow. The affected structure will be cathodic where the stray current enters but will be highly anodic where the stray current returns to the earth. At the point where the current discharges or "jumps off", rapid corrosion of the structure intended to be protected will occur.

Although stray currents are relatively rare on UST systems, common sources include: a) Railroad crossing signals (powered by batteries); b) Traffic signals that have induction type sensors buried in the pavement; c) Portable or fixed emergency power generators; d) Electrical railway systems such as streetcars or subways in urban areas; e) DC (direct current) welding operations and other types of industrial machinery or processes that utilize DC power; and, f) foreign CP systems protecting neighboring pipelines such as natural gas pipelines and buried metallic structures.

If unsteady readings are observed on the protected structure and it has been determined that it is not because of a bad electrical connection, it would be suspect that stray current is affecting the protected structure. In some cases, a pattern can be seen in the potential whereby it alternates between two relatively stable readings. These patterns can sometimes help to identify the source of the stray current. If it is suspected that stray current may be affecting the UST system, a thorough investigation must be conducted as soon as possible by a qualified corrosion expert since stray current can cause a rapid failure of the affected structure.

**Cathodic Interference -** When the impressed current cathodic protection system operating on the structure being protected causes an unintended current on some other nearby structure, this type of stray current is referred to as "cathodic interference". Cathodic interference can cause a rapid failure of the water lines and other buried metallic structures at the facility where the cathodic protection system is operating. Observing what is believed to be an abnormally high (more negative) potential on a buried metallic structure, would suggest that the impressed current system operating on the UST system is causing cathodic interference.

Instances where cathodic interference may be present include: a) copper water lines that are not bonded to the impressed current system and have a polarized potential of greater than -200 mV; b) metallic flex connectors associated with fiberglass reinforced plastic piping that have abnormally high (more negative) potentials and are not bonded to the impressed current system; c) sti-P3® tanks are buried at a facility where there is an impressed current system operating and are not bonded to the negative circuit. When the sti-P3® tanks have zinc anodes and a potential more negative than -1100 mV (more negative than -1600 mV in the case of magnesium anodes) is observed, it is likely that cathodic interference is occurring. Because of the potential for stray current to impact sti-P3® tanks, it is normally necessary to bond them into the impressed current system.

A corrosion expert must be consulted whenever cathodic interference is suspected in order to properly investigate and make any repairs/modifications that may be necessary.

## 6.5 Dissimilar Metals/Bimetallic Couples

The effect of bimetallic couples must also be considered whenever structure-to-soil potentials are obtained during the survey of a cathodic protection system. The concept of dissimilar metals/bimetallic couples and the impact they can have on the proper evaluation of cathodic protection systems is a difficult and controversial subject and a full discussion is beyond the scope of this document. However, be aware that bimetallic couples may substantially influence the structure-to-soil potentials of a tank system to the extent that the 100 mV polarization criterion may not be applicable. Because the validity of the 100 mV criterion may be suspect, consideration should be given to only utilizing the -850 mV instant off criterion when evaluating impressed current systems. A brief discussion follows.

Caution must be exercised when evaluating steel UST systems that have metals of lower electrochemical potential electrically connected to them. Typically, bimetallic couples are only of concern on impressed current systems (or shorted galvanic anode systems with supplementary impressed current) since those steel components protected by galvanic systems are electrically isolated from other metallic structures. Copper, stainless steel and carbon steel rebar in concrete are all metals of lower potential that are commonly of concern. Sources of copper at UST facilities include the water service lines and the grounding system of the electrical power grid. Sources of stainless steel can include flex couplings and fittings. Sources of rebar in concrete can include deadman(s) used to anchor the tanks in the excavation as well as the rebar in the concrete pad over the tank. Steel in concrete passivates and behaves electrochemically as if it were copper. Since the AC power supply to the submersible turbine pump should be continuous with the electrical service grounding system, which may in turn be continuous with the water lines, a significant amount of copper may be coupled to the steel UST system. Connections of the other more-noble-than-steel metal components mentioned above are quite common.

The effect this type of bimetallic couple has on the impressed current system can sometimes be clearly seen on those UST systems that store fuel for emergency power generators. Commonly these generator tank systems are installed with copper supply and return lines. When these tanks were retrofitted with an impressed current system, the copper lines were bonded into the cathodic protection system. In these instances, it is not uncommon to observe native structure-to-soil potentials on the UST system of -450 mV or more positive.

If the native structure-to-soil potential of the UST system is substantially lower than what would normally be expected, it is likely that a significant amount of copper is electrically bonded to the UST system. Typically, the expected native potential of a steel UST system should not be more positive than -500 mV.

To illustrate the effect of the copper-steel couple, consider the following example: A steel UST system that is coupled to copper has a native structure-to-soil potential of -300 mV with the bimetallic couple intact. If the copper couple is broken the UST system native potential is -600 mV. With the copper couple intact, the polarized (off) potential of the UST system is -450 mV. Although the voltage shift satisfies the 100 mV polarization criterion (from -300 mV to -450 mV), it is likely that the steel UST system is not adequately protected. This is because the UST system is not polarized at least 100 mV beyond the native potential of the steel. Since the true native potential of the steel UST system in this example is -600 mV, it would need to reach a polarized (instant off) potential of -700 mV or more negative.

Because the unaffected native potential of steel UST systems is generally not known, the application of the 100 mV polarization criterion would be inappropriate when there is a significant amount of copper (or other more noble metal) electrically continuous. For this reason, it is almost always mandatory to demonstrate that the UST system satisfies the "850 instant off" criterion when evaluating a cathodic protection system that is or may be electrically connected to more noble metals such as copper or stainless steel or steel in concrete. If it does not pass, then the short must be cleared and/or a CP expert must evaluate the situation to resolve it.

## 6.6 Other Test Considerations

Various other factors can affect the accuracy of structure-to-soil potentials. Listed below are some of the more common factors:

**Contact Resistance –** In order to obtain an accurate structure-to-soil potential, a good (low resistivity) contact between the reference electrode and the soil must be made. Sometimes, the soil at the surface is too dry and water needs to be added in order to lower the resistance between the reference electrode and the soil. In addition, if the porous ceramic tip of the reference electrode becomes clogged or contaminated it should be replaced since this in itself can cause a high contact resistance.

**Contaminated Soil –** Ensure that the soil the reference electrode is placed in is free of contamination. Hydrocarbon contamination can cause a high resistance between the reference electrode and the soil.

**Current Requirement Testing –** When a current requirement test is conducted on galvanically protected tanks (refer to STI R972-01 for a description of this test), the affected structure can exhibit an elevated (more negative) structure-to-soil potential during the test and for a period of time after the test is completed. This is due to a temporary polarization of the tested structure which will dissipate over a period of time ranging from a few minutes to perhaps a few days depending on several different factors. Therefore, time sufficient for the temporary polarization of the affected structure to "drain-off" after a current requirement test is conducted must be allowed before an accurate structure-to-soil potential can be obtained. In addition, any potential measured with the battery connected should be disregarded as this measurement contains a large voltage drop. Only instant off voltages are meaningful when the battery is connected.

**Drought Conditions –** On occasion, it has been observed that structure-to-soil potentials can be improved by running water into the backfill material of the tank bed when extended periods of no rain have occurred. This is commonly done by placing a water hose in one of the tank bed observation wells or ground water (not vapor) monitoring wells (or other access points) and allowing the water to run for a period of a few hours. This practice serves to lower the resistance of the backfill material. However, keep in mind that the resistivity of the soil is not appreciably lowered if the moisture content is 20% or higher. Use a voltmeter with an input impedance greater than 10M ohm for accurate data collection. Even in drought conditions a CP test must be passed.

**Electrical Shorts –** When a substandard reading is observed on a galvanically protected system, it is common to find that some other metallic object is electrically connected to the protected structure. For instance, on sti-$P_3$® tanks, the nylon bushings installed in the tank bungs were sometimes removed when the various risers and other tank system components were installed or an electrical conduit was buried in contact with the tank shell.

**Electromagnetic Interference –** Overhead high voltage power lines, railroad crossing signals, airport radar systems and radio frequency transmitters (CB radios, cellular phones, etc.) can all cause an interference that will result in an inaccurate voltage reading.

**Galvanized Metals -** Buried metals that have a high electrochemical potential can also influence the voltage observed if the reference electrode is placed in close proximity to such metals. For instance, the steel of some of the manways that are installed to provide access to the tank appurtenances may be galvanized. If the reference electrode is placed in the soil of such a manway, an artificially high (more negative) potential may be observed. This is actually a raised earth effect although the galvanized metal is not acting to cathodically protect the buried structure of concern.

**Parallel Circuits –** Care should be taken to ensure that the person conducting the structure-to-soil testing does not allow their person to come into contact with the electrical components of the testing equipment. If the person touches the electrical connections, an error may be introduced due to the creation of a parallel circuit.

**Pea Gravel –** Because pea gravel or crushed stone typically has a very high electrical resistivity, it is necessary to ensure that it is saturated with water when attempting to measure structure-to-soil potentials with the reference electrode placed in the pea gravel. Use a voltmeter with an input impedance greater than 10M ohm for accurate data collection. Evaluate any effect high contact resistance may have by changing the input resistance of the voltmeter as described in Section 6.1.1. As an alternative way to evaluate the effect contact resistance may have, place the reference electrode remotely. If the remote reading is substantially more negative than the local, high resistance is indicated. Placement of a saturated sponge on the surface of the pea gravel may help overcome high contact resistance.

**Photovoltaic Effect –** It is known that sunlight striking the viewing window of a reference electrode can have an effect (as much as 50 mV) on the voltages observed when conducting testing. You should ensure that the viewing window of the reference electrode is kept out of direct sunlight. As an alternative, the viewing window can be covered with black electrical tape in order to prevent any sunlight from reaching the copper-copper sulfate solution.

**Poor Connection –** If the observed structure-to-soil potentials are unsteady and the voltmeter will not stabilize, suspect a bad connection somewhere. Ensure that all electrical connections are clean, tight, and good contact is made between the test lead and the structure.

**Shielding –** Sometimes, a buried metallic structure that is between the reference electrode and the structure being tested will cause the reference electrode to be unable to “see” the structure being tested. Shielding is commonly cited when low potentials are observed with the reference electrode placed locally over sti-$P_3^{®}$ tanks due to the various tank risers, pump heads, piping, electrical conduits and metallic manways that are typically located over the tank.

**Temperature –** The temperature of the reference electrode affects the voltages that are observed when conducting cathodic protection testing. You may need to make a correction to the observed potential in some extreme and/or marginal cases. The “standard” temperature is considered to be $77^{o}$ F. For every degree less than 77 add 0.5 mV to the observed voltage. For every degree above 77 subtract 0.5 mV from the observed voltage. To illustrate this, consider the following (in order to simplify the calculation, the negative sign is dropped from the structure-to-soil potential): A voltage of 845 mV is observed when the temperature is $57^{o}$ F. In this case the corrected voltage would then be 855 mV ($20^{o}$ X 0. 5 mV = 10 mV. Therefore: 845 mV + 10 mV = 855 mV). It is advisable to control the temperature of the electrode prior to each use.

## 6.7 Continuity Testing

When conducting an evaluation of a cathodic protection system, it is normally necessary to establish that the cathodically protected components of a UST system are either electrically isolated or electrically continuous depending on the type of cathodic protection system. Ohmmeters (continuity testers or resistivity meters) such as those utilized to test automotive wiring circuits are not acceptable for use on buried metallic structures and should never be used for testing continuity of UST system components unless overseen by a corrosion expert. The “fixed cell-moving ground” method and the “point-to-point” method are the two commonly utilized ways to test continuity and are discussed in more detail below.

**Point-to-Point Method** - An easy and usually more accurate way to test continuity is the “point-to-point” method. With this method, a reference electrode is not utilized. The two structures that are to be tested are simply touched with each lead of the voltmeter and the voltage difference (if any) is observed. For example, if trying to establish that electrical isolation exists between a tank and the fill riser associated with that tank, simply touch the fill riser with one of the voltmeter leads and the tank shell with the other voltmeter lead and observe the voltage difference. (Structure to shunt testing is not recommended.)

When conducting point-to-point testing, any current that is flowing through the UST components can cause an inaccurate test result. Impressed current systems must be turned off.

When determining whether electrical continuity or isolation is provided, the following guidelines are generally accepted for point-to-point surveys:

- If the voltage difference observed between the two structures is 1 mV or less, the two structures are considered to be electrically continuous with each other.

- If the voltage difference observed between the two structures is 10 mV or greater, the two structures are considered to be electrically isolated from each other.

- If the voltage difference observed between the two structures is greater than 1 mV but less than 10 mV, the result is inconclusive and further testing beyond the scope of this document is necessary.

**Fixed Cell - Moving Ground Method -** Another commonly accepted method of conducting a continuity survey is referred to as fixed cell – moving ground. In this method, the reference electrode is placed at a location remote from any of the cathodically protected structures. Potentials of all the metallic structures present at the site are then measured without moving the reference electrode (refer to Appendix E for a more complete description). Because the conditions found at the reference electrode/electrolyte interface can change over a short period of time (causing the observed potential to change), it is important to conduct this type of testing as quickly as possible.

When determining whether electrical continuity or isolation is provided, the following guidelines are generally accepted for fixed cell – moving ground surveys:

- If two or more structures exhibit potentials that vary by 1 mV or less, the structures are considered to be electrically continuous.
  (See NACE Standard TM-01-01-2001, paragraphs 11.3.3 and 11.4.3.)

- If two or more structures exhibit potentials that vary by 10 mV or greater, the structures are considered to be electrically isolated.

- If two or more structures exhibit potentials that vary by more than 1 mV but less than 10 mV, the result is inconclusive and further testing (point-to-point) is necessary.
  (See NACE Standard TM-01-01-2001, paragraphs 11.3.3 and 11.4.3.)

### 6.7.1 Continuity Testing of Galvanic Systems

In order for sacrificial anodes to function efficiently, the protected component must be electrically isolated from any other metallic structures that may be connected to or in contact with the protected structure. This is generally accomplished through the use of dielectric bushings and unions and by making sure that no additional metallic structures come into contact with the protected structure.

On those systems where adequate cathodic protection has not been achieved, it is common to find that some unintended metallic structure is electrically continuous with the protected structure. Frequently, an electrical conduit is in contact with a sti-$P_3^{®}$ tank or the tank bung nylon bushings are missing or damaged. If metallic tank hold down straps were improperly installed, they will wear through the coating (e.g., epoxy/aliphatic urethane) on the tank over time and cause premature anode failure. With metallic piping, the shear valve anchoring bracket usually provides an electrical bond with the dispenser cabinet and all of the other metal connected to it. When this is the case, the anodes are trying to protect much more metal than intended and the life of the anodes is shortened.

### 6.7.2 Continuity Testing of Impressed Current Systems

In an impressed current cathodic protection system all components of the UST system must be electrically continuous for them to be protected. Various bonds may be required in order to ensure that continuity has been provided. Failure to establish continuity in an impressed current system can result in accelerated corrosion of the electrically isolated components.

Carefully check all bonds when evaluating an impressed current system as these are of critical importance. Commonly, tanks are bonded into the negative circuit by attachment to the tank vent lines above ground. Because of this, it is easy for the integrity of the bonds to be compromised. It is equally important to ensure that the positive lead wire(s) have continuity. Any break in the insulation or dielectric coating of the positive circuit will allow current to discharge from the break and cause rapid corrosion failure of the wire. This is why it is absolutely critical that all buried positive circuit splices are properly coated and insulated.

## 6.8 Reference Electrode Placement

### 6.8.1 General

Where the reference electrode is placed when taking structure-to-soil potential measurements is of critical importance. It is also essential that the exact location of the reference electrode placement be documented so that anyone could come back at a later date and reasonably duplicate the test. Reference electrode placement must be indicated by both written description and visually shown on a drawing of the tank system. Appendix K of this guidance document provides for both written and visual description of reference electrode placement.

### 6.8.2 Local Placement

Placement of the reference electrode is considered local when it is contacting the soil directly over the structure that is being tested. As NACE Standard RP0285-2002 Section 5.1.5 states, reference electrodes/readings shall not be placed/taken through concrete or asphalt. As discussed in Section 6.3, consideration of any effect active anodes have (raised earth) must be considered when selecting the appropriate location for local placement.

In addition, shielding of the reference electrode by other buried metallic components may also need to be considered. For instance, it is necessary to ensure that the tip of the reference electrode is below the metallic skirting found on most manways. If the tip of the reference electrode is not below the metal skirt, it may be shielded from “seeing” the cathodic protection current.

Ideally, the tip of the reference electrode should be as close to the structure-to-soil interface as is practical in order to minimize the voltage drop present in the soil.

(Concrete has been shown to shift measured potentials through the concrete by as much as 300mV in either direction--thus valid readings cannot be taken over concrete. Some CP experts have been able to use the 100mV shift test through concrete since the rebar and concrete matrix effects are the same for both voltage readings, but for this guidance this method is not recommended. Potentials through asphalt are generally always lower than the true reading--this makes readings through asphalt problematic—thus for this guidance the NACE Standard RP0285-2002 applies.).

### 6.8.3 Remote Placement

**This approach is ONLY valid for electrically isolated USTs which are protected with galvanic anodes directly attached to the UST (e.g., sti-$P_3$® but not retrofit galvanic anode systems).** The remote potential represents the average potential of the entire surface of the protected structure and may be the most accurate assessment of CP protection on an UST system. The purpose of remote placement is to eliminate any effect that raised earth may be contributing to the measurement of the structure-to-soil potential and to overcome any effects shielding may have.

Placement of the reference electrode is considered remote to the electrically isolated UST when it is placed in the soil a certain distance away from the UST that is being tested. There are several different factors that determine the distance necessary in order to reach remote earth and a full discussion is beyond the scope of this document. However, a remote condition can normally be achieved when the reference electrode is placed between 25 and 100 feet away from any protected structure.

Depending on the conditions specific to the particular location where the cathodically protected structure is, the minimum distance to remote earth may be considerably more than 25 feet. Therefore, it is important to establish that the reference electrode is truly remote when obtaining a structure-to-soil potential. In order to ensure that remote earth has been achieved, place the reference electrode at least 25 feet away from the protected structure and observe the potential. Move the reference electrode out away from the protected structure another 10 feet or so and observe the potential. If there is no significant difference in the two potentials, it can be assumed that remote earth has been achieved. If there is a significant difference, continue moving the reference electrode out away from the protected structure until no significant difference is observed.

When selecting a location to place the reference electrode to establish remote earth, it is essential that there are no other cathodically protected structures (e.g. natural gas lines) in proximity to the reference electrode. Foreign cathodically protected structures can cause an abnormally high (more negative) potential that is not indicative of the remote potential of the structure being measured. It is also important that there are no other buried metallic structures in the vicinity of the reference electrode. Any metallic structure that is buried near the reference electrode could possibly affect the structure-to-soil potential that is observed on the protected structure.

In addition to the above considerations, attempt to select the remote placement such that the reference electrode can “see” the structure being tested. This means that there should not be any buried metallic structure between the remote reference electrode placement and the protected structure. If it is suspected that shielding may be affecting the observed potential, place the reference electrode away from the protected structure in a different direction.

### 6.8.4 Number of Test Points

**All galvanic cathodic protection systems shall be tested with at least three placements of the reference electrode with one of those placements taken locally, one taken remotely, and the third location at the discretion of the tester/expert.** This approach is ONLY valid for electrically isolated USTs which are protected with galvanic anodes directly attached to the UST (e.g., sti-$P_3$® but not retrofit galvanic anode systems (see 6.8.5)).

**All impressed current systems must have at least three placements taken locally.** In order to pass the structure-to-soil survey, all test potentials must indicate that adequate cathodic protection has been provided. If none of the test potentials satisfies one of the cathodic protection criteria, the structure fails the overall test. If any one or more of the test potentials indicates adequate cathodic protection but the other(s) do not, the result of the test is inconclusive. If the test result is inconclusive, repairs must be made or a corrosion expert must evaluate the data and/or conduct further testing to declare the UST system either passes or fails. Always avoid obtaining readings near the anodes.

### 6.8.5 Galvanic Placement

All galvanic cathodic protection systems shall be tested with at least three placements of the reference electrode with one of those placements taken locally, one taken remotely, and the third location at the discretion of the tester/expert. This approach is ONLY valid for electrically isolated USTs which are protected with galvanic anodes directly attached to the UST (e.g., sti-$P_3$® but not retrofit galvanic anode systems). A CP expert should be consulted in testing galvanic retrofit designs due to their complexities.

**Although it may be common practice for some testers/experts to take three placements over the tank/piping, this does not meet this guidance requirement.** The remote potential may provide additional information by which to evaluate the cathodic protection system. However, the structure may not be passed based on the remote potential itself. In all circumstances, the potential obtained with the reference electrode placed locally must indicate that adequate cathodic protection has been provided. (Remember that petroleum contaminated soils can alter reference cell readings so space-out the test locations in clean soils over the tank to avoid problems.)

### 6.8.6 Impressed Current Placement

Impressed current cathodic protection systems shall be tested with the reference electrode placed locally at a minimum of three locations. In order to pass the survey, all potentials obtained must satisfy either the 850 instant off or the 100 mV polarization (formation or decay) criteria. The tester should obtain structure to soil potentials from as many soil access points along the structure as is practical. If any of the potentials indicate that adequate cathodic protection has not been provided, the structure should be failed.

Although not required by this guidance document, it may be useful to place the reference electrode remotely when testing an impressed current system. The remote potential may provide additional information by which to evaluate the cathodic protection system. However, the structure may not be passed based on the remote potential itself. In all circumstances, the potential obtained with the reference electrode placed locally must indicate that adequate cathodic protection has been provided. (Remember that petroleum contaminated soils can alter reference cell readings so space-out the test locations in clean soils especially over the tank to avoid problems.)

Additionally, special circumstances may require that a remote potential be obtained when testing impressed current systems. For instance, if there are active sacrificial anodes buried in close proximity to the structure being tested, the local potential may be influenced by raised earth. The voltage drop caused by the sacrificial anodes would preclude the accurate measurement of the local structure-to-soil potential. If it is known that sacrificial anodes are impacting the potentials obtained locally, remote potentials must be obtained.

The remote potential obtained under these special circumstances must meet either the "850 off" or the 100 mV polarization criteria in order for the tested structure to pass the survey. An explanation must be given in the “comments” section of "XIV CATHODIC PROTECTION SYSTEM SURVEY" of the VADEQ cathodic protection system evaluation form as to why the remote potential must be considered. The remote potentials should be indicated on the form by designating remote (R1, R2, etc.) in the location code column of Section XIV.

## 6.9 Soil Access

All structure-to-soil potentials that are intended to satisfy one of the three acceptable test criteria found in Section 6.2 of this guideline must be obtained with the reference electrode placed in contact with the soil. Therefore, the person conducting the evaluation must either confirm that soil access is available or make prior arrangements with the owner of the UST system to secure soil access.

NACE Standard (RP0285-2002) – "Standard Recommended Practice - Corrosion Control of Underground Storage Tank Systems by Cathodic Protection"  NACE standards are revised periodically. Users are cautioned to obtain the latest edition; information in an outdated version of the standard may not be accurate.

Section 5: Criteria for Cathodic Protection

5.1 General

5.1.5 Voltage measurements on UST systems are to be made with the reference electrode located on the electrolyte surface as close as possible to the UST system. Consideration must be given to voltage (IR) drops other than those across the structure/electrolyte boundary, the presence of dissimilar metals, and the influence of other structures that may interfere with valid interpretation of voltage measurements. All readings shall be taken with reference electrodes that are in contact with the electrolyte. **Readings shall not be taken through concrete or asphalt.** Soil contact may be established through at-grade openings, by drilling a small hole in the concrete or asphalt, or by contacting a seam of soil between concrete and asphalt.

Note: In accord with the NACE Standard, this guidance document does not allow the placement of the reference electrode on concrete, asphalt, or any other paving material to achieve satisfactory structure-to-soil potentials. Likewise, the practice of placing the reference electrode on a crack or expansion joint of concrete or asphalt paving is not recognized as an acceptable method of obtaining satisfactory structure-to-soil potentials. Also, placement of the reference electrode in an observation (monitoring) well to obtain a passing reading may not provide valid data.

While it may be useful to obtain data by placing the reference electrode on a crack in the pavement or in an observation well, the structure-to-soil potentials obtained by such placement are not in themselves acceptable to demonstrate adequate cathodic protection. Therefore, the person conducting the evaluation must either confirm that soil access is available or make prior arrangements with the owner of the UST system to secure soil access in areas where pavement cover exists over the entire tank.

Access may be provided by drilling holes through the concrete or asphalt pavement or the installation of proper cathodic protection test stations. A practical way to provide soil access is to drill a ½ inch diameter hole in the pavement so that a "pencil" type reference electrode (3/8 inch diameter) can be inserted through the pavement and into the soil. Upon completion of the survey, the hole should be filled with a fuel resistant caulking material so that easy access can be provided at a later date. As an alternative, a two inch diameter hole could be drilled to allow use of a standard reference electrode. A short length of PVC pipe could be epoxied in the hole and plugged with a threaded cap.

Various cathodic protection test stations/manways are available for installation. PP2® and PP4® test stations should not always be relied solely upon since it is hard to tell where and to what the test lead wires are connected. Whenever, a new tank system is installed or the pavement is reworked around an existing system, provisions for access to the soil must be made so that adequate cathodic protection testing may be accomplished.

## 6.10 Cathodic Protection Test Locations

Because there are many different possible tank and cathodic protection system configurations that may occur, it is not feasible to attempt to illustrate every situation that may exist. The examples given in the following sections are offered as representative of some typical scenarios to illustrate the general principles. It may sometimes be necessary to utilize judgment to apply the intent of this guidance document when circumstances arise that are not specifically addressed in this guidance document.

- All galvanic cathodic protection systems shall be tested with at least three placements of the reference electrode with one of those placements taken locally, one taken remotely, and the third location at the discretion of the tester/expert.

- Impressed current systems shall be tested with the reference electrode placed locally over the structure in a minimum of three locations.

### 6.10.1 Galvanically Protected (sti-P$_3$®) Tanks

All sti-P$_3$® tank cathodic protection systems shall be tested with at least three placements of the reference electrode with one of those placements taken locally, one taken remotely, and the third location at the discretion of the tester/expert. Examples of appropriate locations to place the reference electrode locally would be near the one-third, midpoint, or two-thirds parts of the tank (see Figure 3). However, if access to the soil is not available at the middle of the tank, the reference electrode may be placed at any point along the centerline of the tank but not directly over the anodes at each end of the tank.

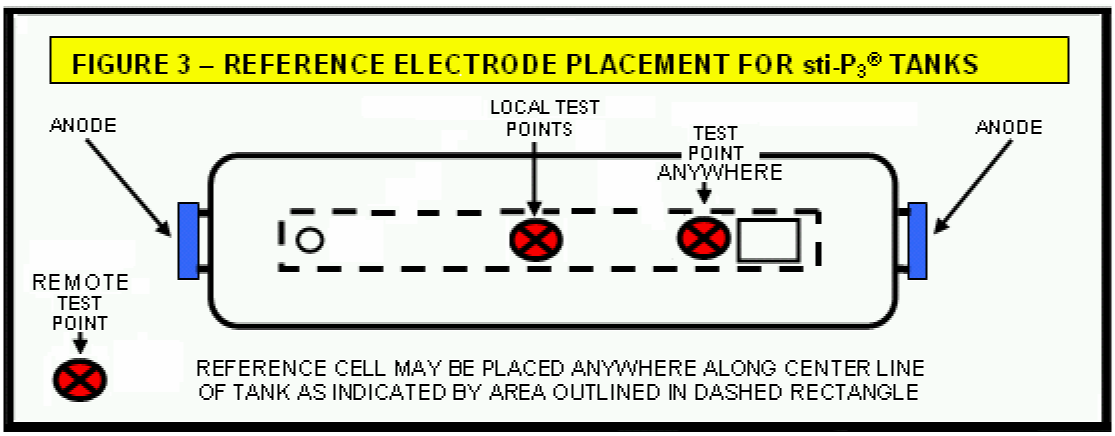
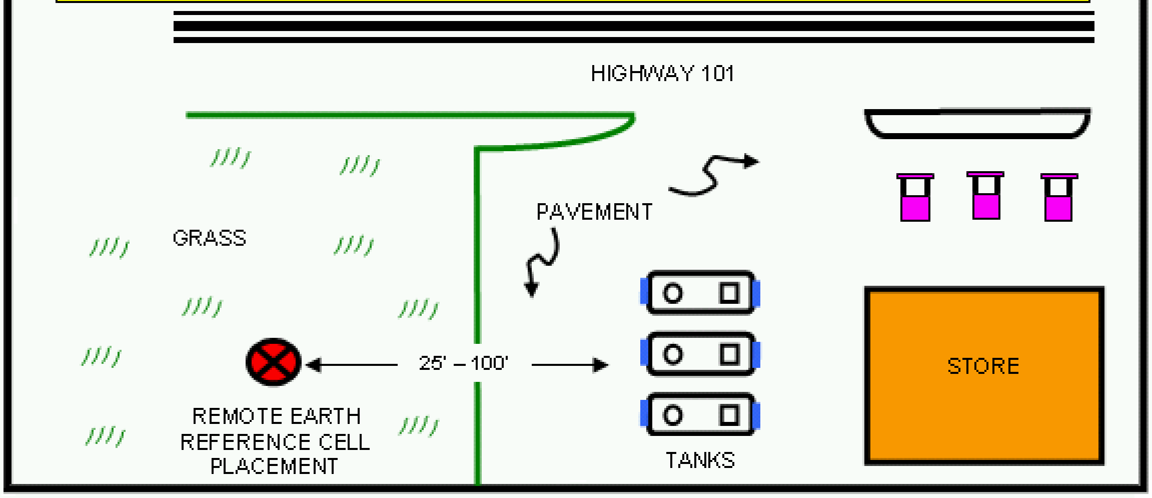


FIGURE 3 – REFERENCE ELECTRODE PLACEMENT FOR sti-P$_3$® TANKS

Caution should be exercised to ensure that there are no sacrificial anodes installed in the soil around the submersible pump manway to protect any steel piping that may be associated with the tank. If anodes are installed at the pump manway, the reference electrode must be placed in the soil near the opposite end of the tank. In addition to the local potential(s) described above, remote potential(s) may also be obtained. Remote generally means the reference electrode is placed in the soil at least 25 feet away and not more than 100 feet away from the tank you are measuring (See Figure 4). Refer to Section 6.8.3 for more complete discussion of remote reference electrode placement. Care must be taken that any remote location is not in proximity to any other cathodically protected structure (e.g. natural gas lines) or directly over any other kind of buried metallic structure. The remote placement should be such that the reference electrode is aligned with the longitudinal axis of the tanks and can "see" the anodes. This orientation is desirable in order to prevent shielding.

FIGURE 4 – "REMOTE EARTH" REFERENCE ELECTRODE PLACEMENT



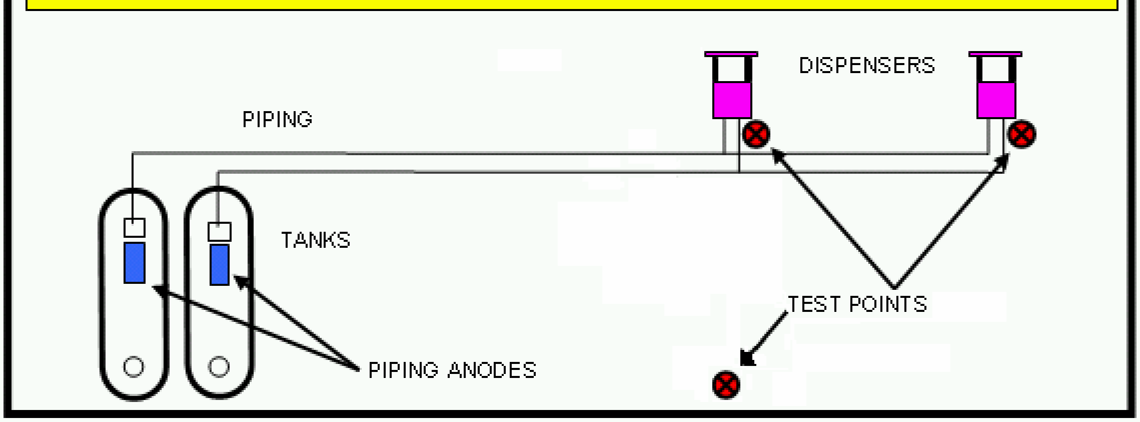

### 6.10.2 Galvanically Protected Metallic Piping

If the location(s) of the anodes are not known, at least one potential (CP test reading) within every 100 feet or less and at least one remote potential overall shall be taken for each UST system(s) with galvanically protected metallic product piping. (See figure 12 "100 foot rule")

When metallic piping is protected by sacrificial anodes, several different possibilities exist as to where would be the appropriate location to place the reference electrode to obtain potentials. Knowing where the anodes that are protecting the piping are installed is of critical importance. When obtaining local potentials, the reference electrode must be placed in the soil directly over the pipe to be evaluated at a point that is the most distant from any anode that may be along the pipe.

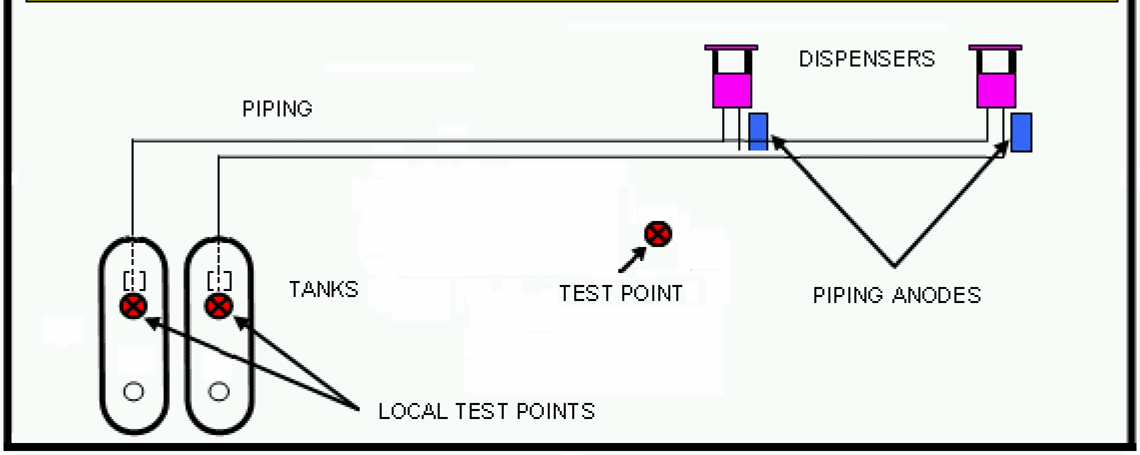
Because it is a common practice to bury piping anodes at the submersible pump manway of a tank, the appropriate location to place the reference electrode to obtain potentials is often at the dispensers (See Figure 5).

FIGURE 5 – REFERENCE ELECTRODE PLACEMENT FOR GALVANICALLY PROTECTED PIPING WHEN PIPING ANODES ARE AT TANKS



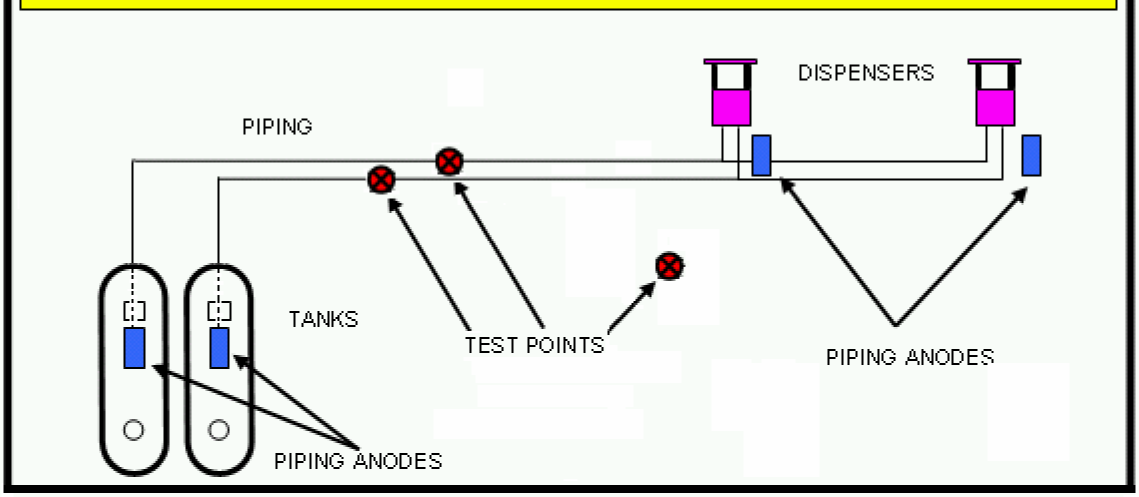
When the piping anodes are installed at the dispensers, the appropriate local reference electrode placement would be at the piping nearest the tanks (usually the submersible turbine pump manway) as shown in Figure 6.

**FIGURE 6 – REFERENCE ELECTRODE PLACEMENT FOR GALVANICALLY PROTECTED PIPING WHEN PIPING ANODES ARE AT DISPENSERS**

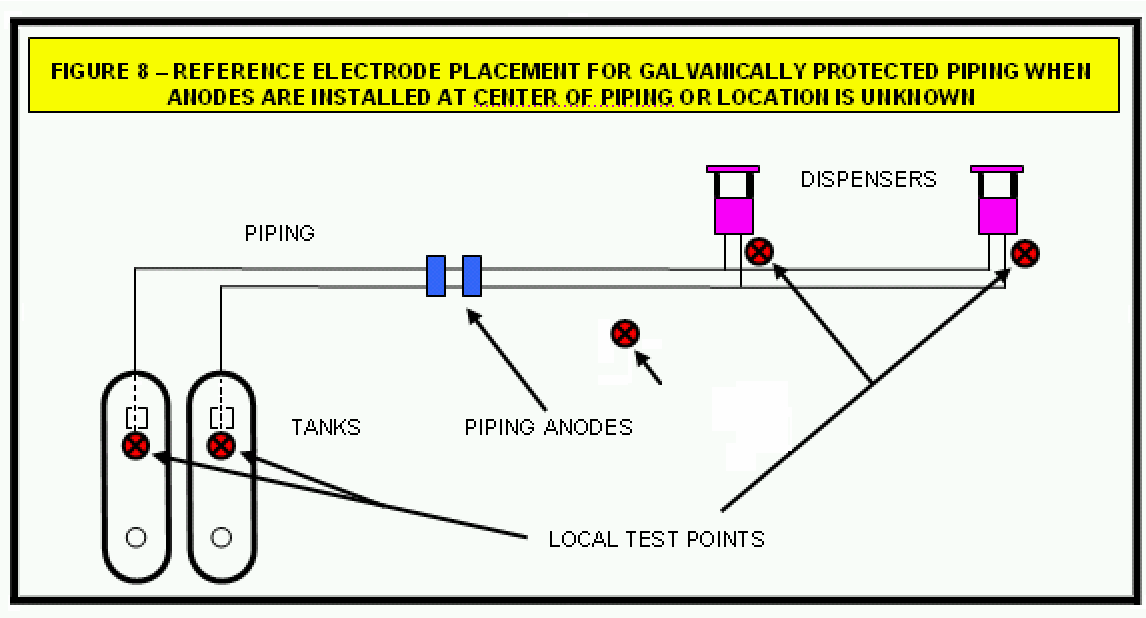



When the piping anodes are located at both the tanks and the dispensers, the reference electrode must be placed at the approximate center of the piping run to obtain potentials (See Figure 7).

**FIGURE 7 – REFERENCE ELECTRODE PLACEMENT FOR GALVANICALLY PROTECTED PIPING WHEN PIPING ANODES ARE AT BOTH ENDS OF THE PIPING**

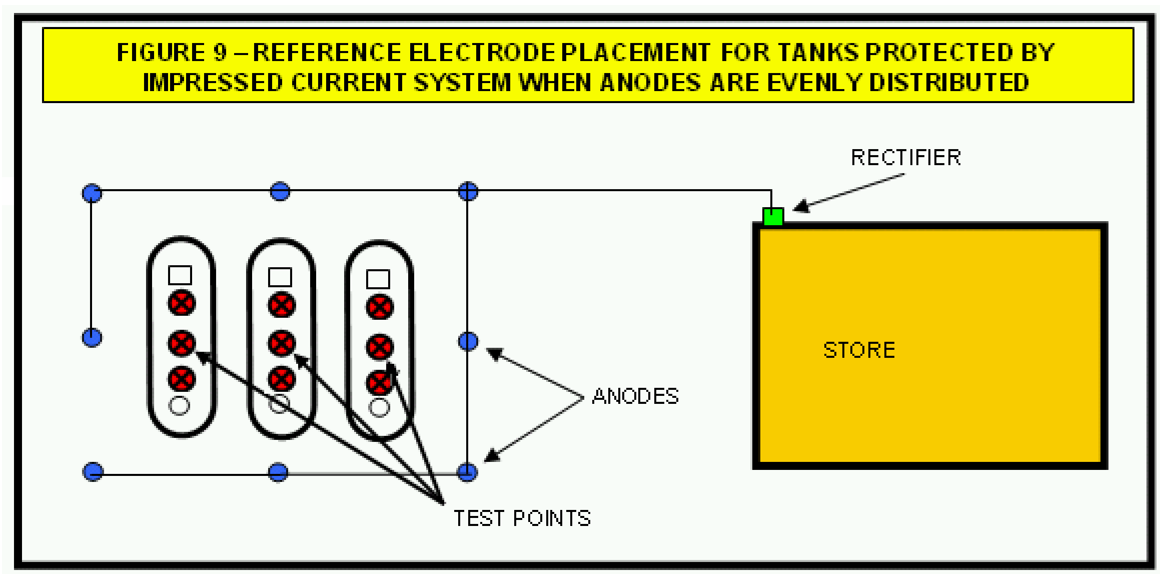



When the anodes are installed at the center of the piping, the reference electrode must be placed at three points--to include both the tank and the dispenser end of the piping to obtain local potentials and one remote (See Figure 8).



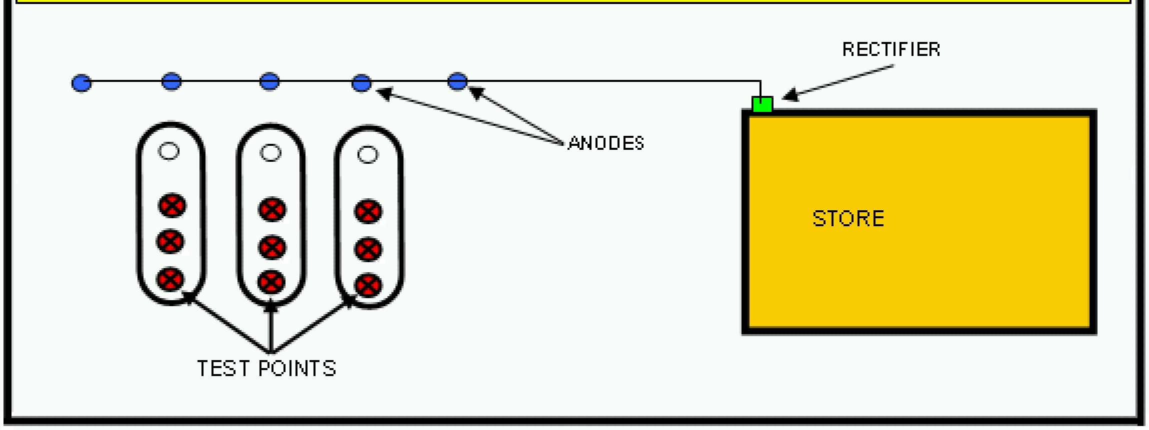

### 6.10.3 Tanks protected by impressed Current

With impressed current cathodic protection systems, at least three tank potentials (CP test readings) shall be measured locally per tank with the impressed current systems(s) interrupted. Where the location of the anodes is known and they are relatively evenly distributed about the tank bed, the appropriate location to place the reference electrode would be in the soil at the middle of the tank (See Figure 9). However, if access to the soil is not available at the middle of the tank, the reference electrode may be placed in the soil at any point along the centerline of the tank similar to that described in Section 6.10.1.




As with the evaluation of any cathodic protection system, the location of the anodes in relation to reference electrode placement can be of critical importance. When selecting the appropriate local placement, it is necessary to place the reference electrode at the point over the structure that is the most distant from any active anode due to the effects of attenuation. Attenuation of the cathodic protection current may occur whereby effective protection is not achieved at some point along a UST system. For instance, if all of the active anodes are along one side of a tank bed, current distribution and attenuation may prevent sufficient protective current from reaching the side of the tanks away from the anodes. The preferred placement of the reference electrode would be along the centerline of the tanks at the end opposite to that where the anodes are installed (See Figure 10).

FIGURE 10 – REFERENCE ELECTRODE PLACEMENT FOR TANKS PROTECTED BY IMPRESSED CURRENT SYSTEM WHEN ANODES ARE UNEVENLY DISTRIBUTED

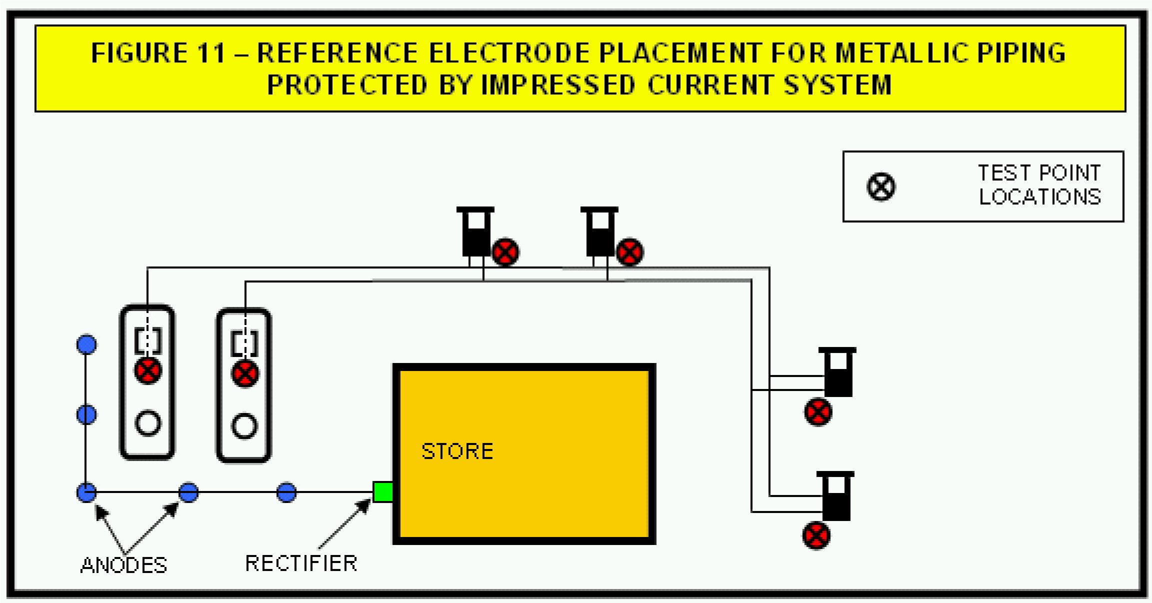



If it is not known where the anodes are installed, at least three measurements are recommended along the centerline of the tank. Testing should be conducted at as many locations along the centerline of the tank as are available. Ensure that soil access is available at each end of the tank and in the middle, and record all three structure-to-soil potentials. If any one of the measured potentials does not meet one of the acceptable criteria, the structure should be failed.

In addition, experienced testers and experts may be competent to measure the individual circuits in an impressed current system and a determination can be made as to which anodes are functional and how the current is distributed throughout the groundbed. How the current is distributed should be considered when choosing reference electrode placement when conducting a structure-to-soil potential survey. If for instance it is known that the majority of the rectifier output current is directed to only those anodes along one end of a tank bed, the reference electrode should be placed at the opposite end of the tank bed.

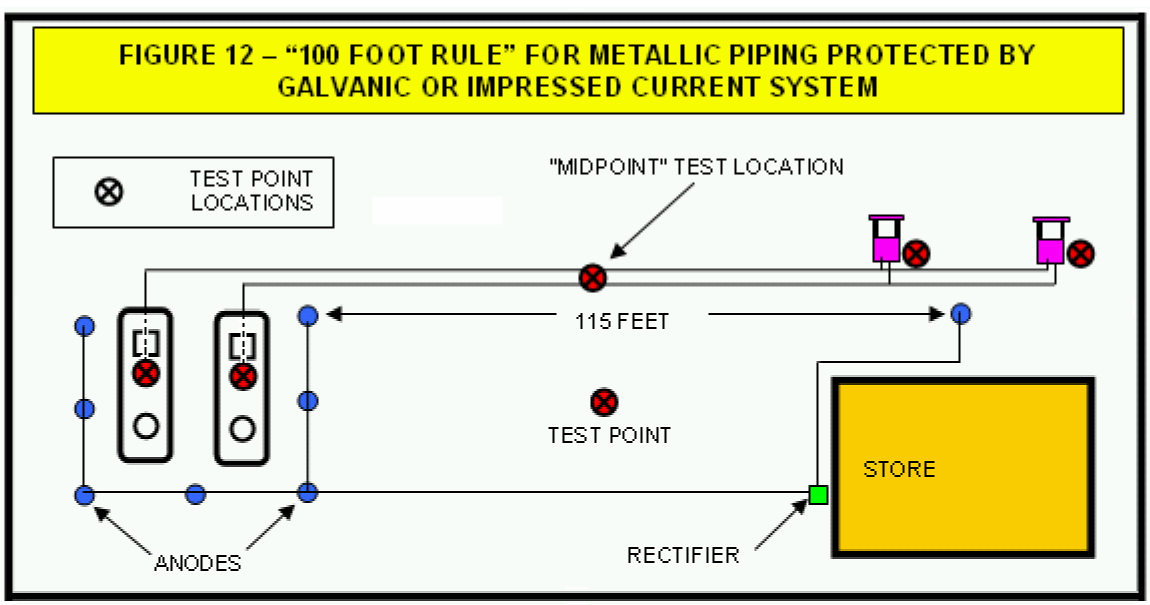
### 6.10.4 Piping Protected by Impressed Current

Due to the high degree of variability that exists in anode placement and piping configurations, structure-to-soil potentials must be obtained by placing the reference electrode at both the tank and dispenser end of any piping that is protected by impressed current (See Figure 11). With impressed current cathodic protection systems, the local pipe potentials <u>(CP test readings)</u> shall be measured with the ellectrode properly placed locally over the pipe and the impressed current systems(s) interrupted. Just as with any other type of cathodic protection system, <u>knowing where the anodes that are protecting the piping are installed is of critical importance.</u>




### 6.10.5 "100 Foot Rule" for Piping

In an attempt to somewhat simplify and standardize minimal CP pipe testing, for both galvanic and impressed current systems, if more than 100 feet of piping exists between any two anodes, the reference electrode shall also be placed at 100 foot increments or less (see Figure 12). If the distance is greater than 100 feet but less than 200 feet the reference electrode should be placed in the middle e.g., 150 feet of piping the placement will be at 75 feet. In addition, if it is not known where the piping anodes are located, there can be no more than 100 feet of piping between any two test points--in some cases preferably only 50 feet. In addition, at least one remote potential overall shall be taken for each galvanic UST piping system.



# SECTION 7 - DOCUMENTATION OF EVALUATION

## 7.1 Documentation

As with any kind of testing or work that is being performed at a UST facility, it is critical that proper documentation is made of all activities and test procedures. Without proper documentation, the evaluation of a cathodic protection system through the application of a structure-to-soil potential survey is of little value.

Although it has been previously stated, the exact location where the reference electrode was placed in order to obtain a passing structure-to-soil potential is of critical importance and cannot be overemphasized. For this reason, an exact description of where the reference electrode was placed for each structure-to-soil potential obtained during the survey is an absolute necessity. **Failure to properly document reference electrode placement will result in the survey being deemed invalid.**

Additionally, in order to effectively evaluate the survey of a cathodic protection system it is essential to be able to clearly understand how the survey was conducted. Likewise, when a re-survey of an existing system is being conducted it is important that the tester understands how the previous survey was conducted. Various methods of documentation may be necessary in order to clearly convey the procedures and survey results. In the sections that follow, some of the more critical aspects of documentation are discussed in more detail.

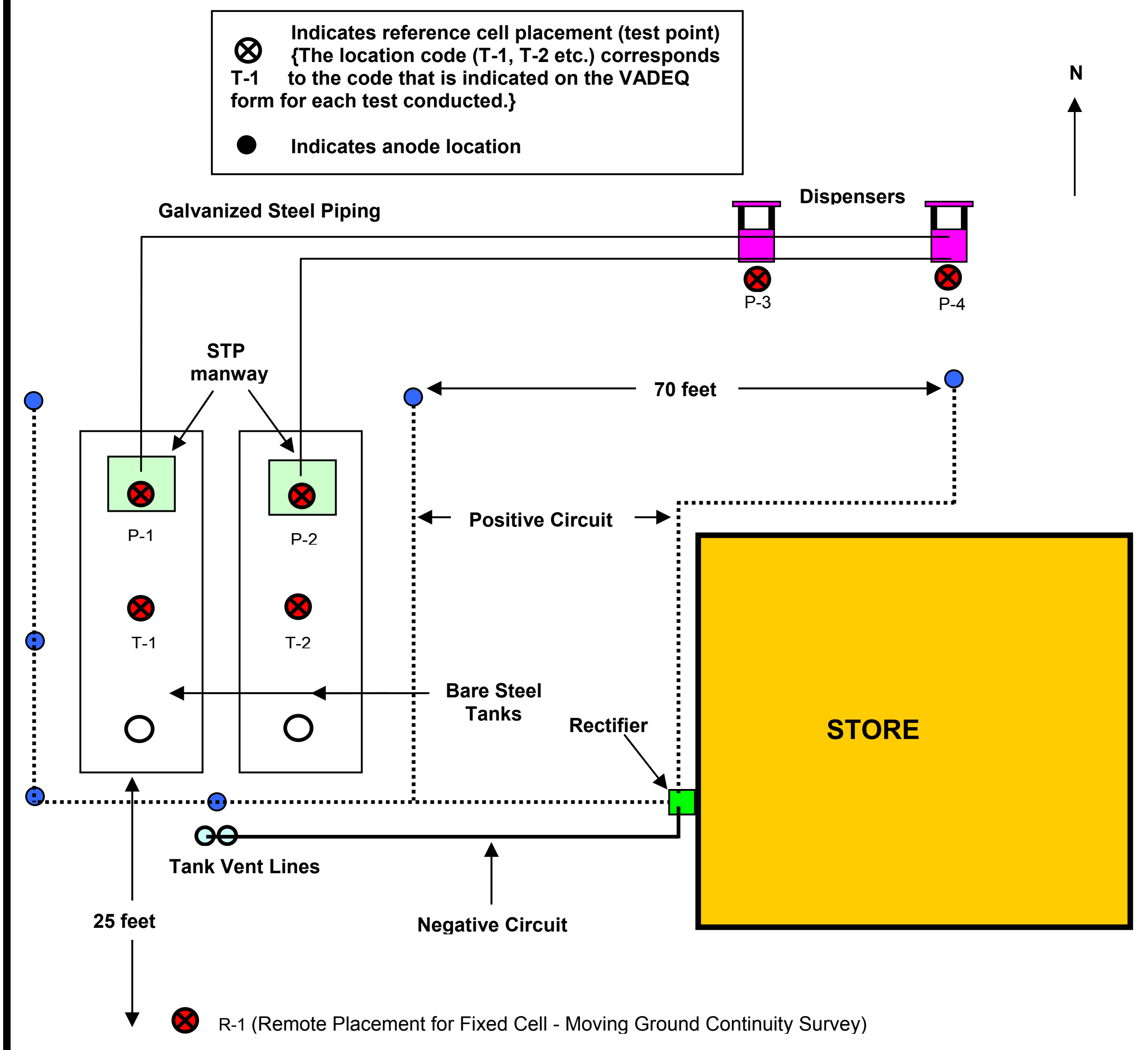
### 7.1.1 As Built Drawings

If any modification to the construction of the cathodic protection system is made (e.g. supplemental anodes) it is necessary to show the modification on a photocopy (not the original) of the “as built” drawings. If no as built drawing is available, indicate the location of any anode addition on the site drawing that is constructed as part of the evaluation. Dated "as built" drawings are required whenever a cathodic protection system is installed or substantially modified. The drawings should include: a) how many anodes were installed (number and pounds, e.g., (5) 17lb); b) what type of anodes were installed (e.g., magnesium, zinc, etc.); c) where were the anodes installed; d) how deep were the anodes installed; e) what type of wire was used; f) how were the wires bonded, etc.

### 7.1.2 Site Drawing

Whenever a cathodic protection survey is conducted, a site drawing depicting the UST system, the cathodic protection system and any related features of the facility must be constructed. The CP contractor must indicate on the drawing where the reference electrode was placed for each of the structure-to-soil potentials utilized to obtain a passing evaluation. Figure 13 is an example of a site drawing that shows the type of information that is necessary to properly complete the evaluation.

**FIGURE 13 – EXAMPLE OF A SITE DRAWING CONSTRUCTED AS PART OF A UST SYSTEM CATHODIC PROTECTION SURVEY**




While it is understood that the CP contractor will not always know where all of the pertinent components of the cathodic protection system may be buried, all that is known must be indicated. It is very important to show where the anodes are located on the site drawing. If it is not known where the anodes are buried, voltage gradients in the soil may help determine the approximate location as described in the raised earth discussion of Section 6.3.

Should any modifications to the cathodic protection system be made, it is very important that such modifications be both visually indicated on the site drawing and dated and a written narrative made that describes the work conducted. If "as built" drawings are available, it is acceptable to utilize these drawings for the purposes of meeting the requirements of this section. Any modifications or changes to the UST and/or cathodic protection systems that have been made since the construction of the "as built" drawings must be included.

### 7.1.3 VADEQ UST Cathodic Protection Evaluation Forms

Whenever a UST cathodic protection survey is conducted in the Commonwealth of Virginia, the form prescribed by the VADEQ (Appendix K) shall be utilized to document the survey. However, use of the prescribed form is not intended to limit other kinds of documentation that may be desirable in order to complete the evaluation. For instance, it may be necessary to provide photographs, or a written narrative describing various aspects of the evaluation or a repair/modification that is not captured by completion of the form.

### 7.1.4 Pass / Fail / Inconclusive

In order to assure uniformity in the manner in which cathodic protection evaluations are documented, the technician must determine a test result as prescribed in the VADEQ cathodic protection evaluation form found in Appendix K of this document. The terms “pass” and “fail” are utilized for this purpose. Therefore, it is necessary to clarify what these terms mean and their applicability as related to the evaluation of cathodic protection systems utilizing the VADEQ forms.

An evaluation conducted by an individual who is only qualified as a cathodic protection tester must result in one of three conclusions, pass, fail or inconclusive. If the person conducting the evaluation is qualified as a corrosion expert, the evaluation must result in either pass or fail.

**Pass -** The term “pass” as related to Section IV and V (tester’s/corrosion expert’s evaluation) of the VADEQ cathodic protection system evaluation form is taken to mean that the structure-to-soil potential survey indicates all of the protected structures at a facility meet at least one of the three accepted criteria.

Pass as related to Section XIV (potential survey) of the VADEQ cathodic protection system evaluation form means that the individual structure that is being tested meets at least one of the accepted criteria.

**Fail -** The term “fail” as related to Section IV and V (tester’s/corrosion expert’s evaluation) of the VADEQ cathodic protection system evaluation form means that the structure-to-soil potential survey indicates that there are one or more protected structures at a facility that do not meet any of the accepted criteria.

Fail as related to Section XIV (potential survey) of the VADEQ cathodic protection system evaluation form means that the individual structure that is being tested does not meet any of the accepted criteria.

**The term “inconclusive” means that a person qualified only as a tester is unable to conclusively evaluate the cathodic protection system and <u>in this case a corrosion expert must make the “pass” or “fail” determination</u>**. A cathodic protection tester may write in “inconclusive” in section IV of the evaluation form whenever one or more of the conditions listed in Section 7.2 of this document are applicable **<u>until a corrosion expert makes the pass or fail determination.</u>**

“Inconclusive” as related to Section XIII (continuity testing) of the VADEQ cathodic protection system evaluation forms means that it cannot be determined if the individual structure that is being tested is either electrically isolated in the case of galvanic systems or is electrically continuous in the case of impressed current systems **until a corrosion expert makes a determination.**

"Inconclusive" as related to Section XIV of the VADEQ cathodic protection system evaluation form is utilized when both the local and any remote potential (galvanic) measurements do not result in the same conclusion. If for instance the local potential was -900 mV but a remote potential was -700 mV an inconclusive would result since the local indicates that adequate cathodic protection is provided but the remote does not.

## 7.2 Corrosion Expert's Evaluation

Because the VADEQ has allowed those individuals who may only have minimal training in the principles of cathodic protection to conduct testing of such systems, it must be recognized that there will be instances where the expertise of someone who is more qualified and better understands the principles involved will be necessary.

Some of the more obvious scenarios where a person with a level of expertise equivalent to a "corrosion expert" {as defined in Section 2.1 (CFR Part 280.12) of this document} is necessary are given below. If any of the conditions given below are met, a corrosion expert must evaluate the survey results obtained by a tester and/or conduct further testing and complete Section V of the VADEQ cathodic protection system evaluation form. If the structure-to-soil potential survey is conducted by a person who is qualified as a corrosion expert, completion of Section V of the VADEQ form is all that is necessary.

A corrosion expert is required to evaluate and/or conduct the survey when:

1. Supplemental anodes are added to a galvanic cathodic protection system and an accepted industry standard is not followed and/or properly documented.

2. Supplemental anodes or other changes in the construction of an impressed current system are made.

3. It is known or suspected that stray current may be affecting the protected structure.

4. The repair and/or addition of supplemental anodes to bare steel/galvanized piping that is galvanically protected (see Section 5.1.3) and an acceptable industry standard is not followed and/or properly documented.

5. An inconclusive was declared (by a CP tester) when testing a galvanically protected structure because both the local and any remote potential did not indicate the same result (one indicated pass but the other indicated fail).

6. Continuity on an impressed current system is found to be insufficient (system fails).

7. Adjustments to the rectifier current are made that are outside the original design specifications.

Although not specifically listed above, it should be recognized that there might be additional circumstances that may arise that will require evaluation, and/or design by a corrosion expert.

## 7.3 What if the Evaluation Result is Fail?

It is important for the CP contractor to properly and promptly notify the tank owner if an evaluation of the cathodic protection system fails. Necessary repairs should be accomplished within 90 days of receipt of the “failed” evaluation. **The tank owner/operator is responsible for ensuring that the cathodic protection system is maintained in a manner that will provide adequate corrosion protection to the UST system.**

As it is recognized that many factors may cause a lower than desired voltage to be obtained during a structure-to-soil survey, there may be several different courses of action appropriate to resolve the “fail”. For instance, it is not uncommon to simply retest a sti-P3® tank that has failed a cathodic protection survey at a later date and achieve a passing result (e.g., after a dry period ends and when soil moisture levels are higher.)

Therefore, a 90-day re-testing period is allowed whenever a fail is obtained during which no action is necessary to repair or modify the cathodic protection system. This applies only to those galvanic and impressed current systems that appear to be in good working condition. If there are obvious problems with a system or the testers are unable to achieve a pass within the 90-day window, the tank owner must make any repairs and/or modifications that are necessary to achieve a pass. Repairs and/or modifications must be completed as soon as practical but no more than 90 days is allowed after expiration of the “90 day window”.

# APPENDIX A

## INDUSTRY CODES/STANDARDS, REFERENCES AND REGULATIONS

### INDUSTRY CODES/STANDARDS

American Petroleum Institute (API) RP1632 3rd Edition “Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems”.

American Petroleum Institute (API) RP1615 5th Edition “Installation of Underground Petroleum Storage Systems”.

NACE International RP0169-02 “Control of External Corrosion on Underground or Submerged Metallic Piping Systems”.

NACE International TM0101-2001 “Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Tank Systems”.

NACE International RP0285-2002 “Corrosion Control of Underground Storage Tank Systems by Cathodic Protection”.

Petroleum Equipment Institute (PEI) RP 100-2000 “Recommended Practices for Installation of Underground Liquid Storage Systems”.

Steel Tank Institute (STI) R892-91 “Recommended Practice for Corrosion Protection of Underground Piping Networks Associated with Liquid Storage and Dispensing Systems”.

Steel Tank Institute (STI) R972-01 “Recommended Practice for the Installation of Supplemental Anodes for sti-$P_3^{®}$ USTs”.

Steel Tank Institute (STI) R051 “Cathodic Protection Testing Procedures for sti-$P_3^{®}$ USTs”.

### REFERENCES

Department of Defense MIL-HDBK-1136 “Maintenance and Operation of Cathodic Protection Systems”.

Department of Defense MIL-HDBK-1136/1 “Cathodic Protection Field Testing”.

### REGULATIONS

**Federal** - Federal Regulations Chapter 40 Part 280 “Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tank Systems”.

**State (VA)** - 9VAC25-580, et seq. “Underground Storage Tanks: Technical Standards and Corrective Action Requirements”.

# APPENDIX B

## GLOSSARY

**100 mV POLARIZATION –** One of the three criteria that are commonly accepted as indicating adequate cathodic protection has been achieved. It is typically measured by interrupting the protective current on an impressed current system. When the current is interrupted, an “instant off” potential is recorded and the structure under cathodic protection is then allowed to depolarize until a change of at least 100 mV in potential is observed. Not more than 24 hours should be allowed for the depolarization to occur when conducting this test. If documented well, 100mV of polarization “formation” can also be used.

**-850 mV ON –** One of the three criteria that are commonly accepted as indicating adequate cathodic protection has been achieved. It is measured with the protective current applied with consideration for voltage drops and is typically the only measurement possible with galvanic systems since the anodes cannot be disconnected. This criterion is not applicable to impressed current systems since a large portion of the “on” measurement can be comprised of a voltage drop when the protective current is applied.

**-850 mV (“Instant”) OFF** - One of the three criteria that are commonly accepted as indicating adequate cathodic protection has been achieved. It is measured with the protective current interrupted (either the current from the rectifier is shut off or the sacrificial anodes are disconnected). This criterion is considered by most to be the best indicator that adequate cathodic protection has been provided.

**ANODE –** The electrode of an electrochemical cell where oxidation (corrosion) occurs. With respect to cathodic protection, it can be thought of as the place where electrons leave the surface of a metal. Common galvanic anodes are made of zinc or magnesium.

**AMPERE (AMP) –** The basic unit of current flow in an electric circuit. Amperage can be thought of as “gallons per minute” in a water system.

**AS BUILT DRAWINGS –** Drawings that show how a system was actually installed in the field. Sometimes, unforeseen factors prevent the installation of a system as it was intended in the design drawings and this is why it is important to have detailed and accurate “as built” drawings.

**ATTENUATION -** The protective effects of cathodic protection current diminish as you move away from the source of the protective current. To illustrate this, on an impressed current system where the ground bed is installed only on one side of the tank bed, the end of the tanks away from the ground bed will receive less protective current than the side of the tanks closest to the anodes. Attenuation of protective current applies to galvanic systems as well.

**CATHODE –** The electrode of an electrochemical cell where reduction (and no corrosion) occurs. With respect to cathodic protection, it can be thought of as the place where current enters the surface of a metal.

**CATHODIC PROTECTION –** The technique of causing the entire surface of a metallic structure to become a cathode with respect to its external environment (soil). This is accomplished by supplying an electric current sufficient to overcome the tendency of naturally occurring electrical currents to leave the metallic structure.

**CATHODIC PROTECTION EVALUATION –** The interpretation of whether or not a cathodic protection system is providing sufficient corrosion protection. An evaluation incorporates all cathodic protection testing, surveys, rectifier operation/output measurements, consideration of voltage drops, condition of dielectric coatings, continuity, bond integrity, circuit integrity and any other factors or site specific conditions that may have an influence on the operation and effectiveness of a cathodic protection system.

**CATHODIC PROTECTION SURVEY –** Refers to the process whereby all of the structure-to-soil measurements and tests necessary to contribute to the final evaluation of a system are obtained.

**CATHODIC PROTECTION TEST –** Refers to the process whereby a structure-to-soil measurement is obtained.

**CP CONTRACTOR** - Refers to any person or entity licensed as a contractor with the Board of Contractors in Virginia who also meets the minimum qualifications to perform cathodic protection testing in a manner that is consistent with the procedures of this guidance document.

**CONTINUITY –** As related to cathodic protection, continuity means that two metallic structures are electrically continuous. With impressed current systems all protected structures must be continuous and this is normally accomplished through the use of wires referred to as continuity bonds.

**CORROSION** – The deterioration of a material (usually a metal) caused by an electro-chemical reaction with its environment. Corrosion of metals involves the flow of electrons (current) between an anode and a cathode. Corrosion will occur where the electrons leave the surface of a metal.

**CURRENT REQUIREMENT TEST –** A method of temporarily creating an impressed current cathodic protection system on a galvanically protected structure so that it can be determined how much protective current is necessary in order to achieve adequate cathodic protection. This is normally done by connecting a battery (direct current ) to the structure to be tested and to a temporary anode.

**DIELECTRIC MATERIAL –** A coating or other material that does not conduct electricity. Various coatings are utilized and some examples are the "fusion-bonded epoxy" found on factory coated steel piping and coal tar epoxies and other coatings (e.g., aliphatic urethanes) commonly found on sti-$P_3$® tanks.

**DISTRIBUTED GROUND BED –** Used to describe an anode configuration in which the anodes are more or less equally distributed around the metallic structure that is intended to be protected.

**ELECTROLYTE –** As related to UST cathodic protection systems, electrolyte refers to the soil or water surrounding the metallic structure.

**ELECTROMAGNETIC INTERFERENCE –** As related to corrosion protection, it is an external electrical current that causes an error in a voltmeter measurement. Sources are commonly associated with high voltage AC power lines, radio frequency transmitters and airport radar systems.

**FAIL –** See Section 7.1.4.

**FIELD INSTALLED –** Refers to any impressed current system or sacrificial anode cathodic protection system that is installed on site at a pre-existing UST location or when sacrificial anodes are installed on site to new metallic pipe. Any cathodic protection system except for those associated with unmodified sti-$P_3$® tanks may be thought of as "field installed".

**FINAL POTENTIAL (VOLTAGE) –** The voltage that is observed at the end of the depolarization period associated with the measurement of "100 mV polarization". The final voltage must be at least 100 mV less than the "instant off" voltage in order to meet the 100 mV polarization criterion for adequate cathodic protection.

**"FIXED CELL – MOVING GROUND" –** A technique for measuring continuity in a UST system whereby the reference electrode is placed in the soil at a location remote from the UST system and is left undisturbed (fixed cell) while potentials are measured on various parts of the UST system (moving ground).

**GALVANIC (SACRIFICIAL) ANODE –** A metal of high electro-potential (see Appendix J) that is used to protect another metal. Zinc and magnesium are two metals that are commonly utilized in the protection of UST systems.

**GALVANIC CATHODIC PROTECTION –** A cathodic protection system that utilizes sacrificial anodes to provide the protective current. The anode will corrode (sacrifice itself) instead of the metal it is protecting. The anode provides a protective current (reverses the electron flow) because it has a higher electrochemical potential than the metal it is intended to protect. Galvanic systems are normally limited to the protection of well coated structures because they have a very low driving potential.

**IMPRESSED CURRENT ANODE –** A metal that is utilized to deliver the current from a rectifier to the soil in order to protect the intended metallic structure. Impressed current anodes are commonly made of graphite, high silicon cast iron and "mixed-metal oxides" because the metal must be highly resistant to corrosion in order to have an acceptably long life span.

**IMPRESSED CURRENT CATHODIC PROTECTION –** A cathodic protection system in which the protective current is supplied by an external source (rectifier). The level of protective current that is delivered to the structure is adjustable and can be much higher than that associated with galvanic anodes. For this reason, impressed current systems are utilized on those UST systems that are uncoated or require a high amount of protective current.

**INCONCLUSIVE -** See Section 7.1.4.

**INSTANT OFF POTENTIAL (VOLTAGE) –** The voltage that is observed momentarily after the power to an impressed current cathodic protection system is interrupted. It is used as the base line from which to begin calculating a "100 mV polarization". The second number that appears after the current is interrupted is considered the proper value to represent the instant off potential.

**ISOLATION –** As related to cathodic protection, isolation means that two metallic structures are electrically discontinuous. With galvanic systems a protected structure must be electrically isolated and this is normally accomplished through the use of nylon bushings and dielectric unions.

**LOCAL POTENTIAL (VOLTAGE) –** The structure-to-soil potential of a metallic structure that is measured with the reference electrode placed in the soil immediately over the protected structure.

**NACE INTERNATIONAL –** Formerly the National Association of Corrosion Engineers International.

**NATIVE POTENTIAL (VOLTAGE) –** The structure-to-soil potential of a metallic structure exhibited before any cathodic protection is applied.

**ON POTENTIAL (VOLTAGE) –** The structure-to-soil potential of a metallic structure that is measured with the protective current applied

**PARALLEL CIRCUIT –** Can be caused by the person conducting the test making contact with a metallic part of the test leads, or reference electrode when conducting structure-to-soil potential measurements. The creation of parallel paths must be avoided since inadvertent errors can be introduced.

**PASS –** See Section 7.1.4

**PASSIVATION -** When a metal undergoes passivation, an oxidation layer forms on the surface of the metal due to corrosion and can be defined as the loss of chemical reactivity. The oxidation layer acts as a coating and prevents or slows further corrosion of the metallic object since oxygen is prevented from reaching the underlying metal.

**PHOTOVOLTAIC EFFECT –** Sunlight striking the electrolyte solution in a copper-copper sulfate reference electrode can cause an error in the observed structure-to-soil potential and must be avoided.

**"POINT-TO-POINT" -** A technique for measuring continuity in a UST system whereby each lead of a voltmeter is connected to the two metallic structures of interest (negative lead to one structure and positive to the other). The voltage difference (if any) measured with the voltmeter connected in this manner indicates if continuity is present or not.

**POLARIZATION –** The change in the structure-to-soil potential of a metallic structure due to the application of a protective current. In this guidance document, polarization is considered to mean cathodic polarization - that is, the potential of the metal is shifted in the negative direction.

**POLARIZED POTENTIAL –** The structure-to-soil potential of a metallic structure that is observed after the protective current is applied and sufficient time has elapsed for the structure to completely polarize.

**RAISED EARTH –** Term used to describe the high voltage gradient found in the soil around an active impressed current or sacrificial anode. Placement of the reference electrode in proximity to an active anode will cause an abnormally high (more negative) structure-to-soil potential than would be present if the anode were not in close proximity.

**RECTIFIER –** A device utilized in impressed current systems that changes AC power to DC power.

**REFERENCE ELECTRODE –** Also referred to as a reference cell or a half-cell. A device whose electrochemical potential is constant that is used to measure the structure-to-soil potential of buried metallic structures. The potential that is observed on the buried metallic structure is relative to the potential of the reference electrode. The potential of a buried metallic structure would be zero if it were of the exact same composition as the reference electrode if all sources of measurement error were eliminated.

**RESISTANCE –** A measurement of the tendency of a substance to inhibit the flow of electrical current. Resistance in UST cathodic protection systems is generally meant to refer to the electrical properties of the backfill materials (soil).

**REMOTE EARTH –** The structure-to-soil potential of a metallic structure that is measured with the reference electrode placed in the soil at a point well away (remote) from the protected structure. Remote earth is generally thought of as at least 25 feet and not more than 100 feet away. Remote earth is established when the observed structure-to-soil potential does not significantly change no matter how far away the reference electrode is from the protected structure.

**SACRIFICIAL ANODE –** See Galvanic Anode.

**SHIELDING –** A structure that prevents or diverts an electrical current from reaching the desired location. Normally thought of as something that stops a reference electrode from being able to "see" the metallic structure on which one is attempting to measure a structure-to-soil potential.

**sti-$P_3$® TANK –** A steel tank manufactured to the standard created by the Steel Tank Institute that comes from the factory with a "pre-engineered" cathodic protection system. The "P3" means that the steel tank is protected in three ways: 1) A protective dielectric coating is factory applied; 2) Sacrificial anodes (zinc/magnesium) are factory installed on the tanks and 3) dielectric bushings are installed to facilitate electrical isolation of the tank.

**STRAY CURRENT –** An electrical current that travels along an unintended path. Normally thought of as a current from some external source that enters a protected metallic structure at one point that then exits at another point. The point where the stray current exits the protected structure can be subject to intense corrosion and failure may rapidly occur.

**STRUCTURE-TO-SOIL POTENTIAL –** Also know as "pipe-to-soil potential' or "structure-to-electrolyte potential" – The difference in the potential of the surface of a buried metallic structure and the electrolyte (soil) that surrounds it with respect to a reference electrode in contact with the electrolyte (soil). Can be thought of as the voltage difference between a buried metallic structure and the soil that it is buried in.

**VOLTAGE –** The basic unit of force in an electric circuit. Voltage can be thought of as "pounds per square inch pressure" in a water system.

**VOLTAGE (IR) DROP –** With respect to UST cathodic protection systems, voltage drops may be thought of as any voltage that causes an error in the observed structure-to-soil potential. Whenever a current is flowing through a resistance, a voltage drop is present and is part of the voltage measurement obtained

# APPENDIX C

| GENERALIZED INTERPRETATION OF STRUCTURE-TO-SOIL POTENTIAL MEASUREMENTS (VOLTAGES) OBTAINED ON GALVANIC CATHODIC PROTECTION SYSTEMS | |
|---|---|
| Listed in this table are some generalized observations that can be applied to the interpretation of structure-to-soil potentials. Depending on the specific site conditions and other factors, differing interpretations are possible. | |
| **VOLTAGE (mV) "ON"** | **GENERALIZED INTERPRETATION** |
| **POSITIVE** | Test leads are reversed (negative should be connected to the reference electrode and the positive should contact the structure being tested in order to observe negative voltages). Could indicate that stray current is affecting the structure (consult with a corrosion expert). |
| **0 to -100** | Usually occurs when attempting to measure a structure that has a test lead that is not continuous with the tank. Because one is measuring the potential of a copper wire with reference to the copper-copper sulfate half-cell, the potential is zero or very near it. Disregard test lead and make direct contact with the protected structure. |
| **-101 to -399** | Try again – A reading in this range is not normally seen on an underground steel structure. Could indicate that steel structure is electrically connected to a significant amount of a more noble metal (e.g. copper). Very corroded low carbon steel may also be indicated. |
| **-400 to -599** | Steel structure does not meet regulatory requirements. Usually means that the steel structure has no cathodic protection. Existing sacrificial anodes could be completely "burned-out" or were never there to begin with. |
| **-600 to -849** | Steel structure does not meet regulatory requirements. Usually means that the steel structure has anodes but for whatever reason, something is causing a low reading that may indicate adequate cathodic protection has not been provided. The anodes may be trying to protect a structure that requires more current than they can produce. The protected steel structure may not be electrically isolated from all other metallic structures (conduct continuity testing). The environmental conditions may not be favorable at the time you are attempting to obtain the reading. Retest during the next 90 days to see if an acceptable reading can be obtained. |
| **-850 to -1100** | Steel structure protected by zinc anodes meets regulatory requirements and cathodic protection is judged to be adequate. Readings in this range are expected on most sti-$P_3$® tanks that have not been modified and are reading "good" since nearly all come from the manufacturer with zinc anodes. |
| **-850 to -1600** | Steel structure protected by magnesium anodes meets regulatory requirements and cathodic protection is judged to be adequate. Readings in this range are typically expected on steel piping that is reading "good" since magnesium anodes are generally installed on piping. Also may find readings up to -1600 mV on a sti-$P_3$® tank that has been retrofitted or was supplied at the factory with magnesium anodes. |
| **MORE NEGATIVE THAN -1100 WITH ZINC ANODES ONLY** | Voltages more negative than -1100 mV are theoretically not possible if there are only zinc anodes installed. If a reading is more negative than -1100 mV and you are sure magnesium anodes are not present, suspect that stray current may be affecting the cathodically protected structure. A corrosion expert should be contacted immediately since stray current can cause a corrosion failure in a relatively short period of time. |
| **MORE NEGATIVE THAN -1600** | Voltages more negative than -1600 mV are theoretically not possible with any sacrificial anode cathodic protection system. If a reading is more negative than -1600 mV on any galvanic cathodic protection system, suspect that stray current may be affecting the cathodically protected structure. A corrosion expert should be contacted immediately since stray current can cause a corrosion failure in a relatively short period of time. |
| **VARIABLE** | If the voltmeter readings vary, suspect that stray current may be affecting the cathodically protected structure. Sometimes, the stray current can cause a pattern to develop that is recognizable. An example would be the on/off pattern of a nearby DC powered welding operation. A corrosion expert should be contacted immediately since stray current can cause a corrosion failure in a relatively short period of time. |
| **RAPIDLY FLUCTUATING** | If the voltmeter will not stabilize, it usually means that there is a high electrical resistance somewhere. Check all lead wires and connections and make sure that a solid and clean metal to metal connection exists. Soil where the reference electrode is placed could be too dry. Add water to the soil or wait until a heavy rain occurs and try again. Petroleum contaminated soils may cause a high contact resistance. The tip of the reference electrode may need to be cleaned or replaced. |

# APPENDIX D

| GENERALIZED INTERPRETATION OF STRUCTURE-TO-SOIL POTENTIAL MEASUREMENTS (VOLTAGES) OBTAINED ON IMPRESSED CURRENT CATHODIC PROTECTION SYSTEMS | |
|---|---|
| Listed in this table are some generalized observations that can be applied to the interpretation of structure-to-soil potentials. Depending on the specific site conditions and other factors, differing interpretations are possible. | |
| **VOLTAGE (mV)** | **GENERALIZED INTERPRETATION** |
| **ANY POSITIVE VOLTAGE OR 0 TO -100 "ON" or "OFF"** | Can indicate that the structure is not bonded to the impressed current system (conduct continuity testing). Stray current could be affecting the protected structure (consult a corrosion expert). Positive and negative wires could be reversed (negative must be to protected structure and positive to anode). Test leads are reversed (positive lead should contact structure and negative lead should be connected to reference electrode). Could indicate that the potential of a copper wire is being tested. |
| **-101 to -399 "ON" or "OFF"** | Try again – A reading in this range is not normally seen on an underground steel structure. Could indicate that steel structure is electrically connected to a significant amount of a more noble metal (e.g. copper). Very corroded low carbon steel may also be indicated. |
| **-400 to -599 "ON" or "OFF"** | Usually means that the steel structure has no cathodic protection. Existing impressed current anodes could be completely "burned-out". Continuity of anode lead wires (positive circuit) could be broken. Negative bonds on the protected structures may be broken or non-existent. |
| **-600 to -849 "ON" or "OFF"** | Usually means that the steel structure has some protection but for whatever reason, something is causing a low reading that may indicate adequate cathodic protection has not been provided. The impressed current system may be trying to protect a structure that requires more current than it can produce (rectifier output too small). The impressed current system may not be capable of effectively distributing the required current to all parts of the structure being protected (not enough anodes, anodes improperly installed, soil resistivity too high). The steel structure that is intended to be protected may not be electrically continuous with the other metallic structures under protection (conduct continuity testing). The environmental conditions may not be favorable at the time when attempting to obtain the reading. Retest during the next 90 days. |
| **-850 or MORE NEGATIVE "ON"** | Steel structure may or may not be adequately protected. Usually indicates that the impressed current system is providing current to the structure although the reading normally includes a large voltage (IR) drop. Because the flow of current through the soil causes a voltage drop, the on potential cannot be used to indicate that adequate cathodic protection has been provided. Instant off potentials must be utilized to demonstrate cathodic protection. |
| **-850 or MORE NEGATIVE "OFF"** | Steel structure protected by impressed current system meets regulatory requirements and cathodic protection is judged to be adequate. A potential measurement of -850 mV or more negative with the protective current temporarily interrupted (850 off) is considered to be the best indicator that adequate cathodic protection has been provided. |
| **MORE NEGATIVE THAN -1220 mV "OFF"** | Instant off potentials more negative than -1220 mV are theoretically not possible. If an instant off potential more negative than -1220 mV is observed, you should suspect stray current is affecting the protected structure. Consult a corrosion expert immediately since stray current can cause a rapid corrosion failure of the protected structure. |
| **MORE NEGATIVE THAN -2000 "ON"** | Usually means that a high resistance exists in the ground bed that is causing a large voltage drop. This condition is normally evident by checking the rectifier output since the voltage is very high but the amperage is relatively low. However, you should be cautious when abnormally high voltages are observed since this can have a detrimental effect on cathodically protected structures or the anodes may be rapidly depleted. Stray current may also be generated that can adversely affect other buried metallic structures such as water lines and other utilities. Consult a corrosion expert whenever it is suspected that too much voltage is being generated. |
| **VARIABLE "ON" or "OFF"** | If the voltmeter readings vary, suspect that stray current may be affecting the cathodically protected structure. Sometimes, the stray current can cause a pattern to develop that is recognizable. An example would be the on/off pattern of a nearby DC powered welding operation. A corrosion expert should be contacted immediately since stray current can cause a corrosion failure in a relatively short period of time. |
| **RAPIDLY FLUCTUATING "ON" or "OFF"** | If the voltmeter will not stabilize, it usually means that there is a high electrical resistance somewhere. Check all lead wires and connections and make sure that they are making a solid and clean metal to metal connection. Soil where the reference electrode is placed could be too dry. Add water to the soil or wait until a heavy rain occurs and try again. Petroleum contaminated soils may cause a high contact resistance. The tip of the reference electrode may need to be cleaned or replaced. |

# APPENDIX E

## CONTINUITY TESTING PROCEDURE FOR GALVANIC/IMPRESSED CURRENT CATHODIC PROTECTION SYSTEMS

### Fixed Cell – Moving Ground Continuity Test Procedure

1. Place reference electrode in contact with the soil at a location remote (25 – 100 feet) from all cathodically protected structures. Ensure that the remote reference electrode placement is not in proximity to any other cathodic protection systems (e.g. natural gas pipelines) or directly over any buried metallic structure in order to minimize the chances of unwanted interference.
2. Be sure that reference electrode is firmly placed in moist soil and is not in contact with any vegetation.
3. Connect reference electrode to the negative terminal of voltmeter using a long spool of suitable wire.
4. Connect positive lead wire to voltmeter. This lead wire should have a sharp test prod (scratch awl or similar) in order to assure good contact with the metallic structures under test.
5. Place voltmeter on 2 volt DC scale.
6. Contact each buried metallic structure with the positive test lead without moving the reference electrode. Typical items that would be tested during a continuity survey include: all tanks, tank risers, submersible pump heads, piping, flex connectors/swing joints, vent lines, electrical conduits, dispensers, utilities, etc.
7. Obtain voltage for each component and record on VADEQ continuity testing section of evaluation form.
8. Voltages for each component that is tested must be obtained as quickly as possible since the observed potential can change over time. This is because the conditions in the soil where the reference electrode is placed can change over a relatively short period of time.

### Fixed Cell – Moving Ground Data Interpretation (See NACE Standard TM-01-01-2001, paragraphs 11.3.3 and 11.4.3.)

- If two or more structures exhibit potentials that vary by 1 mV or less, the structures are considered to be electrically continuous.
- If two or more structures exhibit potentials that vary by 10 mV or greater, the structures are considered to be electrically isolated.
- If two or more structures exhibit potentials that vary by more than 1 mV but less than 10 mV, the result is inconclusive and further testing (point-to-point) is necessary.

### Point-to-Point Continuity Test Procedure

1. Turn off power to rectifier if testing an impressed current system. This is necessary to obtain accurate results.
2. Connect test leads to voltmeter. Both test leads should have a sharp test prod or suitable clip lead in order to make good contact with tested structures.
3. Place voltmeter on 2 volt (or lower) DC scale.
4. Connect one voltmeter test lead to one of the structures for which continuity is being tested and connect the other voltmeter test lead to the other structure that is being tested.
5. Record voltages observed on each of the two structures that are being compared and record on VADEQ continuity testing section of evaluation form.

Note: Testing with this method does not require a reference electrode. The two structures of interest are simply connected in parallel with the voltmeter and a determination made as to whether or not any potential difference exists between them.

### Point-to-Point Data Interpretation

- If the voltage difference observed between the two structures is 1 mV or less, this indicates that the two structures are considered to be electrically continuous with each other.
- If the voltage difference observed between the two structures is 10 mV or greater, this indicates that the two structures are considered to be electrically isolated from each other.
- If the voltage difference observed between the two structures is greater than 1 mV but less than 10 mV, the result is inconclusive and further testing beyond the scope of this document is necessary.

# APPENDIX F

## STRUCTURE-TO-SOIL TEST PROCEDURE FOR GALVANIC CATHODIC PROTECTION SYSTEMS

1. Place voltmeter on 2 volt DC scale.
2. Connect voltmeter negative lead to reference electrode.
3. Place reference electrode in clean (uncontaminated) soil directly over the structure that is being tested to obtain local potential. At least three potentials are required with at least one local and with at least one remote for each tank - the preferred test point is at the approximate midpoint along the centerline of the tank. Piping requires three readings--measurement at each end of the pipe and at the middle depending upon anode configuration (see Section 6.10.2 of the VADEQ CP guidance document).
   - The reference electrode may not be placed on concrete, asphalt, or other paving materials.
   - Ensure that the reference electrode is placed in a vertical position (tip down).
   - Ensure that the soil where the reference electrode is placed is moist – add tap water if necessary.
   - Ensure that the soil where the reference electrode is placed is <u>not contaminated with hydrocarbons</u>.
   - Ensure that the reference electrode window is not exposed to direct sunlight.
4. Connect voltmeter positive lead to structure that is to be tested.
   - If a test lead wire is utilized to make contact with the tested structure (not recommended), check to ensure that continuity exists between the test lead wire and the structure. This may be accomplished by conducting a point-to-point continuity test as described in Appendix E.
   - Ensure that good metal-to-metal contact is made between the test lead clip/probe and the structure.
   - Ensure that no corrosion exists where the test lead makes contact with the structure. Clean metals as needed to obtain a solid (non-fluctuating) reading when testing.
   - Ensure that your body does not come into contact with the electrical connections.
   - Ensure that test leads are not submerged in any standing water.
   - Ensure that test lead insulation is in good condition.
   - sti-$P_3^{®}$ tanks
     - If the test lead wire is not continuous or is not present, contact with the inside bottom of the tank is necessary. This may be accomplished by connecting the voltmeter lead wire to a test prod mounted onto the bottom of a wooden gauging stick and lowering the stick into the tank fill riser. Be sure that firm contact is made with the tank bottom (note some sti-$P_3^{®}$ tanks may have been lined.) Care should be taken to ensure that any drop tube that may be installed in the tank does not prohibit contact with the tank bottom. If a metallic probe bar is utilized to contact the tank bottom, ensure that the probe bar does not contact the fill riser or any other metallic component of the UST system.
     - If a sti-$P_3^{®}$ tank is equipped with a PP4® test station, the PP4® test station (if compromised) may be disregarded and potentials obtained with a portable reference electrode placed in the soil (local and remote) as described in Section 6.10.1 of this VADEQ CP guidance document.
5. Obtain voltage and record on the VADEQ CP survey form.
6. For any remote readings--place reference electrode in clean soil remote from the protected structure. (Refer to Section 6.10.3 for a discussion of remote reference electrode placement.)
7. Fort any remote readings--obtain voltage and record in the remote column on the VADEQ galvanic cathodic protection form. (Note: if the fixed cell-moving ground method was used to conduct continuity survey, the potential obtained during the continuity survey for each corresponding structure may be transposed to the appropriate column.)

**Data Interpretation** (for a more complete discussion refer to Appendix C of this guidance document)

If both the local and any remote potential are –850 mV or more negative after considering voltage (IR) drops, the 850 on criterion is satisfied and it is judged that adequate cathodic protection has been provided.

If either the local or any remote potential is more positive than –850 mV the test result is inconclusive and further testing and/or repairs are necessary. Alternatively, a person qualified as a corrosion expert could evaluate/conduct the survey and declare a pass or fail based on their interpretation and professional judgment.

# APPENDIX G

## STRUCTURE-TO-SOIL TEST PROCEDURE FOR IMPRESSED CURRENT CATHODIC PROTECTION SYSTEMS

1. Inspect rectifier for proper operation and document necessary information. This includes measurement of output voltage/amperage with a multimeter (do not rely on rectifier meters) and measurement of individual anode circuits (if installation allows such). Record all necessary information under Section IX and X of the VADEQ CP form.
2. Place voltmeter on 2 volt DC scale.
3. Connect voltmeter negative lead to reference electrode.
4. Place reference electrode in clean (uncontaminated) soil directly over the structure that is being tested. At least three local measurements must be taken for each tank - the preferred test point is usually along the centerline of the tank. Piping requires three measurements--at each end of the pipe (see Section 6.10.3 and 6.10.4 of VADEQ guidance document for further explanation).
    - The reference electrode may not be placed on concrete, asphalt, or other paving materials.
    - Ensure that the reference electrode is placed in a vertical position (tip down).
    - Ensure that the soil where the reference electrode is placed is moist – add tap water if necessary.
    - Ensure that the soil where the reference electrode is placed is <u>not contaminated with hydrocarbons</u>.
    - Ensure that the reference electrode window is not exposed to direct sunlight.
5. Connect voltmeter positive lead to structure that is to be tested.
    - Ensure that good metal-to-metal contact is made between the test lead clip/probe and the structure.
    - Ensure that no corrosion exists where the test lead makes contact with the structure.
    - Ensure that your body does not come into contact with the electrical connections.
    - Ensure that test leads are not submerged in any standing water.
    - Ensure that test lead insulation is in good condition.
6. Obtain voltage potential with the protective current applied and record in the on column on the VADEQ impressed current cathodic protection evaluation form.
7. Without moving reference electrode from the position it was in during step 6 above, obtain voltage potential with the protective current temporarily interrupted and record in the instant off column on the VADEQ cathodic protection form.
    - The instant off potential is the 2nd value that is observed on a digital voltmeter the instant the power is interrupted. The first number that appears immediately after power interruption must be disregarded. After the second number appears, a rapid decay (depolarization) of the structure will normally occur.
    - In order to obtain instant off potentials, a current interrupter or a 2nd person is necessary. If a current interrupter is not available, have the second person throw the power switch at the rectifier off for 3 seconds and then back on for 15 seconds. Repeat this procedure until sure an accurate instant off reading has been obtained.
8. Conduct 100 mV polarization decay if unable to obtain an instant off potential of -850 mV or more negative in step 7 above. (Note: While not a requirement of this guidance document, consideration should be given to adjusting the rectifier output until an instant off potential of -850 mV is achieved or the maximum safe output is reached.) It is only necessary to conduct a 100 mV polarization where the lowest (most positive) instant off potential is observed on the UST system.
    - 100 mV of polarization is determined by leaving the power interrupted on the structure until a change of at least 100 mV in the structure-to-soil potential is observed. In calculating the 100 mV decay, the instant off potential obtained in Step 7 above is utilized as the starting point (e.g. if instant off = -800 mV, power must be left off until decayed to -700 mV).
    - Calculate voltage change by subtracting final (or ending) voltage from the instant off voltage and record these values in the appropriate columns on the VADEQ cathodic protection evaluation form.

**Data Interpretation** (for a more complete discussion refer to Appendix D of this guidance document)

- If the instant off potential is -850 mV or more negative, the 850 off criterion is satisfied and it is judged that adequate cathodic protection has been provided.
- If the instant off potential is more positive than -850 mV, the tank may or may not be adequately protected and a 100 mV polarization test is necessary.
- If the structure exhibits more than a 100 mV polarization, the 100 mV polarization criterion is met and it is judged that adequate cathodic protection has been provided. If unable to meet either the 850 instant off or the 100 mV polarization criteria, it is judged that adequate cathodic protection has not been provided and repair/modification is indicated. Alternatively, a person qualified as a corrosion expert could evaluate/conduct the survey and determine that cathodic protection is adequate based on their interpretation.

# APPENDIX H

| CHECKLIST FOR GALVANIC CATHODIC PROTECTION SYSTEM SURVEY | |
|---|---|
| ☐ | Identified UST owner, UST facility, CP tester, tester's qualifications and reason for survey. |
| ☐ | Described UST and cathodic protection system. |
| ☐ | Constructed site drawing depicting all pertinent components of the UST and cathodic protection systems at the facility. |
| ☐ | Reviewed any previous cathodic protection design/repair/testing data that may be available. |
| ☐ | Ensured soil access was available directly over each cathodically protected component at the facility (see Section 6.9.2 of VADEQ cathodic protection guidance document for discussion). |
| ☐ | Conducted continuity testing of all pertinent metallic components at the UST facility by the fixed remote – moving ground and/or the point-to-point method. |
| ☐ | Obtained local structure-to-soil potentials on every cathodically protected structure with the reference electrode placed in the soil directly over the structure under test. |
| ☐ | Obtained any remote potentials or transposed remote potentials obtained during continuity testing for every cathodically protected structure to appropriate column in VADEQ cathodic protection form. |
| ☐ | Indicated location (by code or other means) of reference electrode placement on site drawing for each structure-to-soil potential that was obtained during the survey. |
| ☐ | Described any repairs and/or modifications that were made to the cathodic protection system. |
| ☐ | Indicated whether or not each protected structure met the –850 mV on criteria for both the local and any remote reference electrode placement by indicating pass/fail in the appropriate column of the VADEQ cathodic protection form. |
| ☐ | If only qualified as a tester - indicated the results of the evaluation by marking either pass or fail on the VADEQ cathodic protection form. |
| ☐ | If only qualified as a tester – write in "inconclusive" if any of the conditions found in Section 7.2 of VADEQ cathodic protection guidance document were applicable to the survey. |
| ☐ | If tester indicated "inconclusive", either repairs were conducted or a corrosion expert evaluated/conducted the survey and completed the VADEQ cathodic protection form. |
| ☐ | If a corrosion expert conducted and/or evaluated the survey – indicated the results by marking either pass or fail on the VADEQ cathodic protection form. |
| ☐ | Indicated criteria that were applied to the evaluation by completion of the VADEQ cathodic protection form. |
| ☐ | Indicated action required as a result of the survey by marking either none, retest or repair & retest on the VADEQ cathodic protection form. |
| ☐ | Provided UST owner with any other type(s) of documentation that may be necessary in order to adequately describe the cathodic protection evaluation including the operating status and any repairs or recommendations and attached same to the VADEQ cathodic protection form. |

# APPENDIX I

| CHECKLIST FOR IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM SURVEY | |
|---|---|
| ☐ | Identified UST owner, UST facility, CP tester, tester's qualifications and reason for survey. |
| ☐ | Described UST system and type of cathodic protection. |
| ☐ | Constructed site drawing depicting all pertinent components of the UST and cathodic protection systems at the facility and complete appropriate sections of the VADEQ cathodic protection form. |
| ☐ | Reviewed any previous cathodic protection design/repair/testing data that may be available. |
| ☐ | Checked rectifier for proper operation and measured output voltage/amperage with portable multimeter and indicated all other pertinent information. |
| ☐ | Measured current output of all positive and negative circuits if the system was designed to allow for such (complete the VADEQ cathodic protection form). |
| ☐ | Ensured soil access was available directly over each cathodically protected component at the facility. |
| ☐ | Conducted continuity testing of all pertinent metallic components at the UST facility by the fixed remote – moving ground and/or point-to-point method (complete VADEQ CP form sections). |
| ☐ | Recorded native structure-to-soil potentials in appropriate column in the VADEQ cathodic protection form if this data was available or the system had been down long enough for complete depolarization to occur. ("Native" is usually done prior to startup--takes days-weeks to achieve "native" after startup.) |
| ☐ | Obtained structure-to-soil potential on every cathodically protected structure with the reference electrode placed in the soil directly over the structure under test with the protective current applied (on) and recorded voltages in appropriate column on the VADEQ cathodic protection form. |
| ☐ | Obtained structure-to-soil potential on every cathodically protected structure without moving reference electrode from placement utilized to obtain on potential with the protective current temporarily interrupted (instant off) and recorded voltages in appropriate column on VADEQ CP form). |
| ☐ | Conducted 100 mV polarization test if all protected structures did not meet the -850 instant off criterion. Obtaining a 100 mV decay is only required on that component of the UST system that displays the lowest (most positive) instant off potential in order to demonstrate the criterion has been satisfied. |
| ☐ | Indicated location (by code or other means) of reference electrode placement on site drawing for each structure-to-soil potential that was obtained. |
| ☐ | Described any repairs and/or modifications that were made to the cathodic protection system (complete the VADEQ cathodic protection form). |
| ☐ | Indicated whether or not each protected structure met the –850 mV instant off criteria and/or the 100 mV polarization criteria by indicating pass/fail in the appropriate column on the VADEQ form. |
| ☐ | If only qualified as a tester - indicated the results of the evaluation by marking either pass, fail or wrote-in inconclusive on the VADEQ cathodic protection form. |
| ☐ | If only qualified as a tester - marked "inconclusive" if any of the conditions found in Section 7.2 of VADEQ cathodic protection guidance document were applicable to survey. |
| ☐ | If it was necessary for the tester to indicate "inconclusive", a corrosion expert evaluated the data obtained by a tester and/or conducted his own testing and completed the VADEQ CP form |
| ☐ | If a corrosion expert conducted evaluation – indicated the results by marking either pass or fail on the VADEQ cathodic protection form. |
| ☐ | Indicated criteria that were applied to the evaluation by completion of appropriate section of the VADEQ CP form. |
| ☐ | Indicated action required as a result of the survey by marking either none, retest or repair & retest on the VADEQ cathodic protection form. |
| ☐ | Provided UST owner with any other type(s) of documentation that may be necessary in order to adequately describe the cathodic protection evaluation including the operating status and any repairs or recommendations and attached same to the VADEQ cathodic protection form. |

# APPENDIX J

| TYPICAL POTENTIAL OF SELECTED METALS | |
|---|---|
| The table below lists some common metals and their observed electrical potentials as measured with respect to a copper/copper sulfate reference electrode. | |
| **METAL** | **VOLTAGE (mV)** |
| Magnesium (commercially pure) | -1750 |
| Magnesium (alloy found in typical cathodic protection anode) | -1600 |
| Zinc (nearly 100% pure - as found in typical cathodic protection anode) | -1100 |
| Aluminum (5% zinc alloy) | -1050 |
| Aluminum (pure) | -800 |
| Low Carbon Steel (new – clean & shiny) | -600 to -750 |
| Low Carbon Steel (old – rusty) | -500 to -600 |
| Stainless Steel (active - unpassivated) | -450 to -600 |
| Cast Iron (not graphitized) | -500 |
| Lead | -500 |
| Low Carbon Steel in Concrete | -200 |
| Brass, Bronze | -200 |
| Stainless Steel (passivated) | 50 to -250 |
| Copper | 0 to -200 |
| High Silicone Cast Iron | -200 |
| Carbon, Graphite | +300 |
| Silver | +500 |
| Platinum | +900 |
| Gold | +1200 |

## APPENDIX K

## GALVANIC AND IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM EVALUATION FORM 7531-CP (05/06)

| VIRGINIA DEQ | CATHODIC PROTECTION SYSTEM EVALUATION FORM | 7531-CP (05/06) |
|---|---|---|

- This form should be utilized to evaluate underground storage tank (UST) cathodic protection systems in the Commonwealth of Virginia.
- Access to the soil directly over the cathodically protected structure that is being evaluated must be provided.
- A site drawing depicting the UST cathodic protection system and all reference electrode placements must be completed.

| I. UST OWNER | | II. UST FACILITY | | |
|---|---|---|---|---|
| NAME: | | NAME: | | ID # |
| ADDRESS: | | ADDRESS: | | |
| CITY: | PHONE: | CITY: | | COUNTY: |
| STATE: | ZIP: | STATE: | ZIP: | PHONE: |

## III. REASON SURVEY WAS CONDUCTED (mark only one)

☐ Routine - 3 year ☐ Routine – within 6 months of installation ☐ 90-day re-survey after fail ☐ Re-survey after repair/modification

Date next cathodic protection survey must be conducted ________________________ (required within 6 months of installation/repair & every 3 years thereafter).

## IV. CATHODIC PROTECTION TESTER'S EVALUATION (mark only one)

| | | |
|---|---|---|
| ☐ | **PASS** | All protected structures at this facility pass the cathodic protection survey and it is judged that adequate cathodic protection has been provided to the UST system (indicate all criteria applicable by completion of Section VI). |
| ☐ | **FAIL** | One or more protected structures at this facility fail the cathodic protection survey and it is judged that adequate cathodic protection has not been provided to the UST system(s) (complete Section VII). |

| | | | | |
|---|---|---|---|---|
| TESTER'S NAME: | | | SOURCE OF CERTIFICATION: | |
| COMPANY NAME: | | | TYPE OF CERTIFICATION: | |
| ADDRESS: | | | CERTIFICATION NUMBER: | |
| CITY: | STATE: | ZIP: | PHONE: | |
| CP TESTER'S SIGNATURE: | | | DATE SIGNED: | DATE CP SURVEY PERFORMED: |

## V. CORROSION EXPERT'S EVALUATION (mark only one)

The survey must be conducted and/or evaluated by a corrosion expert when: a) supplemental anodes or other changes in the construction of the cathodic protection system are made; b) stray current may be affecting buried metallic structures or c) an inconclusive result was written in Section VI. (except for under STI-R972 – "Recommended Practice for the Addition of Supplemental Anodes to sti-$P_3$® UST's")

| | | |
|---|---|---|
| ☐ | **PASS** | All protected structures at this facility pass the cathodic protection survey and it is judged that adequate cathodic protection has been provided to the UST system (indicate all criteria applicable by completion of Section VI). |
| ☐ | **FAIL** | One or more protected structures at this facility fail the cathodic protection survey and it is judged that adequate cathodic protection has not been provided to the UST system (indicate what action is necessary by completion of Section VII). |

| | | | |
|---|---|---|---|
| CORROSION EXPERT'S NAME: | | | SOURCE OF CERTIFICATION: |
| COMPANY NAME: | | | TYPE OF CERTIFICATION: |
| ADDRESS: | | | CERTIFICATION NUMBER: |
| CITY: | STATE: | ZIP: | PHONE: |
| CORROSION EXPERT'S SIGNATURE: | | | DATE: |

## VI. CRITERIA APPLICABLE TO EVALUATION (mark all that apply)

| | | |
|---|---|---|
| ☐ | **- 850mV ON / (Instant) OFF** (circle "ON" or "OFF" to specify) | Structure-to-soil potential more negative than –850 mV with respect to a $Cu/CuSO_4$ reference electrode with protective current ON (galvanic) or temporarily interrupted (instant-OFF (impressed)). **Inconclusive?** ☐ |
| ☐ | **100 mV POLARIZATION** | Structure(s) exhibit at least 100 mV of cathodic polarization. **Inconclusive?** ☐ |

## VII. ACTION REQUIRED AS A RESULT OF THIS EVALUATION (mark only one)

| | | |
|---|---|---|
| ☐ | **NONE** | Cathodic protection is adequate. No further action is necessary at this time. Test again by no later than (see Section V). |
| ☐ | **RETEST** | Cathodic protection may not be adequate. Retest during the next 90 days to determine if passing results can be achieved. |
| ☐ | **REPAIR & RETEST** | Cathodic protection is not adequate. Repair/modification is necessary as soon as practical but within the next 90 days. |

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## VIII. DESCRIPTION OF UST SYSTEM

| TANK # | PRODUCT | CAPACITY | TANK MATERIAL | PIPING MATERIAL | FLEX CONNECTORS |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

## IX. IMPRESSED CURRENT RECTIFIER DATA (complete all applicable)

In order to conduct an effective evaluation of the cathodic protection system, a complete evaluation of rectifier operation is necessary.

| | |
|---|---|
| **RECTIFIER MANUFACTURER:** | **RATED DC OUTPUT:** ________________ **VOLTS** _________________ **AMPS** |
| **RECTIFIER MODEL:** | **RECTIFIER SERIAL NUMBER:** |

**RECTIFIER OUTPUT AS INITIALLY DESIGNED OR LASTLY RECOMMENDED (if available):** __________ **VOLTS** __________ **AMPS**

| EVENT | DATE | TAP SETTINGS | | DC OUTPUT | | HOUR METER | COMMENTS |
|---|---|---|---|---|---|---|---|
| | | COARSE | FINE | VOLTS | AMPS | | |
| "AS FOUND" | | | | | | | |
| "AS LEFT" | | | | | | | |

## X. IMPRESSED CURRENT POSITIVE & NEGATIVE CIRCUIT MEASUREMENTS (output amperage)

Complete if the system is designed to allow such measurements (i.e. individual lead wires for each anode are installed and measurement shunts are present).

| CIRCUIT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | TOTAL AMPS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ANODE (+) | | | | | | | | | | | |
| TANK (-) | | | | | | | | | | | |

## XI. DESCRIPTION OF CATHODIC PROTECTION SYSTEM REPAIRS AND/OR MODIFICATION

Complete if any repairs or modifications to the cathodic protection system are made OR are necessary. Certain repairs/modifications as explained in the text of the VADEQ cathodic protection guidance document are required to be designed and/or evaluated by a corrosion expert (completion of Section V required).

- ☐ Additional anodes for an impressed current system (attach corrosion expert's design) .
- ☐ Supplemental anodes for a STI-P3® tank or metallic pipe (attach corrosion expert's design or documentation industry standard was followed).
- ☐ Repairs or replacement of rectifer (explain in "Remarks/Other" below).
- ☐ Anode header cables repaired and/or replaced(explain in "Remarks/Other" below).
- ☐ Impressed current protected tanks/piping not electrically continuous (explain in "Remarks/Other" below).
- ☐ Galvanically protected tanks/piping NOT electrically isolated (explain in "Remarks/Other" below).

**Remarks/Other:**

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## XII. UST FACILITY SITE DRAWING

Attach detailed drawing of the UST and cathodic protection systems. Sufficient detail must be given in order to clearly indicate where the reference electrode was placed for each structure-to-soil potential that is recorded on the survey forms. Any pertinent data must also be included. At a minimum indicate the following: all tanks, piping and dispensers; all buildings and streets; all anodes and wires; location of CP test stations; and, each reference electrode placement must be indicated by a code followed by a “IC” or “G” to indicate the type of CP system (e.g., R1-IC, R2-G, etc.) corresponding with the appropriate line number in Section XIV of this form. (Note, CP test stations (PP4)may be questionable for use as described in Section 6.1.2)

**AN EVALUATION OF THE CATHODIC PROTECTION SYSTEM IS NOT COMPLETE WITHOUT AN ACCEPTABLE SITE DRAWING**.

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# XIII. CATHODIC PROTECTION SYSTEM CONTINUITY SURVEY

- This section may be utilized to conduct measurements of continuity on UST systems that are protected by cathodic protection systems.
- When conducting a fixed cell - moving ground survey, the reference electrode must be placed in the soil at a remote location and left undisturbed.
- Conduct point-to-point test between any two structures for which the fixed cell - moving ground survey is inconclusive or indicates possible isolation.
- For impressed current systems, the protected structure must be continuous with all other protected structures in order to pass the continuity survey.
- For galvanic systems, the structure that is to be protected must be isolated from any other metallic structure in order to pass the continuity survey.

| **FACILITY NAME:** | NOTE: The survey is not complete unless all applicable parts of sections I-XIV are also completed. |
|---|---|

**DESCRIBE LOCATION OF "FIXED REMOTE" REFERENCE ELECTRODE PLACEMENT:**

| STRUCTURE "A" [1] | STRUCTURE "B" [2] | STRUCTURE"A" [3] FIXED VOLTAGE (mV) | STRUCTURE "B" [4] FIXED VOLTAGE (mV) | POINT-TO-POINT [5] VOLTAGE DIFFERENCE | ISOLATED/ [6] CONTINUOUS |
|---|---|---|---|---|---|
| (example) PLUS TANK BOTTOM | (example) PLUS STEEL PRODUCT LINE @ STP | (example) -915 mV | (example) -908 mV | | (example) INCONCLUSIVE |
| (example) PLUS TANK BOTTOM | (example) PLUS STEEL PRODUCT LINE @ STP | | | (example) 1 mV | (example) CONTINUOUS |
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1. Describe the protected structure {"A"} that you are attempting to demonstrate is continuous (e.g. plus tank bottom).
2. Describe the "other" protected structure {"B"} that you are attempting to demonstrate is continuous (e.g. plus steel product line @ STP).
3. Record the fixed remote instant off structure-to-soil potential of the protected structure {"A"} in millivolts (e.g. –915 mV).
4. Record the fixed remote instant off structure-to-soil potential of the "other" protected structure {"B"} in millivolts (e.g. –908 mV).
5. Record the voltage difference observed between structure "A" and structure "B" when conducting "point-to-point" testing (e.g. 1mV).
6. Document whether the test (fixed cell and/or point-to-point) indicated the protected structure was isolated, continuous or inconclusive.

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# XIV. CATHODIC PROTECTION SYSTEM SURVEY

**This section may be utilized to conduct a survey of the cathodic protection system by obtaining structure-to-soil potential measurements.**

- **For Impressed Current (IC) systems**: the reference electrode must be placed (minimum of three locations) in the soil directly above the structure that is being tested and as far away from any active anode as practical to obtain a valid structure-to-soil potential (refer to the VADEQ cathodic protection evaluation guidance document for detailed discussion of electrode placement).
- Both "on" and "instant off" potentials must be measured for each structure that is intended to be under cathodic protection.
- The "instant off" potential must be -850 mV DC or more negative or the 100 mV DC polarization criterion must be satisfied in order to pass.

- **For Galvanic (G) systems**: the reference electrode must be placed (minimum of three locations) with at least one local and at least one placed remotely 25-100 feet away from the structure.
- Both the local and remote voltage must be –850 mV DC or more negative, in order for the structure to pass.
- Inconclusive is indicated when both the local and remote structure-to-soil potentials do not result in the same outcome (both must "pass" or both must "fail").
- As a place to record the "galvanic CP system voltage", use the "On Voltage" fifth column below; and, in cases with supplemental anodes use the "Instant Off" column six.

**FACILITY NAME:**

NOTE: This survey is not complete unless all applicable parts of sections I – XIV are also completed.

| LOCATION CODE [1] | STRUCTURE [2] | CONTACT POINT [3] | REFERENCE CELL PLACEMENT [4] | ON VOLTAGE [5] | INSTANT OFF VOLTAGE [6] | 100 mv polarization | | PASS/ FAIL [9] |
|---|---|---|---|---|---|---|---|---|
| | | | | | | ENDING VOLTAGE [7] | VOLTAGE CHANGE [8] | |
| (example) R1-IC | (example) PLUS STEEL UST | (example) TANK BOTTOM | (example) SOIL @ PLUS TANK STP MANWAY | (example) -1070mV | (example) -875 mV | | | (example) PASS |
| (example) R2A-IC | (example) DIESEL PIPE | (example) DISPENSER 7/8 | (example) SOIL @ DIESEL TANK STP MANWAY | (example) -810 mV | (example) -680 mV | (example) -575 mV | (example) 105 mV | (example) PASS |
| (example) R2B-IC | (example) DIESEL PIPE | (example) DISPENSER 7/8 | (example) SOIL @ DIESEL TANK STP MANWAY | (example) -810 mV | (example) -720 mV | (example) -630 mV | (example) 90 mV | (example) FAIL |
| (example) R3A-G | (example) PREMIUM sti-P3® | (example) TANK BOTTOM | (example) SOIL @ PREM. TANK STP MANWAY | (example) -960 mV | (example) NA | (example) NA | (example) NA | (example) PASS |
| (example) R3B-G | (example) PREMIUM sti-P3® | (example) TANK BOTTOM | (example) SOIL @ PREM. TANK STP MANWAY | (example) -580 mV | (example) NA | (example) NA | (example) NA | (example) FAIL |
| (example) R3C-G | (example) PREMIUM sti-P3® | (example) TANK BOTTOM | (example for supplemental anode cases) SOIL @ PREM. TANK STP MANWAY | (example)- -1070mV | (example) -855mV | (example) NA | (example) NA | (example) PASS |
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**COMMENTS:**

**Use copies of this page as needed for additional reference cell readings.**

**1. Designate numerically or by code on the site drawing each local reference electrode placement (e.g. R1-IC, R2-G, R3-IC…etc.)**

**2. Describe the structure that is being tested (e.g. plus tank; diesel piping; flex connector, etc.)**

**3. Describe where the structure being tested is contacted by the test lead (e.g. plus tank bottom; diesel piping @ dispenser 7/8; etc.)**

4. Describe the exact location where the reference electrode is placed for each measurement (e.g. soil @ regular tank STP manway; soil @ dispenser 2, etc.)

**5. {Applies to all tests} Record the structure-to-soil potential (voltage) observed with the current applied (e.g. –1070 mV.)**

**6. {Applies to all tests} Record the structure to soil potential (voltage) observed when the current is interrupted (e.g. 680 mV.)**

**7. {Applies to 100 mV polarization test only} Record the voltage observed at the end of the test period (e.g. 575 mV.)**

**8. {Applies to 100 mV polarization test only} Subtract the final voltage from the instant off voltage (e.g. 680 mV – 575 mV = 105 mV.)**

**9. Indicate if the tested structure passed or failed one of the two acceptable criteria (850 instant off or 100 mV polarization) based on your interpretation of data.**

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# APPENDIX L

## IMPRESSED CURRENT CP SYSTEM - 60 DAY RECORD OF OPERATION

# COMMONWEALTH OF VIRGINIA
# IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
# 60-DAY RECORD OF RECTIFER OPERATION

- This form may be utilized to document that the cathodic protection system rectifier is checked for operation at least once every 60 days.
- Checked for operation is taken to mean that it was confirmed the rectifier was receiving power and is "turned-on".
- Any significant variance should be reported to the corrosion professional so that any repairs and/or adjustments necessary can be made.

| UST OWNER | | UST FACILITY | |
|---|---|---|---|
| **NAME:** | | **NAME:** | **ID #** |
| **ADDRESS:** | | **ADDRESS:** | |
| **CITY:** | **STATE:** | **CITY:** | **COUNTY:** |

## IMPRESSED CURRENT RECTIFIER DATA

| | |
|---|---|
| Rectifier Manufacturer: | Rated DC Output: ____________ VOLTS ___________AMPS |
| Rectifier Model: | Rectifier Serial Number: |

What is the 'as designed' or lastly recommended rectifier output? ____________ VOLTS ___________AMPS

## 60-DAY LOG OF RECTIFIER OPERATION

| DATE INSPECTED | RECTIFIER TURNED ON? | TAP SETTINGS | | DC OUTPUT | | HOUR METER | INSPECTOR INITIALS | COMMENTS |
|---|---|---|---|---|---|---|---|---|
| | | COARSE | FINE | VOLTS | AMPS | | | |
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## APPENDIX M

## ALTERNATIVES TO CLOSURE FOR UPGRADING VIOLATIONS-- DECISION MATRIX

This matrix assumes release detection is working and has been properly documented for the last year's worth of records. If not, then a site check is recommended on a case-by-case basis. **For all violations, owners are subject to enforcement action in accordance with the DEQ Enforcement Manual in addition to being responsible for the compliance options listed here.** All repairs require a Tank Tightness Test (TTT) afterward per regulation.

| Scenario | Compliance Options other than closure | Comments |
|---|---|---|
| **(1)** Bare steel UST known to have no lining or CP. | Can upgrade with CP or lining after "invasive" (video camera) integrity assessment (ASTM G-158) or manned entry, but no 10 yr. IC + TTT release detection option allowed after upgrade. | |
| **(2)** Bare steel UST with some form of CP upgrade (almost always impressed current) evident, but without documentation that an integrity assessment was properly accomplished and CP properly installed, or that the installed CP system was designed by a CP expert.<br>Six month and three year tests may have been performed, not performed, not documented, or are overdue. **(Includes cases where CP impressed current systems were turned off for more than 90 days.)** | Owner must: (1) obtain TTT (case specifics may necessitate high level TTT); (2) obtain corrosion expert certification of eligibility and system design; and (3) perform CP periodic testing (i.e., -850 mV or 100mV shift test). If tank does not pass TTT it can be lined (if RO agrees) or closed. For such tanks, no 10-year IC+TTT release detection option will be allowed. | Site specific criteria provide for some RO discretion for the appropriate TTT method. |
| **(3)** Bare steel UST upgraded with CP but tank's integrity assessment shows that tank was not eligible for upgrade. However, CP expert has certified installed CP system and tank has passed all subsequent required CP system tests. | Owner must perform high accuracy TTT (tracer type test). If tank passes tracer-type TTT, tank has been brought into compliance and owner may continue with CP without having to do another integrity assessment. If tank fails tracer-type TTT, report suspected release. Most failing tanks will be replaced but in some circumstances may be repaired by lining. Decision to allow tank repair will depend on site-specific circumstances related to tank conditions and remediation requirements. If repair (9-VAC-25-580-110) is appropriate, owner must line tank and must continue CP. For such late-to-upgrade tanks, no 10-year IC+TTT release detection option will be allowed. | |
| **(4)** Bare steel UST with documentation that CP system was properly designed and installed, but subsequent six month or three year test of CP system shows failure or is not documented.<br>(Do not reset 3 yr. clock.) | For systems which failed, repair and retest. For systems which were not tested or tests not documented, simply test CP system.<br>If it passes, tank has been brought into compliance and CP test clock remains on original three year testing cycle (from initial CP upgrade).<br>If it fails, allow repair of CP system in accordance with CP expert recommendations and CP test clock remains on original three-year testing cycle (from initial CP upgrade). | |
| **(5)** Bare steel UST with documentation that CP system was properly designed and installed (passed initial test), but later tests (three year intervals) not documented / performed. | Test CP system.<br>If test fails, repair CP system in accordance with CP expert recommendations. | |

| | | |
|---|---|---|
| **(6)** Bare steel UST with documentation of proper impressed current CP upgrade but it no longer meets –850mV/100mV shift criteria. | Modify CP system – restart six-month test after modification. | |
| **(7)** Bare steel UST with proper CP upgrade and testing documentation. Owner wants to add lining. | Lining a tank, which has already been upgraded with CP, is acceptable but owner still must maintain CP and conduct required CP testing. | EPA/DEQ support more protection of existing bare steel tank upgrades, but lining cannot replace CP as sole method. |
| **(8)** Bare steel UST purported to be lined, but without documentation that lining was installed according to a national code of practice, and without documentation that a required periodic (10 year and five year) internal inspection was conducted and passed. | Internally inspect lining and, if necessary, repair it.<br>(TTT should be conducted (not required) before internal inspection.)<br>If tank fails TTT, report suspected release. Option to internally inspect and repair tank rather than close it will depend on site specific circumstances related to both remediation requirements and condition of tank. | If inspection indicates lining is intact or if lining is repaired, owner has option to add CP and forego periodic lining inspections (See scenario # 11 below.) |
| **(9)** Bare steel UST with documentation of acceptable lining upgrade, but no documentation lining has been inspected at 10-year point and/or every five years thereafter. | Internally inspect lining and, if necessary, repair it. Re-inspect lining at five-year intervals thereafter. | If inspection indicates lining is intact or if lining is repaired, owner has option to add CP and forego periodic lining inspections (See scenario # 11 below.) |
| **(10)** Bare steel UST with no documentation that lining upgrade was performed to national code of practice, but later periodic internal inspections have been documented. | Continue normal internal inspection schedule. | |
| **(11)** Lined tank, owner wants to change to CP (Adding CP to lined "existing" tank saves future lining inspection costs and protects metal structure.) | Requires integrity assessment (ASTM G-158) or CP expert certification that tank is sound and free of holes prior to adding CP – no future lining inspections required. | EPA has always supported increased protection of the primary metal tank structure. This policy is already part of EPA existing tank upgrade guidance. (Manned entry or ultrasonic (internal) through the lining.) |
| **(12)** Bare steel UST with properly documented lining and CP | Owner must meet requirements for CP as a minimum. Lining inspections are not necessary. | |
| **(13)** ACT-100 – Owner asserts tank is ACT-100 but has no proof. | Regions may elect to require the owner to physically demonstrate tank is ACT-100 (e.g., by excavation) or may rely on documentation such as installation records or registration records. | Registration evidence alone can be accepted. |
| **(14)** StiP-3 UST — Owner asserts tank is StiP-3 but has no proof. | Regions may elect to require the owner to demonstrate tank is StiP-3 (e.g., by excavation) or may rely on documentation such as installation records, registration records or a sworn affidavit. | Registration evidence alone can be accepted. (Would a CP test that showed a potential of > -850 be proof that a tank was a StiP-3? No not necessarily but more likely than not, yes.) |

| | | |
|---|---|---|
| **(15)** StiP-3 UST w/o record of required initial six-month test. (Assumes three year test not yet due or due and not performed.) | Perform CP test. If tank passes, proceed with CP at initial three-year intervals. If tank fails, apply STI guidance or impressed current to repair.<br>(Do not reset 3-yr. clock.) | Per Paul Miller at EPA, there is a problem with performing integrity assessments on StiP-3 tanks, in that it's hard to properly apply the statistical analysis to the assessment. Thus, the ASTM G-158 is not recommended. |
| **(16)** StiP-3 with impressed current added--- tank fails 100mV-shift test. | CP expert modifies according to NACE. | |
| **(17)** StiP-3 UST with initial 6-month test but failure to meet 850mV standard. | Repair tank by adding anodes according to STI guidance or by installing impressed current. | |
| **(18)** StiP-3 UST with documentation it passed initial test, but later tests (three year intervals) not documented / performed. | Perform test. If tank passes, tank has been brought into compliance and CP test clock remains on original three year testing cycle (from initial CP upgrade). If tank fails, repair by adding anodes according to STI guidance or by installing impressed current. (Do not reset 3-yr. clock.) | |

# APPENDIX N

# EPA LETTER: CLARIFICATION OF “CORROSION EXPERT” & “CATHODIC PROTECTION TESTER”

**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
WASHINGTON, D.C. 20460

4/16/2001

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

**MEMORANDUM**

**SUBJECT:** Update to the Regulatory Interpretation Request:
Clarification of "Corrosion Expert" and "Cathodic Protection Tester"

**FROM:** Cliff Rothenstein, Director /s/
Office of Underground Storage Tanks

**TO:** EPA UST/LUST Regional Program Managers
State UST Managers

This memorandum provides an update to the memorandum titled ***Regulatory Interpretation Request: Clarification of "Corrosion Expert" and "Cathodic Protection Tester"*** dated September 24, 1994. Since the original memorandum was issued, NACE International has made changes to their certification categories. In particular, they have added two new categories, cathodic protection tester and cathodic protection technician, and have changed some of the requirements for cathodic protection specialist. EPA believes that both of the new certification categories fit under the definition of cathodic protection tester. However, we believe that neither of the new certifications meets EPA's definition of corrosion expert. Attached is an update to the table provided in the September 24, 1994 memorandum. This table describes the various NACE International certifications and shows how each certification fits into EPA's corrosion expert and cathodic protection tester definitions and supercedes the table provided in the September 24, 1994 memorandum.

As always, state agencies may impose requirements that are more stringent than the federal regulations. Owners and operators of UST facilities and members of the contracting community should confer with their state UST program offices to determine whether they interpret corrosion expert and cathodic protection tester definitions differently.

If you have any questions on this issue, please contact Paul Miller of my staff by phone at (703) 603-7165 or by email at miller.paul@epa.gov. For information on NACE International's accreditation programs, please contact NACE International at (281) 228-6200 or visit their website at www.nace.org.

Attachment

cc: Cliff Johnson, NACE International
Kathy Nam, OGC
OUST Desk Officers

## ATTACHMENT: NACE CERTIFICATION LEVELS THAT MEET EPA'S DEFINITIONS OF CORROSION EXPERT AND CATHODIC PROTECTION TESTER

| *EPA Definition (40 CFR §280.12)* | *NACE Certification* | *Expertise/qualifications in corrosion control of USTs* |
|---|---|---|
| **CORROSION EXPERT**<br><br>(The EPA definition requires NACE certification unless the person is a registered PE with certification or licensing that includes education and experience in corrosion control of buried or submerged metal piping systems and metal tanks. **Please check with state and local authorities to determine if their requirements are more stringent.**) | Corrosion Specialist | • Cathodic protection (includes all areas of expertise under Cathodic Protection Specialist)<br>• Coatings and linings<br>• Metallurgy<br>• Plastics (non-metallic materials)<br>• Inhibitors (environmental treatment)<br>• Corrosion assessment<br>• Stray current or cathodic interference testing and analysis<br>• Corrosion site surveys<br>• Corrosion control designs and recommendations<br>• Work/education experience is the same as for Cathodic Protection Specialist plus a Specialty Area Certification. |
| | Level 3 - Cathodic Protection (CP) Specialist | • System design and specifications<br>• Installation supervision<br>• System testing/commissioning<br>• Stray current/cathodic interference testing and analysis<br>• System maintenance<br>• Cathodic protection assessment<br>• Cathodic protection recommendations<br>• Analysis of cathodic protection feasibility<br>• Cathodic protection installation permits/licenses<br>• 4 years CP work experience in responsible charge plus CP level 2 certification or equivalent training plus one of the following:<br>  • 8 additional years CP work experience plus 2 years post-high school training in math or science from an approved technical/trade school<br>  • 2 additional years CP work experience plus 4-year engineering or physical science degree<br>  • Engineer-in-training (EIT) registration or equivalent.<br>  • Professional engineer (PE or P. Eng) or equivalent registration.<br>  • Bachelor's degree in engineering or physical sciences and an advance degree in engineering or physical science that required a qualification exam. |

Continued on the next page

**Updated April, 2001**

<table>
<tr><th>EPA Definition (40 CFR §280.12)</th><th>NACE Certification</th><th>Expertise/qualifications in corrosion control of USTs</th></tr>
<tr><td rowspan="2">CATHODIC PROTECTION TESTER<br><br>(The EPA definition of cathodic protection tester does not require any certification; however, persons holding these NACE certification levels are viewed by EPA as fully meeting regulatory requirements. Please check with state and local authorities to determine if their requirements are more stringent.)</td><td>Level 2 - Cathodic Protection Technician</td><td>• Perform advanced field tests and evaluate the results<br>• Verify stray current interference<br>• Understand AC voltage and its mitigation<br>• Maintain advanced documentation and records, including data plotting<br>• Conduct and understand the importance of periodical surveys, including IR Free readings and polarization decay tests<br>• Install, repair, modify and test rectifiers and component parts such as circuits<br>• Collect data on ER probes<br>• 3 years CP work experience plus high school diploma or GED plus CP level 1 certification or equivalent training<br>–or–<br>1 year CP work experience plus 4-year physical science or engineering degree plus CP level 1 certification or equivalent training<br>–or–<br>2 years CP work experience plus 2-year post high school training from an approved math or science technical/trade school plus CP level 1 certification or equivalent training</td></tr>
<tr><td>Level 1 - Cathodic Protection Tester</td><td>• Perform atmospheric corrosion inspections<br>• Understand the basics of corrosion and cathodic protection theory<br>• Conduct insulator tests and identify shorts in CP systems<br>• Use test instruments to perform a variety of field tests and take rectifier readings<br>• Install galvanic anodes and test<br>• Read shunts and understand their use in rectifiers, bonds, and anodes<br>• Perform the periodic surveys such as structure to soil, soil resistivity, coupon tests, offshore platform and riser surveys, rectifier readings, and surveys of bonds and diodes<br>• Knowledge of reference cells and their installation, testing and safety requirements<br>• Basic location mapping, report preparation and record keeping<br>• 6 months cathodic protection work experience plus high school diploma or GED</td></tr>
</table>

Continued on the next page **Updated April, 2001**

| *EPA Definition (40 CFR §280.12)* | *NACE Certification* | *Expertise/qualifications in corrosion control of USTs* |
|---|---|---|
| **CATHODIC PROTECTION TESTER** (continued)<br><br>(The EPA definition of cathodic protection tester does not require any certification; however, persons holding these NACE certification levels are viewed by EPA as fully meeting regulatory requirements. **Please check with state and local authorities to determine if their requirements are more stringent.**) | Senior Corrosion Technologist | • Installation supervision<br>• System testing and commissioning<br>• System maintenance<br>• Evaluation of system performance<br>• Eight years corrosion work experience, including four years in responsible charge,<br>–or–<br>Bachelor*s degree in physical sciences or engineering plus four years corrosion work experience in responsible charge. |
| | Corrosion Technologist | • Installation supervision<br>• System testing<br>• System maintenance<br>• Installation work<br>• Routine inspections<br>• Preliminary data analysis<br>• Minimum of four years corrosion work experience |
| | Corrosion Technician* | • Routine system testing<br>• System maintenance<br>• Routine inspections<br>• Installation work<br>• Minimum of two years corrosion work experience |

**Updated April, 2001**

*Please note that NACE requires a *Corrosion Technician* performing as a CATHODIC PROTECTION TESTER be directly supervised by a *Corrosion Technologist, Senior Corrosion Technologist, Cathodic Protection Specialist,* or *Corrosion Specialist.*

Note: NACE International Certification requires a combination of fulfillment of formal education and work experience requirements as well as successfully passing a certification examination pertinent to the category of certification. All applicants must provide documented proof of acceptable work experience in the field of corrosion causes and mechanisms.

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MAY, 2006