CONTINUITY TESTING PROCEDURE FOR GALVANIC CATHODIC PROTECTION SYSTEMS

Fixed Cell – Moving Ground Continuity Test Procedure

1. Place reference electrode in contact with the soil at a location remote (25 – 100 feet) from all cathodically protected structures. 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 the continuity testing portion of the form DEP8052 and DEP8053.
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 2 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 2 mV but less than 10 mV, the result is inconclusive and further testing (point-to-point) is necessary.

Point-to-Point Continuity Test Procedure

- Turn off power to rectifier if testing an impressed current system. This is necessary to obtain accurate results.
- 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.
- Place voltmeter on 2 volt (or lower) DC scale.
- Connect one voltmeter test lead to one of the structures for which continuity is being tested and connect the other voltmeter test lead to the other structure that is being tested.
- Record voltages observed on each of the two structures that are being compared and record on the continuity testing portion of the form DEP8052 and DEP8053.

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

Point-to-Point Data Interpretation

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

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

1. Place voltmeter on 2 volt DC scale.
2. Connect voltmeter negative lead to reference electrode.
3. Place reference electrode in clean soil directly over the structure that is being tested to obtain local potential. At least one local potential is required for each tank - the preferred test point is at the approximate midpoint along the centerline of the tank. Piping may require measurement at each end of the pipe and at the middle depending upon anode configuration (see Section 6.10.2 of this outline).
   - The reference electrode may not be placed on concrete or other paving materials.
   - Ensure that the reference electrode is placed in a vertical position (tip down).
   - Ensure that the soil where the reference electrode is placed is moist – add tap water if necessary.
   - Ensure that the soil where the reference electrode is placed is not contaminated with hydrocarbons.
   - Ensure that the reference electrode window is not exposed to direct sunlight.
4. Connect voltmeter positive lead to structure that is to be tested.
   - If a test lead wire is utilized to make contact with the tested structure 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 as described in Appendix E.
   - Ensure that good metal-to-metal contact is made between the test lead clip/probe and the structure.
   - Ensure that no corrosion exists where the test lead makes contact with the structure.
   - Ensure that your body does not come into contact with the electrical connections.
   - Ensure that test leads are not submerged in any standing water.
   - Ensure that test lead insulation is in good condition.
   - sti-P_3® tanks
   - If the test lead wire is not continuous or is not present, contact with the inside bottom of the tank is necessary. This may be accomplished by connecting the voltmeter lead wire to a test prod mounted onto the bottom of a wooden gauging stick and lowering the stick into the tank fill riser. Be sure that firm contact is made with the tank bottom. Care should be taken to ensure that any drop tube that may be installed in the tank does not prohibit contact with the tank bottom. If a metallic probe bar is utilized to contact the tank bottom, ensure that the probe bar does not contact the fill riser or any other metallic component of the UST system.
   - If a sti-P_3® tank is equipped with a PP4® test station, the PP4® test station is disregarded and potentials must be obtained with a portable reference electrode placed in the soil (both local and remote) as described in Section 6.10.1 of this outline.
5. Obtain voltage and record in the local column on the galvanic cathodic protection system evaluation form DEP8052.
6. Place reference electrode in clean soil remote from the protected structure. (Refer to Section 6.10.3 for a discussion of remote reference electrode placement.)
7. Obtain voltage and record in the remote column on the galvanic cathodic protection system evaluation form DEP8052. (Note: if the fixed cell-moving ground method was used to conduct continuity survey, the potential obtained during the continuity survey for each corresponding structure may be transposed to the appropriate column.)

Data Interpretation (for a more complete discussion refer to Appendix C of this outline)

- If both the local and the remote potential are –850 mV or more negative, the 850 on criterion is satisfied and it is judged that adequate cathodic protection has been provided.
- If either the local or the remote potential is more positive than –850 mV the test result is inconclusive and further testing and/or repairs are necessary. Alternatively, a person qualified as a corrosion expert could evaluate/conduct the survey and declare a pass or fail based on their interpretation and professional judgment.

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

GALVANIC (SACRIFICIAL ANODES) CATHODIC PROTECTION SYSTEM EVALUATION

USTB	KENTUCKY DEPARTMENT FOR ENVIRONMENTAL PROTECTION	*Mail completed form to:* DIVISION OF WASTE MANAGEMENT UNDERGROUND STORAGE TANK BRANCH 200 FAIR OAKS LANE, SECOND FLOOR FRANKFORT, KENTUCKY 40601 (502) 564-5981 http://waste.ky.gov/ust	FOR STATE USE ONLY

GENERAL INFORMATION

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

I. UST OWNER		II. UST FACILITY	
NAME:		NAME:	AGENCY INTEREST NUMBER:
ADDRESS:		ADDRESS:	
CITY:	STATE:	CITY:	COUNTY:

III. CP TESTER			IV. CP TESTER'S QUALIFICATIONS
TESTER'S NAME:			CERTIFICATION: ☐ NACE ☐ STI ☐ OTHER (specify) _____
COMPANY NAME:			
ADDRESS:			CERTIFICATION NUMBER:
CITY:	STATE:	ZIP:	EXPIRATION DATE:
PHONE:	E-MAIL:		

V. REASON EVALUATION WAS CONDUCTED (MARK ONLY ONE)

☐ Initial – within 180 days of installation
☐ Routine – 3 year
☐ Reevaluation after fail due to adverse physical conditions – within 90 days
☐ Reevaluation after repair/modification – within 180 days

Date next cathodic protection system evaluation shall be conducted by: _____

VI. CATHODIC PROTECTION TESTER'S EVALUATION (MARK ONLY ONE)

Date of CP Evaluation: _____

☐ **PASS**	All protected structures at this UST facility pass the cathodic protection system evaluation and it is judged that adequate cathodic protection has been provided to the UST system (indicate all criteria applicable by completion of Section VIII)
☐ **FAIL**	One or more protected structures at this UST facility fail the cathodic protection system evaluation and it is judged that adequate cathodic protection has not been provided to the UST system (complete Section IX)
☐ **INCONCLUSIVE**	If the remote and the local potential readings do not both indicate the same test result on all protected structures (both pass or both fail), the cathodic protection system shall be reevaluated and/or retested by a corrosion expert (complete Section VII)

I certify that I have personally examined and am familiar with the information submitted in this and all attached documents, and that, I believe that the submitted information is true, accurate, and complete.

CP TESTER'S SIGNATURE: DATE:

VII. CORROSION EXPERT'S EVALUATION (MARK ONLY ONE)

Date of CP Evaluation: _____

The evaluation shall 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 without following an acceptable industry code.

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

I certify that I have personally examined and am familiar with the information submitted in this and all attached documents, and that based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete.

CORROSION EXPERT'S SIGNATURE: DATE:

****RETAIN A COPY OF THIS FORM FOR YOUR RECORDS****

AGENCY INTEREST NUMBER:	
VIII. CRITERIA APPLICABLE TO EVALUATION (MARK ALL THAT APPLY)	
☐ **850 ON**	Structure-to-soil potential more negative than -850 mV with respect to a $Cu/CuSO_4$ reference electrode with the protective current applied. (This criterion is applicable to any galvanically protected structure).
☐ **850 OFF**	Structure-to-soil potential more negative than -850 mV with respect to a $Cu/CuSO_4$ reference electrode with the protective current temporarily interrupted. (This criterion is applicable to those galvanic systems where anodes can be disconnected).
☐ **100 mV POLARIZATION**	Structure tested exhibits at least 100 mV of cathodic polarization (This criterion is applicable to those galvanic systems where anodes can be disconnected).
IX. ACTION REQUIRED AS A RESULT OF THIS EVALUATION (MARK ONLY ONE)	
☐ **NONE**	Cathodic protection is adequate. No further action is necessary at this time. Evaluate again 3 yrs from the date of this evaluation. (see section V for exceptions)
☐ **REEVALUATION**	Cathodic protection may not be adequate. Reevaluate during the next 90 days to determine if passing results can be achieved.
☐ **REPAIR & REEVALUATION**	Cathodic protection is not adequate. Repair/modification is necessary as soon as practical, but within the next 90 days.

X. DESCRIPTION OF UST SYSTEM EVALUATED

TANK	PRODUCT	CAPACITY	TANKS	PIPING	FLEX CONNECTORS STP	FLEX CONNECTORS DISPENSERS
1						
2						
3						
4						
5						
6						
7						

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

Provide detailed information about all modifications or repairs made to the cathodic protection system. Attach a detailed drawing of the UST facility and cathodic protection systems. Sufficient detail shall 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. At a minimum indicate the following: ALL TANKS, ALL PIPING, ALL DISPENSERS, ALL BUILDINGS AND STREETS, ALL ANODES AND WIRES, LOCATION OF CP TEST STATIONS, EACH REFERENCE ELECTRODE PLACEMENT (indicated by a code:1,2,T-1,T-2) CORRESPONDING WITH THE APPROPRIATE LINE NUMBER IN SECTION XIII OF THIS FORM.

☐ Supplemental anodes for metallic pipe (attach corrosion expert's design or documentation that industry standard was followed).

☐ Supplemental anodes for a sti-P^{3} ® tank (attach corrosion expert's design or documentation that industry standard was followed).

☐ Galvanically protected tanks/piping not electrically isolated (explain in "Remarks/Other" below).

Remarks/Other:

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AGENCY INTEREST NUMBER:

XII. GALVANIC (SACRIFICIAL ANODE) CATHODIC PROTECTION SYSTEM CONTINUITY SURVEY

This section shall be utilized to conduct measurements of continuity on UST systems that are protected by galvanic cathodic protection systems.

STRUCTURE "A" [1]	STRUCTURE "B" [2]	STRUCTURE "A" [3] FIXED REMOTE VOLTAGE	STRUCTURE "B" [4] FIXED REMOTE VOLTAGE	POINT-TO-POINT [5] FIXED REMOTE VOLTAGE	ISOLATED / CONTINUOUS[6]
(EXAMPLE) PREMIUM TANK BOTTOM	(EXAMPLE) PREMIUM TANK FILL RISER	(EXAMPLE) - 921 mV	(EXAMPLE) - 915 mV		(EXAMPLE) INCONCLUSIVE
(EXAMPLE) PREMIUM TANK BOTTOM	(EXAMPLE) PREMIUM TANK FILL RISER			(EXAMPLE) 17 mV	(EXAMPLE) ISOLATED

COMMENTS:

1 Describe the cathodically protected structure being demonstrated as isolated from unprotected structures (e.g. Premium Tank).
2 Describe the unprotected structure being demonstrated as isolated from the protected structure (e.g. premium tank fill riser).
3 Record the measured structure-to-soil potential of the cathodically protected structure {"A"} in millivolts (e.g. – 921 mV).
4 Record the measured structure-to-soil potential of the unprotected structure {"B"} in millivolts (e.g. – 915 mV).
5 Record the voltage observed between the protected and the unprotected structures when conducting point-to-point testing (e.g. 17 mV).
6 Document whether the test (fixed cell and/or point-to-point) indicated the protected structure was isolated, continuous, or inconclusive.

****RETAIN A COPY OF THIS FORM FOR YOUR RECORDS****

AGENCY INTEREST NUMBER:

XIII. GALVANIC (SACRIFICIAL ANODE) CATHODIC PROTECTION SYSTEM SURVEY

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

LOCATION[1] CODE	STRUCTURE [2]	CONTACT POINT [3]	LOCAL REFERENCE CELL PLACEMENT [4]	LOCAL VOLTAGE [5]	REMOTE VOLTAGE [6]	PASS/FAIL/ INCONCLUSIVE[7]
(example) 1	(example) PLUS TANK	(example) TANK BOTTOM	(example) PLUS TANK STP MANWAY	(example) - 928 mV	(example) - 810 mV	(example) INCONCLUSIVE
(example) 2	(example) PLUS PIPING	(example) DISPENSER 5/6	(example) UNDER DISPENSER 5/6	(example) - 890 mV	(example) - 885 mV	(example) PASS

COMMENTS:

1 Designate numerically or by code on the site drawing each local reference electrode placement (e.g. 1,2,3…, T-1, T-2, P-1, P-2,…. etc.).
2 Describe the structure that is being tested (e.g. plus tank, premium piping, flex connector, etc.).
3 Describe where contact with the structure that is being tested is made (e.g. plus tank @ test lead, diesel piping @ dispenser 5/6, etc.).
4 Describe the exact location where the reference electrode is placed for each "local" measurement (e.g. soil @ plus tank STP, soil @ dispenser 5/6, etc.).
5 Record the structure-to-soil potential measured with the reference electrode placed "local" in millivolts (e.g. – 865 mV)
6 Record the structure-to-soil potential measured with the reference electrode placed "remote" (copy voltage that was obtained during continuity survey)
7 Indicate whether the tested structure passed or failed the – 850 mV "on" criterion based on the interpretation of the test data.

If you have questions on how to fill out this form or to request a review of UST facility records, please contact the UST Branch at (502) 564-5981 or visit our website at http://waste.ky.gov/ust.

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