



Department of
**Environment &
Conservation**



Corrosion Protection

Standardized Inspection Manual

Technical Chapter 4.1

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**STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF UNDERGROUND STORAGE TANKS**

**TECHNICAL CHAPTER 4.1
CORROSION PROTECTION**

EFFECTIVE DATE – October 1, 2015

PURPOSE

The purpose of this technical chapter is to assist Division of Underground Storage Tanks (Division) staff in understanding the requirements for Underground Storage Tank (UST) system corrosion protection design, construction, operation/maintenance, repair, testing, and recordkeeping. Evaluating the performance of these systems, whether during operational inspections by the State or during the periodically required testing by vendors, has resulted in some inconsistencies in understanding and application of testing practices. State policies and regulations have historically deferred to industry standards without specifics in regard to inspection and testing practices. A primary goal of this technical chapter is to standardize the performance evaluation of these systems by detailing specific policies and guidelines that will create a uniformity of understanding and consistency of practice among Division inspectors, testers, and service providers.

This technical chapter contains the current policy of the Division based on the statute and regulations governing the Tennessee Petroleum Underground Storage Tank program. This document supersedes all previously published versions. The most current version of this technical chapter will be posted and always available on the Division's website.

AUTHORITY

All rules referred to in this technical chapter are contained in Chapter 0400-18-01 and are available on the Division of Underground Storage Tanks website at <http://www.state.tn.us/sos/rules/0400/0400-18/0400-18-01.20130121.pdf>



APPLICABILITY

Rule .02(4)(c)1. requires that all corrosion protection systems must be designed, constructed, operated, and maintained to continuously provide corrosion protection to the metal components of that portion of the tank and piping that “routinely contains petroleum” **and is in contact with the ground and/or any liquid**. These components include:

1. Any bare steel (no dielectric coating) tanks or piping*
2. STI-P3® tank systems which original anodes have become depleted
3. All below-grade piping (including piping that is partially above-grade if continuous with below grade piping) **including remote fill piping**
4. Metal flexible connectors including any sections of piping between dispensers or STP heads and the respective flexible connectors **regardless of length**.
5. Any tank or piping with a coating that is determined not to be acceptable by the Division as a “suitable dielectric coating” (Note: dielectric coatings alone are not adequate corrosion protection)*
6. Tank systems constructed with suitable dielectric coatings (such as fiberglass or urethane, ACT-100® tanks) that a corrosion expert requires to be bonded into the same cathodic protection system of other tanks within or near the same tankhold.
7. Or, any other system component that could potentially cause a release of petroleum into the environment as a result of corrosion failure unless a corrosion expert determines CP is not required.

* This only applies to tank systems that were required to be upgraded by the Federal deadline of December 1998 (Tennessee, December 1999). **Existing tank systems and piping currently in operation that did not meet the upgrading requirements by these dates cannot be upgraded and are considered substandard and shall be immediately and permanently closed by removal or closure-in-place as required by rule .07(2).**

The Division does not require corrosion protection on the following components of an underground tank system:

1. Automatic Tank Gauge (ATG) risers and
2. Vapor recovery risers
3. Fill risers, **but only if the fill riser is fitted with a drop tube**. See rule .02(4)(b)5. **If there is no drop tube, the fill riser must be corrosion protected**
4. Vent lines
5. The STP riser including the STP head
6. Interstitial Monitoring risers or any other riser not routinely containing petroleum

REQUIREMENTS

CORROSION SYSTEM DESIGN AND CONSTRUCTION

A **Corrosion Expert** must design all “field installed” corrosion protection systems as required by rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii). (Field Installed systems include the original or subsequent installation of anodes or modification to a galvanic corrosion protection system or an Impressed Current System.) **This does not include anodes installed on isolated flexible connectors that may be in STP sumps or under dispensers.** Documentation that the cathodic protection system is designed by a corrosion expert as required by rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii) must be maintained by the owner and/or operator for inspection by the Division.

CORROSION EXPERT

Corrosion Expert is defined in rule .01(4) and 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 submit documentation for review by the Division that they have accreditation or certification as a Corrosion Specialist or Cathodic Protection Specialist by the National Association of Corrosion Engineers (NACE). If it is determined by the Division that a person has sufficient experience and education to be qualified to take responsible charge in corrosion control of buried or submerged metal piping systems and metal tanks, then that person shall be classified by the Division as a corrosion expert. The Division currently maintains a list of known corrosion experts that may be provided to owner/operators.

To date, the Division has not made any determinations other than those made by NACE regarding who is qualified to be a corrosion expert.

Some examples of situations requiring corrosion expert review:

1. Design of Field-Installed Cathodic Protection Systems.
2. Any modification (including repairs) of the Cathodic Protection System, such as addition of supplemental anodes or other changes in the design or construction of the Cathodic Protection System.
3. Review of Cathodic Protection System test results indicating anomalies, such as: if stray currents are affecting metallic structures, inconclusive CP test results, and any other system test results that the Division determines to require additional expert review.

CATHODIC PROTECTION TESTER

A **Cathodic Protection Tester** is defined in rule .01(4) and 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 systems and metal tanks. 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.

Testing cathodic protection systems is not required to be performed by a corrosion expert to comply with rule .02(4)(c)2. The Division requires that all cathodic protection testing performed by a person meeting the qualifications of a **Cathodic Protection Tester**. All testing must be conducted in accordance with the guidelines as detailed in this technical chapter and all results shall be recorded on the official Tennessee Cathodic Protection Testing Survey Forms (CN-1140 and CN-1309) as required by rule .02(4)(c)2.(iii) and .03(2)(b)2 .

GENERAL DESIGN AND CONSTRUCTION OF TANKS

Tanks must be properly designed and constructed as required by rule .02(4)(a), so that any portion underground that routinely contains petroleum and is in contact with the ground and/or liquid is protected from corrosion by **one** of the following:

- 1) **Fiberglass**-Tank is constructed of fiberglass-reinforced plastic-rule .02(4)(a)1.

- 2) **Steel tank with Cathodic Protection**-Tank is constructed of steel and is protected from corrosion by a cathodic protection system (either galvanic cathodic protection or impressed current cathodic protection)-rule .02(4)(a)2.
- 3) **Composite (Clad)**-Tank is constructed of a steel-fiberglass-reinforced-plastic composite-rule .02(4)(a)4.
- 4) **Jacketed**-Tank is constructed with a fiberglass-reinforced plastic jacket, which has an interstitial space between the inner tank and the outer jacket-rule .02(4)(a)4.
- 5) The tank is constructed of metal without additional corrosion protection measures provided that the tank is installed at a site that is determined by a corrosion expert not to be corrosive enough to cause it to have a release due to corrosion during its operational life.-rule .02(4)(a)5.
- 6) The tank construction and corrosion protection are determined by the Division to be designed to prevent the release of any petroleum in a manner that is no less protective than any of the previously mentioned methods of corrosion protection.-rule .02(4)(a)6.

GENERAL DESIGN AND CONSTRUCTION OF PIPING

Piping must be properly designed and constructed, as required by rule .02(4)(b), so that any portion that routinely contains petroleum and is in contact with the ground and/or liquid is protected from corrosion by **one** of the following methods:

1) Non-metallic (rigid or flexible)

- a. If installed on or after November 1, 2005, shall meet or exceed the Standard for Safety established by Underwriters Laboratory in UL 971 - "Non-Metallic Underground Piping for Flammable Liquids", July 1, 2005. This requirement shall apply to all new and/or replacement piping.-rule .02(4)(b)1.(i)
- b. Pipe marking or labeling shall comply with the Underwriters Laboratory standard as outlined in Division rules.-rule .02(4)(b)1.(ii)

2) Metallic

- a. Dielectrically coated piping: Piping coated with a suitable dielectric material and has cathodic protection.-rule .02(4)(b)2.(i)
- b. Bare steel with cathodic protection system: Bare steel piping to which a galvanic or impressed current system has been added.-rule .02(4)(b)2.(ii)
- c. Isolation: Metallic piping **that is never in contact with the ground and/or liquid** (such as rubber boots acceptable to the Division, excavation of all soil or earthen material that exposes the entire length of the piping, or installation of any containment device that isolates the piping from the ground and/or liquids).-rule .02(4)(b)4.
- d. The piping is constructed of metal without additional corrosion protection measures provided that the piping is installed at a site that is determined by a corrosion expert not to be corrosive enough to cause it to have a release due to corrosion during its operational life.-rule .02(4)(b)3.(i)
- e. The piping construction and corrosion protection are determined by the Division to be designed to prevent the release of any petroleum in a manner that is no less protective than any of the previously mentioned methods of corrosion protection. -rule .02(4)(b)4.

METHODS OF CORROSION PROTECTION

There are two acceptable methods available to meet corrosion protection requirements: Galvanic CP Systems and Impressed Current CP Systems. Metals corrode naturally by the loss of electrons from the surface of the metallic components out into the surrounding soil. Corrosion protection systems reverse this flow of electrons inhibiting the natural process. Galvanic Systems are “passive” corrosion protection systems that utilize anodes made of metals such as magnesium and zinc that corrode instead of the tank or piping. Due to the difference of the innate electric potentials, a naturally occurring electric current flows from the anodes through moisture in the ground to the tank and/or piping resulting in the protection of the metal components. Impressed Current Systems utilize the same principle but with the addition of an external direct current of electricity applied to the system which supplies the flow of electrons necessary to reverse the corrosion process.

- 1) **Galvanic Systems** are comprised of sacrificial anodes that were installed on the ends of the tank by the tank manufacturer such as sti-P3® tanks. These systems may include anodes which were added subsequent to installation such as supplemental anodes bonded to sti-P3® tanks when the original anodes have become depleted. Not only can these systems be installed to protect the tanks, but also steel piping which includes flexible connectors.
- 2) **Impressed Current Systems** are always “Field Installed” systems that are added subsequent to the original installation of the tank system. These systems are designed to protect previously unprotected steel tanks, tanks that the attached anodes (sti-P3® tanks) have become depleted, or tanks which were previously lined internally. These systems can be installed to protect the tanks as well as electrically continuous steel piping.

GALVANIC SYSTEMS

1) Design and Construction

Galvanic systems are also known as sacrificial anode systems because an anode (usually zinc or magnesium) corrodes instead of the metal structure. Because the anode corrodes instead of the metal it is protecting, the anode sacrifices itself. Sacrificial anodes are connected directly to the structure to be protected by either welding or mechanical connection of lead wires. Galvanic systems are generally limited to those tank components that are well coated with a dielectric material (sti-P3® tanks or fusion bonded epoxy coated steel piping) because the available current output of these systems is low. Attempts to protect large areas of uncoated tanks or long runs of piping is generally not practical because the useful life of the anodes is too short or the number of anodes needed is too great.

2) Operation and maintenance/inspection

All galvanic systems must be operated and maintained to continuously provide corrosion protection to the metal components of that portion of the tank, piping and underground ancillary equipment that routinely contains petroleum and is in contact with the ground and/or liquid. See rules .02(4)(a)2. and .02(4)(b)2. Since galvanic systems are “passive” corrosion protection systems, rule .02(4)(c)2.(i) requires only periodic testing every three years to determine if the system is operating properly and the anodes are supplying sufficient protection. There are usually no maintenance requirements for galvanic systems and are limited to repairs to such things as bonding wires for anodes that have been added subsequently to the original installation of the tanks. Due to the nature of construction of the original system or subsequently added anodes, there are no components of galvanic systems usually requiring periodic inspection unless the anode bonding wiring is visible and/or accessible as described above.

3) Repairs

- a. Repairs include but are not limited to the following: replacement of anode(s) if depleted, repair or replacement of damaged bonding wires, and repair/replacement of system components to

achieve isolation. If anodes are added to a sti-P3® tank with depleted anodes, that constitutes a "Field Installation" and requires that the CP system be designed by a corrosion expert, according to rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii). All documents related to the repair and design approval by a corrosion expert must be maintained for the life of the system and transferred to any new owner of the system. See rules .02(4)(c)5.(iii) and .03(2)(d). For replacing depleted anodes on STIP-3 or steel product tanks, all design and construction requirements shall comply with Steel Tank Institute's "Recommended Practice for the Addition of Supplemental Anodes to sti-P3® USTs" (R972) revised January 2006 (or later), or have written repair design calculations signed by a corrosion expert.

- b. The Division will allow the addition of an impressed current system, that is designed by a corrosion expert as required by rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii), to a STI-P3 tank as a repair of the cathodic protection system when the anodes on a cathodically protected tank are depleted. A bare steel tank which never met the 1999 upgrade deadlines may not be upgraded by addition of an impressed current system. Records of this repair must be maintained for the operational life of the UST system as required by rules .02(7)(f) and transferred to any new owner as required by rule .03(2)(d).
- c. Within six (6) months following a repair of a cathodically protected system, the system shall be tested in accordance with rule .02(7)(e) to ensure that it is operating properly and all results shall be recorded on the official Tennessee Cathodic Protection Testing Survey Forms (CN-1140 and CN-1309) as required by rule .02(4)(c)2.(iii) and .03(2)(b)2 .

4) Testing

- a. A Cathodic Protection Tester must inspect all galvanic systems for proper operation within six (6) months of installation and at least every three (3) years thereafter and as stated above tested within six (6) months after a repair. The system must be functioning as designed and is effectively preventing corrosion. See rule .02(4)(c)2. Testing shall be performed in accordance with Appendix 1 and as directed according to instructions in state form CN-1140.
- b. All UST systems to which sacrificial anodes have been added for the purpose of replacing or enhancing an existing galvanic system shall be tightness tested. The tightness test shall be conducted no later than six (6) months, but no sooner than three (3) months, following the addition of the anodes. See rules .02(4)(c)3. and .02(4)(c)5.(iii). The Division may not require tightness testing of flex connectors to which anodes have been added. Records must be transferred to any new owner as required by rule .03(2)(d).
- c. Structures utilizing galvanic cathodic protection will be considered adequately protected according to the criterion in Section 8 of NACE TM0101 when "A negative (cathodic) potential of at least 850 mV with the protective current applied. This potential is measured with respect to a saturated copper/copper sulfate reference electrode contacting the electrolyte. Voltage drops other than those across the structure to electrolyte boundary must be considered for valid interpretation of this measurement." This criterion is also known as "850 on" and is not applicable to impressed current systems.



NOTE: A Cathodic Protection Tester may not use a cathodic protection test station (PP4[®]) that was permanently installed during the original installation of tank system to obtain potential measurements during a cathodic protection test. Also, a cathodic protection test wire (PP2[®]) may not be used unless it has been demonstrated that the wire is continuous with the tank bottom. This is because of continuity issues, unknown location of wire contact point and/or deterioration of the originally installed reference cell resulting in incorrect potential readings.



5) Recordkeeping

Records must be maintained in accordance with the following:

- a. The CP system is to be tested every three (3) years and the results of the last two (2) tests must be maintained and made available upon request by the Division. See rules .02(4)(c)5.(i) and .02(4)(c)2.
- b. A record of the addition of sacrificial anodes to an existing Galvanic System must be retained for the remaining operational life of the underground storage tank system and such records must be

transferred in accordance with Division rules at the time of ownership transfer. See rules .02(4)(c)5.(ii) and .03(2)(d).

- c. The results of tightness testing required when sacrificial anodes have been added for the purpose of replacing or enhancing an existing Galvanic System must be retained for the remaining operational life of the underground storage tank system. Such records must be transferred in accordance with Division rules at the time of ownership transfer. See rules .02(4)(c)3., .02(4)(c)5.(iii) and .03(2)(d).
- d. The results of any cathodic protection system repairs must be maintained for the operational life of the system. See rule .02(7)(f).
- e. Records Transfer. Upon transfer of ownership, including, but not limited to, sale of the tank system, originals and/or copies of all documents required for recordkeeping of corrosion protection systems shall be transferred to the new owner of the tank system at the time of the ownership transfer. See rule .03(2)(d).

IMPRESSED CURRENT SYSTEMS

1) Design and construction

All Impressed Current Systems are "Field Installed" systems and thus required to be designed by a corrosion expert as required by rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii). All design and construction requirements shall comply with NACE Standards RP 0285 (latest revision) for tanks, and RP 0169 (latest revision) for piping.

2) Operation and maintenance/inspection

- a. All Impressed Current Systems must be operated and maintained to continuously provide corrosion protection to the metal components of that portion of the tank, piping and underground ancillary equipment that routinely contains petroleum and is in contact with the ground and/or liquid. See rule .02(4)(c)1.
- b. All Impressed Current Cathodic Protection Systems must be designed to allow determination of current operating status.
 - The rectifier must be visually inspected every sixty days, noting that it is turned on and operating properly. See rule .02(4)(c)4.
 - The results of these inspections must be recorded on the Impressed Current Cathodic Protection System 60-day Record of Rectifier Operation Form CN-1282. See rule .02(4)(c)4.
 - The 60-day Rectifier Log entries shall include the date of inspection, Rectifier On/Off status, voltage output if available, amperage output, hour meter reading if available, name of person inspecting, and any applicable comments. See rule .02(4)(c)4.
 - The last **three** visual inspection results (i.e., the last six (6) months) must be maintained by the owner and/or operator. See rule .02(4)(c)4 and .02(4)(c)5.(iv).

The following conditions may not be providing continuous corrosion protection as required by rule .02(4)(c)1.:

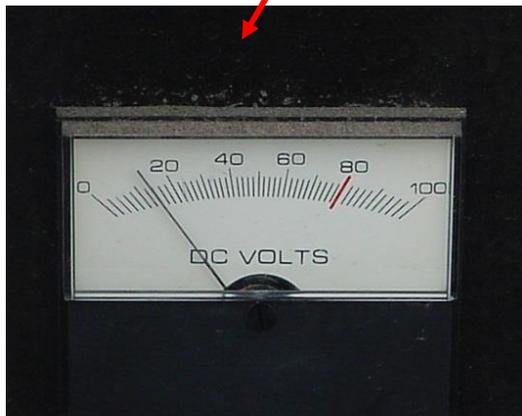
- A properly operating rectifier but the gauges show either no voltage or current at all,
- a malfunctioning rectifier,
- the rectifier gauges showing voltage or current flow with the switch in the 'off' position,
- the rectifier gauge is spiked indicating the maximum voltage or current flow, or
- rectifier logs show an amperage and/ or voltage variance of more than 20% from initial reading to subsequent readings.

If the Impressed Current System has no electrical power, then it is not providing continuous corrosion protection as required by rule .02(4)(c)1.

(Unless otherwise directed by the Division, in accordance with rule .02(4)(c)6.(i), UST systems with impressed current systems which have been turned off or inoperable for a period of less than twelve months, the tanks and lines shall be tightness tested with additional testing thereafter. In accordance with rule .02(4)(c)6.(ii), UST systems with impressed current systems which have been turned off or inoperable for a period of twelve months or more, the tanks shall be permanently closed.)

A CP tester or corrosion expert must determine the cause of the problem and restore the system to a satisfactory operating condition, and unless directed otherwise by the Division, conduct a test of the CP system to document that the system is protecting the tanks as required in rule .02(4)(c)6. This test will suffice for the post repair test required in the rule. The CP tester must engage the services of a corrosion expert when restoration of the CP system to proper operating condition requires any changes to its design or adjustment to rectifier output as required by rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii).

This rectifier shown on the following page contains both an ammeter and voltmeter. To verify that the rectifier is on, these gauges should have values above zero. The readings do not indicate that the system is protecting the tanks and piping, it only indicates that the unit is operating.



3) Repairs

Rule .02(7) requires that owners and/or operators of UST systems shall ensure that repairs will prevent releases due to structural failure **or corrosion** as long as the UST system is used to store petroleum. Rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii) require that field installed cathodic protection systems for tanks and piping be designed by **a corrosion expert**.

The Division has determined that to comply with rules .02(4)(a)2.(ii), .02(4)(b)2.(ii) and .02(7)(a) a corrosion expert must be either involved in the design and installation, approve, oversee, or sign off on all repairs made to cathodic protection systems that affect the operation of the system.

Repairs include, but are not limited to, the following list of activities:

1. Replacing rectifier
2. Adding anodes
3. Replacing broken rectifier components
4. Replacing broken ground wires or anode wires
5. Resolving continuity issues when problems identified and system still does not pass
6. Adding additional structures to an existing CP system.
7. Increasing tap settings on rectifier to achieve passing results

These activities require a retest of the CP system within 6 months following the repair to comply with rules .02(7)(e).

Activities listed below may be considered maintenance and do not require the approval of a corrosion expert under .02(4)(a)2.(ii), .02(4)(b)2.(ii) and .02(7)(a):.

Maintenance includes, but is not limited to, the following list of activities:

1. Routine CP testing
2. Turning rectifier on and off for testing.
3. Replacing blown fuse in rectifier
4. Reburying anode wires that have surfaced
5. Adding a drive-in rod anode to a single, isolated flex connector.
6. Replacing anodes (limited to same size and location as anode being replaced)

4) Testing

- a. A Cathodic Protection Tester must inspect all impressed current systems for proper operation within six (6) months of installation and at least every three (3) years thereafter. The system must be functioning as designed and is effectively preventing corrosion. See rule .02(4)(c)2.
- b. All UST systems to which sacrificial anodes have been added for the purpose of replacing or enhancing an existing impressed current system shall be tightness tested. The tightness test shall be conducted no later than six (6) months, but no sooner than three (3) months, following the addition of the anodes. See rules .02(4)(c)3. and .02(4)(c)5.(iii). The Division may not require tightness testing of flex connectors to which anodes have been added. Records must be transferred to any new owner as required by rule .03(2)(d).
- c. Testing shall be performed in accordance with Appendix 3 and as directed according to instructions in state form CN-1309. Structures utilizing impressed current cathodic protection will be considered adequately protected, as required by rules .02(4)(c)1. and 2. and .02(7), if they meet either:
 - i. The criterion in Section 9 of NACE TM0101: a negative (cathodic) potential of at least 850 mV when the voltage drop from the applied protective current has been eliminated. This second meter reading is known as the "instant off" and is measured with the protective current interrupted when the power to the rectifier is cut off, or by using the min/max function on a meter to capture the instant off reading, or
 - ii. The criterion in Section 10 of NACE TM0101: when a minimum of 100 mV of cathodic polarization (either formation or decay) can be measured on the protected structures. 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. Depolarization may take as long as 24 hours in some cases, but should not exceed 72 hours.

5) Recordkeeping

Records must be maintained in accordance with the following:

- a. The CP system is to be tested every three (3) years and the results of the last two (2) tests must be maintained and made available upon request by the Division. See rule .02(4)(c)2.(i). and .02(4)(c)5.(i).
- b. The results of the sixty (60) day rectifier inspection shall be recorded on the Impressed Current CP System 60 Day Record of Rectifier Operation Form CN-1282 and in accordance with rule .02(4)(c)2.(iii). The results of the last three sixty (60) day rectifier inspections must be retained for inspection by the Division. As required by rule .02(4)(c)5.(iv) and .03(2)(b)2.
- c. The results of any cathodic protection system repairs must be retained for the remaining operational life of the underground storage tank system and such records must be transferred at the time of ownership transfer. See rule .02(7)(f) and .03(2)(d).
- d. Documentation that the cathodic protection system is designed by a corrosion expert and that a corrosion expert was involved with repairs made to the system must be maintained by the owner and/or operator for inspection by the Division. See rules .02(4)(a)2.(ii), .02(4)(b)2.(ii), .02(7)(f), and .03(2)(b).
- e. The results of tightness testing required when sacrificial anodes have been added for the purpose of replacing or enhancing an existing Impressed Current System must be retained for the remaining operational life of the underground storage tank system. See rule .02(4)(c)5.(ii) and .02(7)(f). Such records must be transferred in accordance with Division rules at the time of ownership transfer. See rule .02(4)(c)5.(ii) and .03(2)(d).

Rectifiers used on USTs are manually controlled for the most part. A corrosion expert will determine the amount of current necessary in the design to protect the structures and set the rectifier output accordingly at installation or during modification of the CP system as required by rules .02(4)(a)2.(ii) and .02(4)(b)2.(ii), and as outlined in the definition of corrosion expert in rule .01(4).

If the rectifier is equipped with a **voltmeter**, 60 day voltage readings made by tank owners should be fairly constant unless the rectifier is a constant current rectifier. The tank owner should record current (amps or milliamps) from an **ammeter**. The recorded current readings could vary if the anodes are buried shallow or there are wide seasonal variations in soil moisture content. If the anodes are buried at least 8 feet deep, then measured current output should remain fairly constant. **Any variation in current and/or voltage of more than 20% from initial reading to subsequent readings, must be investigated and repaired if necessary.**

CORROSION PROTECTION FOR FLEXIBLE (FLEX) CONNECTORS

Flex connectors are braided stainless steel fittings used to make connections from a product line to a dispenser or submersible pump. A braided steel mesh protects an interior plastic or non-metallic hose that carries petroleum. There are two different ways to protect flex connectors from corrosion: isolation and cathodic protection.

1) Isolation

Isolation means keeping a flex connector free from all contact with ground and/or water. If a sump can be kept free of water so that the flex connector is never exposed to soil and/ or water, then no further action is necessary under rule .02(4)(b). If the flex connector can come in contact with ground and/or water, then another means of achieving isolation, such as isolation boots, will be necessary to comply with rule .02(4)(b). When used in the context of isolation, water in this Technical Chapter is understood to be a synonymous term for electrolyte as used by NACE.

Isolation boots are plastic materials made for isolating flex connectors and are placed around the entire flex connector and secured. Isolation boots may be either one piece "sleeves" which slip over a flex connector and are secured at both ends with nylon zip ties, or stainless steel band clamps, also known as radiator clamps. Another design is a boot that is heat shrunk directly to a flex connector.

A third kind of isolation boot is a boot that is applied around the pipe and "zipped" or secured with nylon ties, or possibly Velcro fasteners. When boots show signs of degradation they must be replaced. Isolation boots must be secured at both ends in a manner that prevents the flex connector from coming in contact with soil or water to comply with rule .02(4)(b) and .02(4)(c)1. Flex connectors which cannot be isolated from contact with soil or water are not corrosion protected, and cathodic protection is required if isolation cannot be achieved in accordance with rules .02(4)(b)2. and .02(4)(c)1.



One- piece Isolation boot



Zip boot

Following a limited study in 2001 by the Division, a decision was made not to approve the use of tape wraps alone to provide adequate corrosion protection to flex connectors and metallic piping components. See rule .02(4)(b)4. The study showed that exposure to hydrocarbons compromised the integrity of the rubberized tape material. Adhesive tapes provide some protection to metallic surfaces, but under direct burial conditions or exposure to water or other electrolyte, any exposed metal would be subject to corrosion even in the absence of petroleum. Another concern was a reduced likelihood of achieving proper installation under field application conditions, and no assurance that proper application techniques would be used by adequately trained individuals. Tape-wrapped flex connectors must also have a form of galvanic or impressed current cathodic protection, or the flex connector must be situated so that it is never exposed to soil and/or water in order to meet the requirements of rule .02(4)(b)2. and .02(4)(b)4.

2) Cathodic Protection

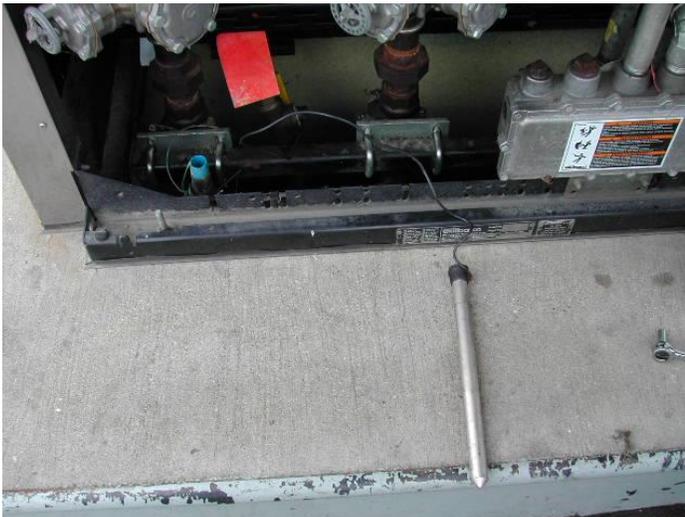
Sacrificial anodes may be attached to isolated flex connectors to achieve cathodic protection. A sacrificial anode is a less noble metal like zinc or magnesium alloys intentionally connected to form a galvanic cell with a more noble metal for the purpose of protecting the more noble metal from corrosion. Some flex connectors have a circular piece of anode material attached during manufacturing. If a factory designed anode is not present, cathodic protection can be added in the field. A spike anode (drive-in rod anode) is attached with a clamp, and then driven into the soil/backfill next to the piping. Sacrificial anodes can be connected to the flex connector at the submersible pump or under the dispenser. Also bracelet anodes can be attached with a U-bolt around the flex connector. In all cases the anodes must be in contact with backfill for the anode to work properly. Cathodic protection systems must be tested every three years as required by rule .02(4)(c)2.(i).

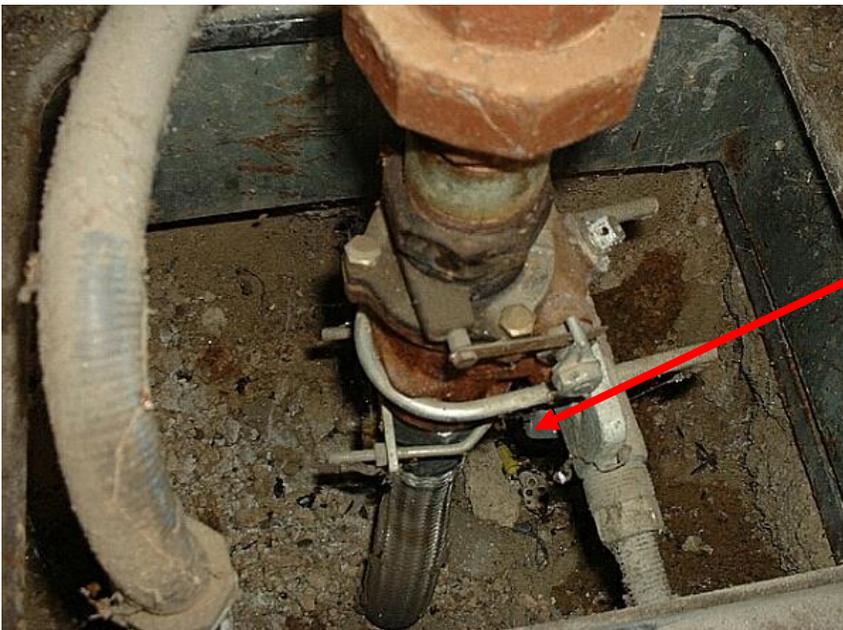


Drive-in rod anodes



Bracelet anode





Note that although this flex connector has a bracelet anode attached, it is ineffective in preventing corrosion. In order to work properly, the anode must be buried in soil.

Drive-in rod, bracelet or bag anodes are designed to provide protection to a **single, isolated flex connector**. They are not designed to provide adequate protection for flex connectors which are electrically continuous with other structures such as the STP, impact valve, dispenser cabinet or other piping components. If a drive-in rod, bracelet or bag anode is used to provide cathodic protection to a flex connector the CP test must determine that the flex connector is isolated as required by rule .02(4)(c)2. The Division issued a memo in October 2009 which said that adding a drive-in rod anode to a **single, isolated** flex connector does not require approval by a corrosion expert. **If the flex connector is electrically continuous with other flex connectors or other components, then follow the testing procedures described below:**

TESTING CATHODIC PROTECTION ON FLEX CONNECTORS

Described below are various conditions which may be encountered when testing flex connectors. These methods may also be used to test short sections of isolated metallic piping. Use the applicable method. The Steel Tank Institute's step by step procedures for testing flex connectors are described in Appendix 4.

Isolated flex connectors: Test continuity between flex connector and connecting component (i.e., either the STP piping or dispenser piping) by using either the point-to-point or fixed-cell/moving ground (remote reference cell placement) method. If isolated, then both local "on" measurements **and** "remote" measurements must be taken and pass (-850 mV). NOTE: When measuring the remote potential, the reference cell must be placed at true "remote earth" (see procedure below). If local "on" and/or remote measurements do not pass, then a local "Instant Off" measurement must be taken by disconnecting the bond wire of the anode. If multiple isolated flexes are present, then all other flexes not being tested must be disconnected from their respective anodes during the testing in order to obtain valid Instant Off measurements. If Instant Off measurements fail, then continue to observe the depolarization to obtain a passing 100 mV shift measurement. For local Instant Off readings, each flex must be tested **individually** by placing the reference cell immediately adjacent to each flex (not the anode) and making contact directly with the flex while disconnecting the bond wire to the anode.

NOTE: Permanently attached anodes, such as "bracelet" anodes, may not allow proper testing of flex connectors if remote readings cannot be obtained or fail. As a result, the instant off/100 mV polarization method must be used. Since disconnecting bracelet anodes is difficult, one solution is to replace bracelet

anodes with spike or bag anodes with bonding wires which can be disconnected in order to conduct the instant off/100 mV polarization.

Shorted (continuous) flex connectors: Test continuity between flex connector and connecting component (i.e., either the STP piping or dispenser piping) by using either the point-to-point or fixed-cell/moving ground (remote reference cell placement) method. If shorted to connecting component, then local Instant Off potentials only must be measured (no remotes required). **If multiple flexes are shorted together in a sump with multiple anodes attached, then the ability to disconnect all anode bonding wires at the same time is recommended.** This may require the anode bond wires to be bonded to one common point to disconnect during testing. To test, disconnect the common bond wire each time and contact each flex separately and conduct separate Instant Off tests for the individual flexes. This method of bonding all wires together will also make future testing more convenient.

Bonding all anode wires to a common point is the **recommended** practice. Alternatively, bond wires that are attached to each flex separately may be tested in the following manner: Contact the first flex, **while all other bond wires are detached**, and disconnect its anode bond wire and conduct Instant Off test. Repeat this procedure for each flex. Again, if Instant Off fails, then continue to observe depolarization to obtain passing 100mV shift.

NOTE: For local Instant Off readings, each flex must be tested individually by placing the reference cell immediately adjacent to each flex (not the anode) and making contact directly with the flex being tested while disconnecting the bond wire.

Flexes within contained sumps: If an anode has been attached to a flex within a contained sump containing water, then only a local Instant Off (or 100 mV shift) potential must be measured. If multiple flexes/anodes are present, then the same procedures previously described for isolated or shorted flexes also apply.

Obtaining true "remote earth": True remote earth is not just placing the reference cell a few feet away from the protected structure. True remote earth must be determined in order to overcome any IR (voltage) drop between the anode and the protected structure. IR drop is the additional voltage produced by the anode in order to overcome resistance in the soil. As a result, the measured voltage for an "on" reading may not be the actual amount of voltage reaching the protected structure. The measurement is actually more negative (the measurement appears more negative than -850 mV). For example: you measure -890 mV when the actual amount reaching the protected structure may only be -820 mV.

Procedure: Place reference cell at least 25 feet away from structure being tested. Measure the remote potential. Move the reference cell another 10 feet away and measure potential again. If the difference in the two measurements is less than 10 mV, then this location represents true remote earth for any structures being tested at the site. If the two measurements are not within 10 mV, then continue to move 10 feet away and measure again until two consecutive measurements are within 10 mV.

Testing of Flex Connectors in "Partially Contained Sump" areas: A partially contained sump is the area surrounding the STP head and associated piping that has a barrier or retaining wall made of plastic, wood, metal, or other material designed to prevent soil/gravel from coming in contact with the pump head/piping. These barriers/walls are not sealed and allow access to the surrounding soil/gravel to a varying degree at the bottom or sides. Part of the STP head and associated flex/piping may be in contact with soil inside as well as outside of these barriers/walls. As a result, flex/piping in contact with soil requires corrosion protection and testing. The configuration of these walls presents some challenges in obtaining proper testing results. The following scenarios may be encountered:

1. Flex/piping in contact with soil and is totally inside the retaining wall area with the STP head. All previously described testing procedures also apply to this scenario. The retaining wall will sometimes cause “shielding” which inhibits obtaining a remote measurement. As a result, in many cases, only local Instant Off/100mV shift measurements can be taken as described previously. The flex/piping is contacted directly and the reference cell placed immediately adjacent to the flex in the soil inside of the retaining wall.
2. Flex/piping in contact with soil inside of the retaining wall area with the STP head **and** also extends into soil outside of the wall (by going through, around, or under it). All previously described testing procedures also apply to this scenario. A problem occurs when attempting to obtain a remote measurement for the portion of the flex/piping **inside** the retaining wall area. The retaining wall will sometimes “shield” the ability to obtain this measurement. As a result, only Instant Off/100mV shift measurements can be taken on the portion inside of the retaining wall. The portion of the same flex/piping **outside** the wall will require separate testing. A remote measurement may be able to be taken here since it is not shielded by the wall. Contact can be made with the flex inside the wall and a separate local “on” measurement obtained with the reference cell placed outside of the wall (by drilling a hole if needed). But, if a remote cannot be obtained in this situation, then an Instant Off/100mV shift measurement is required on the portion outside the wall.

In either scenario, consideration must be given to where the anodes are located. This will affect where the reference cell is placed during testing as well as determining if the anode’s location is adequate to protect the flex/piping regardless of whether it is all inside the wall or also extends outside the wall. Consideration must be given to the material of construction of these walls, i.e., if made of galvanized steel. This may influence the measurements as well as where the reference cell is placed.

Installing anodes: It is important that anodes be attached to the flex connectors properly not only to ensure that the anode is actually bonded to metal continuous with the flex, but to also make future testing more practical. This is especially needed in sumps with high water levels. If the anode bond wire is attached directly to the flex itself and submerged well below the water surface, it may not be accessible in order to conduct Instant Off tests. New anode bond wires, as well as previously installed anodes, may need to have the wire attached to a continuous component (piping or STP head) above the water surface in order to be accessible each successive testing. If the flex is isolated and the wire can only be attached directly to it, then an additional length of bond wire may need to be brought above the surface of the water with a connection which can be detached in order to conduct an Instant Off test.

Short STP piping sections: Piping sections between STP heads and flex connectors that are in contact with the soil and/or water are at risk of failure from corrosion. This short “stub” of piping between the STP head and flex connectors is often overlooked. Although the STP head does not require CP and an isolated flex connector may be adequately booted or have CP added, the stub may be unprotected. If the flex connector is continuous with this stub and if the flex has adequate CP, then it may be sufficient to protect the stub also. Another recommended solution would be to eliminate the soil and/or water contact with this stub.

INTERNALLY LINED TANKS

As of December 22, 2012, all internally lined tanks shall have a cathodic protection system added or be permanently closed as required by rule .02(4)(a)3.(v). All lined tanks must be compatible with the product stored as required by .02(4) (a)3.(i)(II). Records of the lining installation must be maintained for the operational life of the tank as required by rule .02(4)(a)3.(i)(VI) and transferred to any new owners as required by rule .03(2)(d).

1) For internally lined tanks with a CP system (tanks with a properly operating CP system do not require periodic inspections of the internal lining)

- a. The tank owner and/or operator must have CP test records required by rule .02(4)(c)2.(ii), .02(4)(c)5.(i), and .03(2)(b)2. indicating the corrosion protection status. If the tank owner and/or operator does not have the CP records, then they must conduct a CP test as required by rule .02(4)(c)2.
- b. An Impressed Current CP system must remain operational for the remaining life of the tank, as required by rule .02(4)(c)1. and records maintained as required by rule .02(4)(c)5. and .03(2).

For testing and recordkeeping of cathodic protection systems, refer to sections 4 Testing and 5 Recordkeeping above.

2) Internal lining of tanks as a tank repair

If a tank meets any one of the construction standards in rule .02(4)(a)1. through 5., it may be repaired by lining. The Division will consider the lining or relining to be “in a manner that is no less protective”, as allowed in rule .02(4)(a)6., as long as the tank is lined following the requirements of rule .02(4)(a)3. and .02(7)(a) and the record of the lining is maintained for the operational life of the UST system as required by rule .02(7)(f) and records of the lining are transferred to any new tank owner as required by rule .03(2)(d). Tank owners may also submit the lining records to the Division for retention in its files, and the Division will maintain the records following the requirements of rule .14(1).

Exception: If the tank is constructed of fiberglass, rule .02(7)(b) has the additional requirement mandating:

“Repairs to fiberglass-reinforced plastic tanks shall be made by the manufacturers authorized representatives or in accordance with the manufacturer’s specifications.”

Consequently, if the manufacturer of a fiberglass reinforced tank does not allow its tanks to be repaired by lining, rule .02(7)(b) would prevent lining as a repair.

The following conditions must be met for tank owners and/or operators using tank lining as a repair:

- a. Prior to adding the internal lining, the tank integrity must first be assessed and determined to be structurally sound in accordance with NLP Standard 631 and determined to be suitable for internal lining as required by rule .02(4)(a)3.(i)(III).
- b. Rule .02(4)(a)3.(i)(IV) requires linings to be installed in accordance with manufacturer’s instructions. The following standards are allowed by federal rule 40 CFR Part 280.33(a) and (b), and they may be used to comply with rule .02(4)(a)3.(i)(IV) and .02(4)(a)6.:
 - National Leak Prevention Association Standard 631, Chapter 631, Chapter A-Entry, Cleaning, Interior Inspection, Repair, and Lining of Underground Storage Tanks
 - National Leak Prevention Association Standard 631, Chapter D-Lining of Fiberglass Tanks for Compatibility & Repairs That Are Allowed

The NLP standards are available at <http://www.nlpa-online.org/standards.html> and they include requirements like the ones listed below:

- i. Internal tank linings must be installed in accordance with NLP Standard 631 which requires an assessment of the tank shell after cleaning the tank and abrasive blasting of the tank interior. NLP

631 contains specifications for testing for and repairing tank wall perforations. The procedures for assessing the tank shell in NPLA 631 must be followed and if it is determined the tank does not pass the assessment, the tank is not suitable for lining.

- ii. The tank assessment must be done by a company trained and qualified to do this work, and tank lining must be installed in accordance with NPLA 631 and lining manufacturer's instructions, by a company trained and qualified to do tank lining.
- c. Rule .02(7)(a) requires that repairs to UST systems be made to prevent releases due to structural failures or corrosion as long as the UST system is used to store petroleum. In accordance with rule .02(4)3., any tank lining must be installed to effectively prevent a release due to corrosion for the operational life of the system.
- d. The Division asks to be given sufficient advance notice of the tank entry, cleaning, assessment, repair, and lining installation to have staff on site during every phase of the process. Complete documentation of the repair process is considered a tank repair record and must be maintained for the life of the system as required by rule .02(7)(f) and transferred to any new owner as required by rule .03(2)(d).

3) Lining and relining tanks to assure compatibility with alternative fuels

If a tank meets any one of the construction standards in rule .02(4)(a)1. through 5., it may be lined or relined to meet the compatibility requirements of rule .02(5). The Division will consider the lining or relining to be "in a manner that is no less protective", as allowed in rule .02(4)(a)6., as long as the tank is lined following the requirements of rule .02(4)(a)3. and .02(7)(a) and the record of the lining is maintained for the operational life of the UST system as required by rule .02(7)(f) and records of the lining are transferred to any new tank owner as required by rule .03(2)(d). If records are not maintained, the tank would be considered incompatible with alternative fuels. Tank owners may also submit the lining records to the Division for retention in its files, and the Division will maintain the records following the requirements of rule .14(1).

REFERENCES

1. Guidelines for the Evaluation of Underground Storage Tank Cathodic Protection Systems. Mississippi Department of Environmental Quality, July 1, 2002
2. NACE Standard TM0101-2012, NACE International
3. NACE Recommended Practice RP 0285- "Corrosion Control of Underground Storage Tank Systems by Cathodic Protection" NACE International
4. NACE Recommended Practice RP 0169- "Control of External Corrosion on Underground or Submerged Metallic Piping Systems" NACE International
5. Steel Tank Institute (STI) Recommended Practice R892 "Recommended Practice for Corrosion Protection of Underground Piping Networks Associated with Liquid Storage and Dispensing Systems" Steel Tank Institute
6. Steel Tank Institute (STI) Recommended Practice R972 "Recommended Practice for the Installation of Supplemental Anodes for sti-P3® UST's" Steel Tank Institute

7. Steel Tank Institute (STI) Recommended Practice R051 "Cathodic Protection Testing Procedures for sti-P3® UST's" Steel Tank Institute
8. Technical Interpretation and Guidance Regarding the Combination of Cathodic Protection and Internal Lining, December 4, 1995 Environmental Protection Agency

APPENDICES

1. Structure-to-Soil Test Procedure for Galvanic CP Systems
2. Continuity Testing Procedure for CP Systems
3. Structure-to-Soil Test Procedure for Impressed Current CP Systems
4. Test Procedure for Flex Connectors
5. Commonly Used Definitions
6. Impressed Current CP Testing Survey
7. Galvanic CP Testing Survey
8. Impressed Current CP System 60 Day Record of Rectifier Operation Form

APPENDIX 1

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

For tanks with galvanic cathodic protection systems in which the anodes cannot be disconnected, a minimum of one local potential measurement near the UST center and away from the anodes and one remote potential measurement must be taken.^{1,2} Alternatively, three potential measurements, one at each of the UST ends and one near the center of the UST, and one remote potential measurement may be taken.^{1,2}

It is vital that proper equipment and proper techniques be used when testing cathodic protection on UST systems.

Proper Copper/Copper Sulfate Reference Electrode Usage³

- Reference electrode may not be placed on concrete or other paving materials to make potential readings. Drill holes in concrete to obtain access to soil over tank and piping if necessary.
- Ensure that the reference electrode is placed in a vertical position (tip down).
- Ensure that soil where the reference electrode is placed is moist – add tap water if necessary.
- Ensure that soil where the reference electrode is placed is not contaminated with hydrocarbons.
- Ensure that the reference electrode window is not exposed to direct sunlight.

Proper Cathodic Protection Measurement Techniques³

- 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.
- Ensure that any drop tube that is installed in the tank does not prohibit contact with the tank bottom.
- If a metallic probe is used to contact the tank bottom, ensure that the probe does not contact the fill riser or any other metallic component of the UST system.

Mandatory Test Procedure:

STI-P3® tanks³

1. Place voltmeter on 2 volt DC scale.
2. Connect voltmeter negative lead to reference electrode.
3. Place reference electrode in clean soil at a true remote earth* from the protected structure.
4. Positive voltmeter lead will be used to contact tank bottom, external tank shell or structure being tested. This may be accomplished by connecting the voltmeter lead wire to a copper test prod mounted to the bottom of a wooden gauging stick and lowering the stick into the tank fill riser.
5. Obtain voltage and record in the remote voltage column on Tennessee Galvanic Cathodic Protection Survey Form CN-1140. More than one remote potential reading may be made if desired.
6. Move reference electrode to a point near the center of the tank along the midline directly over the structure that is being tested to obtain local potential reading(s). More than one local potential reading may be made if desired.
7. Obtain voltage and record in the local voltage column on CN-1140.

Note: If a sti-P3® tank is equipped with a PP4 test station, the PP4 test station is disregarded and potentials must be obtained with a portable reference electrode placed in the soil at both local and remote earth locations.³

If a test lead wire or PP2 test station is utilized to make contact with the tested structure you must ensure that continuity exists between the test lead wire and the structure. This may be accomplished by conducting a point-to-point continuity test.³

Cathodically protected steel piping with galvanic anodes³

Steel piping is tested by following Steps 1-7 above and making the contact from the positive voltmeter lead to a point on the piping. Piping requires measurement at each end of the pipe. If more than 100 feet of piping exist between any two anodes, the reference electrode must also be placed at the midpoint between the two anodes that are separated by more than 100 feet. 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.

* **True Remote Earth** is determined by placing the reference cell at least 25 feet away from any structure that is to be tested, taking a reading then moving the reference cell at least 10 feet farther from the first remote cell test location. If the two readings are within 10 mV of each other, then true remote earth has been established. If the difference between the two readings is greater than 10 mV, then move another 10 feet away from the structure and take another reading. Once 2 consecutive locations that are within 10 mV of each other are obtained, that will be true remote earth and the remote structure readings are made with the reference cell in this location.

Data Interpretation for Cathodic Protection Testers^{1,2,3}

Pass- If both the local and the remote potential are -850 mV or more negative, the -850 mV on criterion is met and adequate cathodic protection has been demonstrated.

Fail - If both the local and the remote potential are more positive than -850 mV, the -850 mV on criterion is not met and adequate cathodic protection has not been demonstrated.

Inconclusive- If either the local or the remote potential is more positive than -850 mV for all structures tested, the test result is inconclusive and further testing and/or repairs are necessary.

Incomplete- If one or more of the structures tested pass the above criteria and other structures fail the above criteria, the tester may issue an incomplete result on CN-1140. Structures which do not pass the above criteria are not considered corrosion protected, and further testing and/or repairs are necessary.

NOTE: Any NACE certified **corrosion expert** may evaluate results of the survey or conduct the survey and declare a pass or fail based on their interpretation of the data and professional judgment.

Continuity Testing

If test results are **Fail** or **Inconclusive**, a tester may perform continuity testing to determine if the protected structure is shorted. This can help determine why the minimum -850 mV was not achieved. See Appendix 2 for Continuity Testing Procedure.

References

1. NACE Standard TM0101-2012, NACE International
2. Cathodic Protection Testing Procedures for STI-P3 USTs, R051, Steel Tank Institute, January 2006
3. Guidelines for the Evaluation of Underground Storage Tank Cathodic Protection Systems. Mississippi DEQ, July 1, 2002.

APPENDIX 2

CONTINUITY TESTING PROCEDURE FOR CATHODIC PROTECTION SYSTEMS (GALVANIC & IMPRESSED CURRENT)

Adapted from Mississippi Department of Environmental Quality, July 1, 2002

Fixed Cell – Moving Ground Continuity Test Procedure (must not be used for impressed current systems)

1. Place reference electrode in contact with the soil at a location remote (25 – 100 feet) from all cathodically protected structures. You must 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 Tennessee cathodic protection survey 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

- If two or more structures exhibit potentials that vary by 5 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 5 mV but less than 10 mV, the result is inconclusive and further testing (point-to-point) is necessary.

Point-to-Point Continuity Test Procedure must be used with impressed current systems; may be used with galvanic systems)

1. Turn off power to rectifier if testing an impressed current system and disconnect the negative cable at the rectifier. 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 millivolt DC scale.

4. Connect one voltmeter test lead to one of the structures for which continuity is being tested; connect the other voltmeter test lead to the other structure being tested or preferably, the negative rectifier lead wire.
5. Record voltages observed (millivolt difference) on each of the two structures that are being compared and record on Tennessee cathodic protection survey form. Reconnect the negative lead wire to the rectifier when testing is completed.

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 5 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 5mV but less than 10 mV, the result is inconclusive and further testing is necessary.

APPENDIX 3

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

Adapted from Mississippi Department of Environmental Quality, July 1, 2002

For a tank with impressed current CP systems, a minimum of three local potential measurements, one at each of the UST ends and one near the center of each UST must be taken. ¹ For metal piping, one reading shall be collected at each dispenser, midpoints of steel piping greater than 100 feet in length, and metal piping at STP sumps. Record all necessary information on the Tennessee Impressed Current Cathodic Protection Survey Form (CN-1309). It is vital that proper equipment and proper techniques be used when testing cathodic protection on UST systems.

Proper Copper/Copper Sulfate Reference Electrode Usage²

- Reference electrode may not be placed on concrete or other paving materials to make potential readings. Drill holes in concrete to obtain access to soil over tank or piping if necessary.
- Ensure that the reference electrode is placed in a vertical position (tip down).
- Ensure that soil where the reference electrode is placed is moist – add tap water if necessary.
- Ensure that soil where the reference electrode is placed is not contaminated with hydrocarbons.
- Ensure that the reference electrode window is not exposed to direct sunlight.

Proper Cathodic Protection Measurement Techniques²

- 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.
- Ensure that any drop tube that is installed in the tank does not prohibit contact with the tank bottom.
- If a metallic probe is used to contact the tank bottom, ensure that the probe does not contact the fill riser or any other metallic component of the UST system.

Mandatory Test Procedure:

1. Inspect rectifier for proper operation and document information on Division Form CN-1309.
2. Measure rectifier output (voltage/ amperage) with a multimeter (do not rely on rectifier gauge readings). Measurement of individual anode circuits may also be made if there is a junction box present.
3. Place voltmeter on 2 volt DC scale.
4. Connect voltmeter positive lead to structure to be tested and connect voltmeter negative lead to reference electrode.
5. Place reference electrode in clean soil directly over the structure that is being tested. Take at least three (3) measurements for each tank, preferably at the approximate midpoint and at each end of the tank along the centerline if tank length can be verified, or for small capacity tanks, one (1) local measurement over the tank top for every 10 feet of tank length. Piping requires measurement at each end of the pipe and at midpoints of piping over 100 feet in length.
6. Obtain voltage potential with the protective current applied and record in the On Voltage column on Form CN-1309.
7. Without moving reference electrode from the position it was in during step 6 above, obtain voltage potential with the protective current temporarily interrupted (instant off*) and record in the Instant Off Voltage column on CN-1309. *If any instant off potential reading is more positive than -850 mV, the tank may or may not be adequately protected and a 100 mV shift must be performed. See below.*
8. Disconnect and make contact with the negative cable of the rectifier and determine continuity for all structures that are required to be protected by impressed current using point-to-point method. See **Appendix 2** for Continuity Testing Procedure.

100 mV depolarization (shift)

Must be performed whenever instant off potential of -850 mV or more positive for any reading in step 7 is not observed.

100 mV of polarization is determined by interrupting the polarized potential 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 at least -700 mV for the 100 mV polarization to be demonstrated). Depolarization may take as long as 24 hours in some cases, but cathodic protection power to the structure should not be interrupted for more than 72 hours.

Calculate voltage change by subtracting final (or ending) voltage from the instant off voltage and record these values in the appropriate columns on CN-13099.

Data Interpretation for Cathodic Protection Testers

Pass- one of the following two criteria must be met in order for the structure to be protected:

1. If all instant off potentials are -850 mV or more negative, the -850 off criterion is met and adequate cathodic protection has been demonstrated and further testing is not necessary. *If the instant off potentials are more positive than -850 mV, the tank may or may not be adequately protected and a 100 mV polarization test may be performed.*
2. If the structure exhibits more than 100 mV polarization, the 100 mV polarization criterion is met and adequate cathodic protection has been demonstrated

For impressed current systems, the instant off potential should never exceed -1.6 volts (-1600 millivolts). Such high readings can cause coatings to disbond and result in metal embrittlement.

Fail - If neither the - 850 instant off nor the 100 mV polarization criteria are met, adequate cathodic protection has not been demonstrated and repairs/modification will be necessary to achieve cathodic protection.

Inconclusive - The cathodic protection survey of an impressed current system must be evaluated by a corrosion expert because it cannot be determined that the protected structures are continuous or other factors may result in high readings

NOTE: A NACE certified corrosion expert may evaluate results of the survey or conduct the survey and determine that cathodic protection is adequate based on their interpretation.

*The instant off potential is the second 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. Alternately, the instant off reading may be captured by using the min/max function on the meter if the meter is so equipped.

In order to obtain instant off potentials, a current interrupter or a second person may be necessary. If a current interrupter is not available, have a second person throw the power switch at the rectifier off for 2 seconds and then back on for 15 seconds. Repeat this procedure until you are sure an accurate instant off reading has been obtained.

References

1. NACE Standard TM0101-2012, NACE International
2. Guidelines for the Evaluation of Underground Storage Tank Cathodic Protection Systems. Mississippi DEQ, July 1, 2002.

APPENDIX 4

TEST PROCEDURE FOR FLEX CONNECTORS

(adapted from Steel Tank Institute procedure)

The following procedures will describe how to determine potential readings for a flex connector relative to a copper/copper sulfate reference electrode. The flex connector may be considered protected if the potential readings meet one or more of the criteria described below for cathodic protection. Results of these tests must be recorded on the applicable Division's official cathodic protection survey form.

The procedure for testing a flex connector will depend on where and how a flex connector is installed. Flex connectors may be either directly buried in soil or submerged in water within a containment sump.

All flex connectors must be tested by either:

1. Obtaining passing local and remote measurements, (**PROCEDURE A**) or
2. Obtaining passing Instant Off and/or 100 mV shift measurements. (**PROCEDURE B**)

PROCEDURE A. -850 mV "current on" Criterion

This procedure is applicable to flex connectors directly buried in soil.

A total of 3 test measurements (one local and two at remote earth) are required for each directly buried flex connector when using the -850 mV current on criterion.

1. Set the voltmeter to the 2 volt DC scale.
2. Make contact to the flex connector with the positive lead of the voltmeter.
3. Connect the negative lead of the voltmeter to the reference electrode.
4. Place the reference electrode in the soil immediately adjacent to the flex connector.
5. Record the voltage observed on the voltmeter as the "local" potential.
6. Place the reference electrode in the soil approximately 25 feet away from the flex connector and any other cathodically protected structure at the facility and note voltage observed on the voltmeter.
7. Move the reference electrode 10 feet further away, place in the soil and observe the voltage.
8. If the voltage observed in step 6 is within 10 mV of the voltage observed in step 7, then it may be assumed that the reference electrode is at "remote earth".
9. If the voltages observed in steps 6 and 7 are not within 10 mV of each other, continue moving the reference electrode until the voltages obtained at two different locations are within 10 mV of each other.

Determination of PASS/FAIL

Pass = All three potential measurements must be -850 mV or more negative.

Fail = One or more of the three potential measurements are less than -850 mV.

NOTE: There may be situations when a remote earth reading cannot be obtained. This may occur when the flex connector is in contact with water within a sealed containment sump at a STP or dispenser. Also, certain conditions, such as shielding by metallic or non-metallic skirts or retaining walls at sumps or inaccessibility of soil remotely, may prevent obtaining good remote measurements. As a result, if remote measurements cannot be obtained for whatever reason, then Procedure B - Instant Off and/or 100mV shift must be used.

PROCEDURE B. -850 mV instant off or 100 mV Shift Criterion

This procedure is applicable to flex connectors directly buried in soil, or to flex connectors submerged or partially submerged underwater within a containment sump, or in situations as described above where remote measurements cannot be taken.

1. Set the voltmeter to the 2 volt DC scale.
2. Make contact to the flex connector with the positive lead of the voltmeter.
3. Connect the negative lead of the voltmeter to the reference electrode.
4. Place the reference electrode in the soil immediately adjacent to the flex connector.
5. Record the voltage observed on the voltmeter as the on potential.
6. Without moving the reference electrode, disconnect the anode lead wire(s) and record the instant off potential (Note: All anodes on all flex connectors at the same sump must be disconnected in order to utilize the -850 mV instant off or 100 mV Shift criteria.)
7. If the instant off potential is not -850 mV or more negative, then the anode may remain temporarily disconnected and the flex connector allowed to depolarize in an effort to demonstrate a shift in the potential of 100 mV or greater.

Determination of PASS/FAIL:

Pass = The instant off potential is -850mV or more, **OR** the shift in the potential is 100 mV or greater.

Fail = The instant off potential is less than -850 mV, **OR** the shift in the potential is less than 100 mV.

Note: When attempting to demonstrate the 100 mV shift criterion has been met, the ending voltage is subtracted from the instant off voltage.

For example: If the instant off voltage is recorded as -730 mV and the ending voltage is recorded at -550 mV then the potential shift would be 180 mV and the flex connector would pass the test. If the instant off voltage is -735 mV and the ending voltage is -680 mV, then the shift would only be 55 mV and the flex connector would fail the test.

APPENDIX 5

COMMONLY USED DEFINITIONS

Anode—the part of a corrosion cell where oxidation (corrosion) occurs. Electrons flow away from the anode and carry metal ions.

Cathode—the part of a corrosion cell at which is protected by the anode. Reduction is the principal reaction occurring at the cathode. Electrons flow toward the cathode in the corrosion cell.

Cathodic protection—a process that reduces the corrosion rate of a metal surface by making that surface the cathode of a corrosion cell.

Conductivity— the measure of the ability of a material to conduct an electric charge. (Conductivity is the reciprocal of resistivity.)

Continuity bond—a metallic connection that provides electrical continuity between structures.

Corrosion—deterioration of a material, usually a metal, that results from a chemical or electrochemical reaction with its environment.

Current— a flow of electric charge or the amount of electric charge flowing past a specified point per unit of time.

Delamination— separation of layers in a material or separation between one or more coats from another coat within a coating system.

Disbondment—the loss of adhesion between a coating and the substrate.

Discontinuity—a condition in which the electrical path through a structure is interrupted by something that acts as a dielectric or insulating fitting.

Corrosion cell — an electrochemical system consisting of an anode and a cathode in metallic contact and immersed in an electrolyte. This process produces an electrochemical reaction involving oxidation of the anode and reduction of the cathode. The anode and cathode may be different metals or dissimilar areas on the same metal surface.

Electrode—a material that conducts electrons, is used to establish contact with an electrolyte, and through which current is transferred to or from an electrolyte.

Electrode potential—the potential of an electrode in an electrolyte as measured against a reference electrode.

Electromotive series—a list of elements arranged according to their standard electrode potentials.

Galvanic anode—a metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

Galvanic corrosion—accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte.

General corrosion - corrosion that is distributed more-or-less uniformly over the surface of a material.

Half cell—commonly used in the field to refer to a reference electrode, It may be comprised of a copper rod and a copper sulfate solution commonly used for measuring corrosion of steel with respect to copper. It may also be made of a silver and silver chloride solution for measuring in marine environments.

Holiday—a discontinuity in a protective coating that exposes unprotected surface to the environment.

Hydrogen embrittlement—metal degradation caused by the presence of hydrogen within a metal or alloy resulting from the application of too much protective current on the structure being protected.

Impressed current—an electric current supplied by a power source that is external to the electrode system. An example is direct current for cathodic protection.

Impressed current anode— a suitable electrode used in an impressed current system.

Instant-off potential—the polarized half-cell potential of an electrode taken immediately after the cathodic protection current is interrupted, which closely approximates the potential without IR drop (i.e., the polarized potential) when the current was on.

Ion—an electrically charged atom or group of atoms.

IR drop—the voltage across a resistance when current is applied in accordance with Ohm's law.

Lining—a coating or layer of sheet material adhered to the interior surface of a container used to protect the container against corrosion by its contents and/or to protect the contents of the container from contamination by the container material.

Localized corrosion—corrosion at discrete sites also known as pitting or crevice corrosion.

Negative return—a point of connection between the cathodic protection negative cable and the protected structure.

Ohm's Law - the current through a conductor between two points is directly proportional to the potential difference across the two points. Voltage = current x resistance.

Passivation—the process in metal corrosion by which metals become passive generally by having a coating form on the surface that isolates the metal from the electrolyte.

Pinhole—a minute hole through a coat or coats that exposes an underlying coat or the substrate.

Pit—a surface cavity with depth equal to or greater than the minimum dimension at the opening.

Pitting—localized corrosion of a metal surface that is confined to a small area and takes the form of cavities called pits.

Polarization—the change from the corrosion potential as a result of current flow across the electrode/electrolyte interface.

Polarized potential— the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

Protective coating—a coating applied to a surface to protect the substrate from corrosion.

Reference electrode—an electrode having a stable and reproducible potential, used in the measurement of other electrode potentials.

Remote earth—a location on the earth far enough from the affected structure that the soil potential gradients associated with currents entering the earth from the affected structure are insignificant.

Sacrificial (galvanic) protection—reduction of corrosion of a metal by electrically connecting the metal to a galvanic anode. (a form of cathodic protection).

Shielding— preventing the cathodic protection current from reaching its destination or diverting it from its natural path.

Stray current—current flowing through paths other than the intended circuit.

Stray-current corrosion—corrosion resulting from stray current.

Structure-to-electrolyte potential—the potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.

Structure-to-soil potential—see structure-to-electrolyte potential.

Structure-to-structure potential—the potential difference between metallic structures, or sections of the same structure, in a common electrolyte.

Uniform corrosion—corrosion that proceeds at exactly the same rate over the surface of a material.

APPENDIX 6

IMPRESSED CURRENT CATHODIC PROTECTION TESTING SURVEY

(Modifications are made to these forms from time to time. Please check the Division's website for the most current version of the State's official form)



**DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF UNDERGROUND STORAGE TANKS**

William R Snodgrass Tennessee Tower
312 Rosa L. Parks Avenue, 12th Floor
Nashville, TN 37243

IMPRESSED CURRENT CATHODIC PROTECTION TESTING SURVEY

- This form must be utilized to evaluate underground storage tank (UST) cathodic protection systems in the State of Tennessee.
- Access to the soil directly over the cathodically protected structure that is being evaluated must be provided.

I. UST FACILITY

II. UST OWNER

NAME:		NAME:	
FACILITY ID NUMBER:		COMPANY:	
ADDRESS:			
CITY:	COUNTY:	CITY:	STATE:

III. CP TESTER

TESTER'S NAME:		COMPANY:	
ADDRESS:			
CITY:	STATE:	PHONE NUMBER:	

IV. REASON SURVEY WAS CONDUCTED (mark only one)

- Routine - 3 year
 Routine – within 6 months of installation
 Re-survey after fail
 Re-survey after repair/modification
- Date next cathodic protection survey must be conducted by: _____ (required within 6 months of installation/repair, or every 3 years).

V. 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 applicable criteria by completion of Section VII).
- FAIL** One or more components did not pass the cathodic protection survey.
- INCONCLUSIVE** The cathodic protection survey must be evaluated by a corrosion expert for such reasons as it cannot be determined that the protected structures are continuous, or other factors may result in high readings, etc. (complete Section VI).

CP TESTER'S SIGNATURE: _____ DATE CP SURVEY PERFORMED: _____

VI. 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 impressed current system are made; b) stray current may be affecting buried metallic structures; or c) an inconclusive result was indicated in Section V.

- PASS (based on above criteria)**
 FAIL (based on above criteria)

CORROSION EXPERT'S NAME:	COMPANY NAME:
NACE INTERNATIONAL CERTIFICATION NUMBER:	

CORROSION EXPERT'S SIGNATURE: _____ DATE: _____

VII. CRITERIA APPLICABLE TO EVALUATION (mark all that apply)

- 850 OFF** Structure-to-soil potential more negative than -850 mV with respect to a Cu/CuSO₄ reference electrode with protective current temporarily interrupted (instant-off).
- 100 mV Polarization** Structure(s) tested exhibit at least 100 mV of cathodic polarization.

VIII. 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 the date specified in Section IV.
- RETEST** Cathodic protection may not be adequate. Retest to determine if passing results can be achieved.
- REPAIR & RETEST** Cathodic protection is not adequate. Repair/modification is necessary as soon as practical.

IX. DESCRIPTION OF UST SYSTEM

FACILITY NAME:			FACILITY ID NUMBER:		
TANK #	PRODUCT	CAPACITY	TANK MATERIAL	PIPING MATERIAL	FLEX CONNECTORS / LOCATION
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

If metal flex connectors are present, are they corrosion protected?

YES Method: Isolation (booted) Isolation (contained in sump or no soil contact)

NO Action taken: _____

Attached Anode¹

¹If the flex connectors are protected by sacrificial anodes, test accordingly and include in Section XVI on this form.

X. 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 LAST MEASURED (if available): _____ VOLTS _____ AMPS

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

Check all that apply: single amp/voltmeter dual amp/voltmeter red/green indicator light

XI. IMPRESSED CURRENT POSITIVE CIRCUIT MEASUREMENTS (output amperage)

Complete if system design allows 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	8	10	TOTAL
ANODE (+)											

XII. DESCRIPTION OF CATHODIC PROTECTION SYSTEM REPAIRS AND/OR MODIFICATION

Complete if repairs or modifications to the cathodic protection system are made or are necessary. Certain repairs/modifications as explained in the text of the Standardized Compliance Inspection Manual, Technical Chapter 4.1 Corrosion Protection, are required to be designed and/or evaluated by a corrosion expert (completion of Section VI required). Attach corrosion expert's calculations and diagram and have corrosion expert sign Section VI.

- Additional anodes for an impressed current system (attach corrosion expert's design).
- Repairs or replacement of rectifier (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).

Remarks/Other _____

XIII. UST FACILITY SITE DRAWING

Attach detailed legible drawing or use the space provided to draw a sketch 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. Include details such as: all tanks, piping, and dispensers; buildings and streets; anodes and wires; and location of rectifier. Each CP test (reference electrode placement) location must be indicated by a code (1,2, T-1, D-1, etc.) corresponding with the appropriate line number in Section XV. of this form.

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

XVI. FLEXIBLE CONNECTOR CATHODIC PROTECTION SYSTEM

- This form will be utilized to conduct a survey of galvanic protected flexible connectors by obtaining structure-to-soil potential measurements.
- A minimum of one measurement must be made with the reference electrode placed in soil directly over the tested structure (local) **and** one measurement at a remote earth location, at least 25-100 feet away from the structure.
- Flex connectors in contained sumps or continuous with dispenser cabinets or STPs must use instant off or voltage change (100 mV shift) to determine protected status.
- If either local or remote reading is more positive than -850 mV, obtain instant off by disconnecting anode. If instant off is more positive than -850 mV, then conduct 100 mV polarization and record ending voltage. If difference between instant off and ending voltage is more than 100 mV, the result is **PASS**. If difference is less than 100 mV, or either local or remote reading is more positive than -850 mV, then structure is not protected and the result is **FAIL**.

FACILITY NAME: _____

FACILITY ID NUMBER: _____

Location of Remote Reference Cell Placement, if Applicable (also designate on site drawing):

E X A M P L E S	TANK #, PRODUCT, CAPACITY ¹	FLEX LOCATION ²	WHERE ANODE ATTACHED?	CONTINUOUS OR ISOLATED? ³	CONTACT POINT ⁴	LOCAL VOLTAGE ⁵	REMOTE VOLTAGE ⁶	INSTANT OFF VOLTAGE (if necessary)	100 mV POLARIZATION		PASS/FAIL ⁷
									ENDING VOLTAGE (if necessary)	VOLTAGE CHANGE	
	#2 DIESEL 8,000	DIESEL FLEX AT STP	ON FLEX	ISO.	ON FLEX	-875 mV	-760 mV	-860 mV			PASS
	#3 REGULAR 10,000	REG. FLEX AT DISPENSER 3/4	PIPING ABOVE SHEAR VALVE	CONT.	PIPING ABOVE SHEAR VALVE	-980 mV		-845 mV	-790 mV	55 mV	FAIL
	#4 PREMIUM 10,000	PREM. FLEX IN CONTAINED SUMP	STP HEAD	CONT.	STP HEAD			-910 mV			PASS

COMMENTS: _____

¹ Designate the number, product, and capacity of the tank with which the flex connector is associated.
² Indicate location of flex being tested (e.g. REGULAR FLEX AT DISPENSER 3/4, DIESEL FLEX AT STP, etc.)
³ Continuity or isolation of flex connectors must be documented before completion of this section to determine whether to use remote or instant off/100 mV polarization. If testing flex connectors only, include Continuity Survey section (XIV.) of this form with this section.
⁴ Designate exact point of contact when testing flex (i.e., if isolated, must contact only the flex itself. If continuous with another component, can contact either one.)
⁵ Record the structure-to-soil potential measured with the reference electrode placed "local" in millivolts (e.g. -875 mV, -980 mV, etc.).
⁶ Record the structure-to-soil potential measured with the reference electrode placed "remote" (or use the voltage measurements obtained during continuity survey if remote reference cell placement was used).
⁷ Indicate whether the tested structure passed or failed based on your interpretation of the test data.

APPENDIX 7

GALVANIC CATHODIC PROTECTION TESTING SURVEY

(Modifications are made to these forms from time to time. Please check the Division's website for the most current version of the State's official form)



DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF UNDERGROUND STORAGE TANKS

William R Snodgrass Tennessee Tower
312 Rosa L. Parks Avenue, 12th Floor
Nashville, TN 37243

GALVANIC CATHODIC PROTECTION TESTING SURVEY

- This form must be utilized to evaluate underground storage tank (UST) cathodic protection systems in the State of Tennessee.
Access to the soil directly over the cathodically protected structure that is being evaluated must be provided.

I. UST FACILITY

NAME:
FACILITY ID NUMBER:
ADDRESS:
CITY: COUNTY:

II. UST OWNER

NAME:
COMPANY:
ADDRESS:
CITY: STATE:

III. CP TESTER

TESTER'S NAME: COMPANY:
ADDRESS: LIST CERTIFICATION, IF ANY:
CITY: STATE: PHONE NUMBER:

IV. REASON SURVEY WAS CONDUCTED (mark only one)

- Routine - 3 year
Routine - within 6 months of installation
Re-survey after fail
Re-survey after repair/modification
Date next cathodic protection survey must be conducted by: (required within 6 months of installation/repair, or every 3 years).

V. 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 applicable criteria by completion of Section VII).
INCOMPLETE 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 (complete Section VIII).
FAIL All tanks or piping did not pass the cathodic protection survey (complete Section VIII).
INCONCLUSIVE If the remote and local do not both indicate the same result on all protected structures (both pass or fail), inconclusive is indicated and the resurvey must be evaluated and/or conducted by a corrosion expert.(Complete section VI.)

CP TESTER'S SIGNATURE: DATE CP SURVEY PERFORMED:

VI. CORROSION EXPERT'S EVALUATION (mark only one)

The survey must be conducted and/or evaluated by a corrosion expert when: a) an inconclusive is indicated for any protected structure since both the local and the remote structure-to-soil potentials do not result in the same outcome (both pass or both fail); b) repairs to galvanized or uncoated steel piping are conducted or c) supplemental anodes are added to the tanks and/or piping.

- PASS (based on above criteria)
FAIL (based on above criteria)

CORROSION EXPERT'S NAME: COMPANY NAME:

NACE INTERNATIONAL CERTIFICATION NUMBER:

CORROSION EXPERT'S SIGNATURE: DATE:

VII. CRITERIA APPLICABLE TO EVALUATION (mark all that apply)

- 850 ON Structure-to-soil potential more negative than -850 mV with respect to a Cu/CuSO4 reference electrode with the protective current applied (applicable to any galvanically protected structure).
850 OFF Structure-to-soil potential more negative than -850 mV with respect to a Cu/CuSO4 reference electrode with protective current temporarily interrupted (applicable only to galvanic systems where the anodes can be disconnected).
100 mV Polarization Structure tested exhibits at least 100 mV of cathodic polarization (applicable to galvanic systems where the anodes can be temporarily disconnected).

VIII. 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 the date specified in Section IV.
REPAIR & RETEST Cathodic protection is not adequate. Repair/modification is necessary as soon as practical.

IX. DESCRIPTION OF UST SYSTEM

FACILITY NAME:			FACILITY ID NUMBER:		
TANK #	PRODUCT	CAPACITY	TANK MATERIAL	PIPING MATERIAL	FLEX CONNECTORS / LOCATION
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

If metal flex connectors are present, are they corrosion protected?	<input type="checkbox"/> YES	Method:	<input type="checkbox"/> Isolation (booted)	<input type="checkbox"/> Isolation (contained in sump or no soil contact)
	<input type="checkbox"/> NO	Action taken:	<input type="checkbox"/> Attached Anode ¹	

¹If the flex connectors are protected by sacrificial anodes, test accordingly and include in Section XIV. on this form.

X. DESCRIPTION OF CATHODIC PROTECTION SYSTEM REPAIRS AND/OR MODIFICATION

Complete if repairs or modifications to the cathodic protection system are made or are necessary. Certain repairs/modifications as explained in the text of the Standardized Compliance Inspection Manual, Technical Chapter 4.1 Corrosion Protection are required to be designed and/or evaluated by a corrosion expert (completion of Section VI. required).

- Adding supplemental anodes for a sti-P₃[®] tank (attach corrosion expert's design).
- Adding supplemental anodes for metallic pipe (attach corrosion expert's design).
- Resolving continuity issues when problems identified and system does not pass (attach explanation).

Remarks/Other: _____

XI. UST FACILITY SITE DRAWING

Attach detailed legible drawing or use the space provided to draw a sketch 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. Include details such as: all tanks, piping, and dispensers; buildings and streets; anodes and wires; and location of rectifier. Each CP test (reference electrode placement) location must be indicated by a code (1,2, T-1, D-1, etc.) corresponding with the appropriate line number in Section XIII. of this form.

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

XIV. FLEXIBLE CONNECTOR CATHODIC PROTECTION SYSTEM

- This form will be utilized to conduct a survey of galvanic protected flexible connectors by obtaining structure-to-soil potential measurements.
- A minimum of one measurement must be made with the reference electrode placed in soil directly over the tested structure (local) **and** one measurement at a remote earth location, at least 25-100 feet away from the structure.
- Flex connectors in contained sumps or continuous with dispenser cabinets or STPs must use instant off or voltage change (100 mV shift) to determine protected status.
- If either local or remote reading is more positive than -850 mV, obtain instant off by disconnecting anode. If instant off is more positive than -850 mV, then conduct 100 mV polarization and record ending voltage. If difference between instant off and ending voltage is more than 100 mV, the result is **PASS**. If difference is less than 100 mV, or either local or remote reading is more positive than -850 mV, then structure is not protected and the result is **FAIL**.

FACILITY NAME: _____

FACILITY ID NUMBER: _____

Location of Remote Reference Cell Placement, if Applicable (also designate on site drawing):

E X A M P L E S	TANK #, PRODUCT, CAPACITY ¹	FLEX LOCATION ²	WHERE ANODE ATTACHED? ³	CONTINUOUS OR ISOLATED? ³	CONTACT POINT ⁴	LOCAL VOLTAGE ⁵	REMOTE VOLTAGE ⁶	INSTANT OFF VOLTAGE (if necessary)	100 mV POLARIZATION		PASS/FAIL ⁷
									ENDING VOLTAGE (if necessary)	VOLTAGE CHANGE	
	#2 DIESEL 8,000	DIESEL FLEX AT STP	ON FLEX	ISO.	ON FLEX	-875 mV	-760 mV	-860 mV			PASS
	#3 Regular 10,000	REG. FLEX AT DISPENSER 3/4	PIPING ABOVE SHEAR VALVE	CONT.	PIPING ABOVE SHEAR VALVE	-980 mV		-845 mV	-790 mV	55 mV	FAIL
	#4 PREMIUM 10,000	PREM. FLEX IN CONTAINED SUMP	STP HEAD	CONT.	STP HEAD			-910 mV			PASS

COMMENTS: _____

¹ Designate the number, product, and capacity of the tank with which the flex connector is associated.
² Indicate location of flex being tested (e.g. REGULAR FLEX AT DISPENSER 3/4, DIESEL FLEX AT STP, etc.)
³ Continuity or isolation of flex connectors must be documented before completion of this section to determine whether to use remote or instant off/100 mV polarization. If testing flex connectors only, include Continuity Survey section (XII.) of this form with this section.
⁴ Designate exact point of contact when testing flex (i.e., if isolated, must contact only the flex itself. If continuous with another component, can contact either one.)
⁵ Record the structure-to-soil potential measured with the reference electrode placed "local" in millivolts (e.g. -875 mV, -980 mV, etc.).
⁶ Record the structure-to-soil potential measured with the reference electrode placed "remote" (or use the voltage measurements obtained during continuity survey if remote reference cell placement was used).
⁷ Indicate whether the tested structure passed or failed based on your interpretation of the test data.

APPENDIX 8

IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM 60-DAY RECORD OF RECTIFIER OPERATION FORM

(Modifications are made to these forms from time to time. Please check the Division's website for the most current version of the State's official form)

