CONTINUITY TESTING PROCEDURE FOR IMPRESSED CURRENT CATHODIC PROTECTION SYSTEMS

Fixed Cell – Moving Ground Continuity Test Procedure

1. Place reference electrode in contact with the soil at a location remote (25 – 100 feet) from all cathodically protected structures. 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 IMPRESSED CURRENT CATHODIC PROTECTION SYSTEMS

1. Inspect rectifier for proper operation and document necessary information. This includes measurement of output voltage/amperage with a multimeter (do not rely on rectifier gauges) and measurement of individual anode circuits (if installation allows such). Record all necessary information under Section XI and XII of the impressed current cathodic protection system evaluation form DEP8053 form.
2. Place voltmeter on 2 volt DC scale.
3. Connect voltmeter negative lead to reference electrode.
4. Place reference electrode in clean soil directly over the structure that is being tested. At least one measurement must be taken for each tank - the preferred test point is usually the center of the tank. Piping normally requires measurement at each end of the pipe.

   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.
5. Connect voltmeter positive lead to structure that is to be tested.

   Ensure that good metal-to-metal contact is made between the test lead clip/probe and the structure.

   Ensure that no corrosion exists where the test lead makes contact with the structure.

   Ensure that your body does not come into contact with the electrical connections.

   Ensure that test leads are not submerged in any standing water.

   Ensure that test lead insulation is in good condition.
6. Obtain voltage potential with the protective current applied and record in the on column on the impressed current cathodic protection evaluation form DEP8053.
7. Without moving reference electrode from the position it was in during step 6 above, obtain voltage potential with the protective current temporarily interrupted and record in the instant off column on the impressed current cathodic protection evaluation form DEP8053.

   The instant off potential is the 2nd value that is observed on a digital voltmeter the instant the power is interrupted. The first number that appears immediately after power interruption must be disregarded. After the second number appears, a rapid decay (depolarization) of the structure will normally occur.

   In order to obtain instant off potentials, a current interrupter or a 2nd person is necessary. If a current interrupter is not available, have the second person throw the power switch at the rectifier off for 3 seconds and then back on for 15 seconds. Repeat this procedure until you are sure an accurate instant off reading has been obtained.
8. Conduct 100 mV polarization decay if you are unable to obtain an instant off potential of -850 mV or more negative in step 7 above. (Note: While not a requirement of this form, consideration should be given to adjusting the rectifier output until an instant off potential of -850 mV is achieved or the maximum safe output is reached.) It is only necessary to conduct 100 mV polarization where the lowest (most positive) instant off potential is observed on the UST system.

   100 mV of polarization is determined by leaving the power interrupted on the structure until a change of at least 100 mV in the structure-to-soil potential is observed. In calculating the 100 mV decay, the instant off potential obtained in Step 7 above is utilized as the starting point (e.g. if instant off = -800 mV, power must be left off until decayed to -700 mV).

   Calculate voltage change by subtracting final (or ending) voltage from the instant off voltage and record these values in the appropriate columns on the impressed current cathodic protection evaluation form DEP8053.

Data Interpretation

If the instant off potential is -850 mV or more negative, the 850 off criterion is satisfied and it is judged that adequate cathodic protection has been provided.

If the instant off potential is more positive than -850 mV, the tank may or may not be adequately protected and a 100 mV polarization test is necessary.

If the structure exhibits more than 100 mV polarization, the 100 mV polarization criterion is met and it is judged that adequate cathodic protection has been provided. If you are unable to meet either the 850 instant off or the 100 mV polarization criteria, it is judged that adequate cathodic protection has not been provided and repairs/modification are indicated. Alternatively, a person qualified as a corrosion expert could evaluate/conduct the survey and determine that cathodic protection is adequate based on their interpretation.

GENERALIZED INTERPRETATION OF STRUCTURE-TO-SOIL POTENTIAL MEASUREMENTS (VOLTAGES) OBTAINED ON IMPRESSED CURRENT CATHODIC PROTECTION SYSTEMS

Listed in this table are some generalized observations that can be applied to the interpretation of structure-to-soil potentials. Depending on the site-specific conditions and other factors, differing interpretations are possible.

VOLTAGE (mV)	GENERALIZED INTERPRETATION
ANY POSITIVE VOLTAGE OR 0 TO -100 "ON" or "OFF"	Can indicate that the structure you are attempting to measure is not bonded to the impressed current system (conduct continuity testing). Stray current could be affecting the protected structure (consult a corrosion expert). Positive and negative wires could be reversed (negative must be to protected structure and positive to anode). Test leads are reversed (positive lead must contact structure and negative lead must be connected to reference electrode). Could indicate that you are measuring the potential of a copper wire.
-101 to -399 "ON" or "OFF"	Try again – A reading in this range is not normally seen on an underground steel structure. Could indicate that steel structure is electrically connected to a significant amount of a more noble metal (e.g. copper). Very corroded low carbon steel may also be indicated.
-400 to -599 "ON" or "OFF"	Usually means that the steel structure has no cathodic protection. Existing impressed current anodes could be completely "burned-out". Continuity of anode lead wires (positive circuit) could be broken. Negative bonds on the protected structures may be broken or non-existent.
-600 to -849 "ON" or "OFF"	Usually means that the steel structure has some protection but for whatever reason, something is causing a low reading that may indicate adequate cathodic protection has not been provided. The impressed current system may be trying to protect a structure that requires more current than it can produce (rectifier output too small). The impressed current system may not be capable of effectively distributing the required current to all parts of the structure you are trying to protect (not enough anodes, anodes improperly installed, soil resistivity too high). The steel structure that is intended to be protected may not be electrically continuous with the other metallic structures under protection (conduct continuity testing). The environmental conditions may not be favorable at the time you are attempting to obtain the reading. Retest during the next 90 days.
-850 or MORE NEGATIVE "ON"	Steel structure may or may not be adequately protected. Usually indicates that the impressed current system is providing current to the structure although the reading normally includes a large voltage (IR) drop. Because the flow of current through the soil causes a voltage drop, the on potential cannot be used to indicate that adequate cathodic protection has been provided. Instant off potentials must be utilized to demonstrate cathodic protection.
-850 or MORE NEGATIVE "OFF"	Steel structure protected by impressed current system meets regulatory requirements and cathodic protection is judged to be adequate. A potential measurement of -850 mV or more negative with the protective current temporarily interrupted (850 off) is considered to be the best indicator that adequate cathodic protection has been provided.
MORE NEGATIVE THAN -1220 mV "OFF"	Instant off potentials more negative than -1220 mV are theoretically not possible. If you observe an instant off potential more negative than -1220 mV, you should suspect stray current is affecting the protected structure. Consult a corrosion expert immediately since stray current can cause a rapid corrosion failure of the protected structure.
MORE NEGATIVE THAN -2000 "ON"	Usually means that a high resistance exists in the ground bed that is causing a large voltage drop. This condition is normally evident by checking the rectifier output since the voltage is very high but the amperage is relatively low. However, you should be cautious when abnormally high voltages are observed since this can have a detrimental effect on cathodically protected structures or the anodes may be rapidly depleted. Stray current may also be generated that can adversely affect other buried metallic structures such as waterlines and other utilities. Consult a corrosion expert whenever it is suspected that too much voltage is being generated.
VARIABLE "ON" or "OFF"	If the voltmeter readings vary, 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 "ON" or "OFF"	If the voltmeter will not stabilize, it usually means that there is a high electrical resistance somewhere. Check all lead wires and connections and make sure that 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.

IMPRESSED CURRENT 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 http://waste.ky.gov/ust**	**FOR STATE USE ONLY**

- 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

NAME:	
ADDRESS:	
CITY:	STATE:

II. SITE INFORMATION

NAME:	AGENCY INTEREST NUMBER:
ADDRESS:	
CITY:	COUNTY:

III. CP TESTER

TESTER'S NAME:		
COMPANY NAME:		
ADDRESS:		
CITY:	STATE:	ZIP:
PHONE:	EMAIL:	

IV. CP TESTER'S QUALIFICATIONS

CERTIFICATION:
☐ NACE ☐ STI
☐ OTHER (specify) _____

CERTIFICATION NUMBER:

EXPIRATION DATE:

V. REASON SURVEY 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:

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AGENCY INTEREST NUMBER:

VIII. CRITERIA APPLICABLE TO EVALUATION (MARK ALL THAT APPLY)

☐ **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. (Instant-off).
☐ **100 mV POLARIZATION**	Structure tested exhibits at least 100 mV of cathodic polarization.

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. Test again 3 yrs from the date of this test. (see section V for exceptions)
☐ **REEVALUATION**	Cathodic protection may not be adequate. Retest 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

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

XI. IMPRESSED CURRENT RECTIFIER DATA

RECTIFIER MANUFACTURER: | **RATED DC OUTPUT: _____ VOLTS _____ AMPS**

RECTIFIER MODEL: | **RECTIFIER SERIAL NUMBER:**

RECTIFIER OUTPUT AS INITIALLY DESIGNED OR LASTLY RECOMMENDED: _____ VOLTS _____ AMPS

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

XII. IMPRESSED CURRENT POSITIVE & NEGATIVE CIRCUIT MEASUREMENTS (OUTPUT AMERAGE)

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

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

XIII. DESCRIPTION OF CATHODIC PROTECTION SYSTEM REPAIRS AND/OR MODIFICATION AND SITE DRAWING

Provide detailed information about all modifications or repairs made to the cathodic protection system. Certain repairs or modifications require design and/or evaluation by a corrosion expert (complete section VII). 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 XIV OF THIS FORM.

☐ Additional anodes for an impressed current system (attach corrosion experts 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 (attach additional pages as necessary):

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AGENCY INTEREST NUMBER:

XIV. IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM CONTINUITY SURVEY

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

STRUCTURE "A" [1]	STRUCTURE "B" [2]	STRUCTURE "A" [3] FIXED REMOTE INSTANT OFF VOLTAGE	STRUCTURE "B" [4] FIXED REMOTE INSTANT OFF VOLTAGE	POINT-TO-POINT [5] VOLTAGE DIFFERENCE	ISOLATED /[6] CONTINUOUS/ INCONCLUSIVE
(EXAMPLE) PLUS TANK BOTTOM	(EXAMPLE) PLUS STEEL PRODUCT LINE @ STP	(EXAMPLE) - 915 mV	(EXAMPLE) - 908 mV		(EXAMPLE) INCONCLUSIVE
(EXAMPLE) PLUS TANK BOTTOM	(EXAMPLE) PLUS STEEL PRODUCT LINE @ STP			(EXAMPLE) 1 mV	(EXAMPLE) CONTINUOUS

COMMENTS:

1 Describe the cathodically protected structure {A} being demonstrated as isolated from unprotected structures (e.g. plus tank bottom).
2 Describe the "other" protected structure {B} being demonstrated as continuous (e.g. plus steel product line @ STP).
3 Record the fixed remote instant off structure-to-soil potential of the protected structure {"A"} in millivolts (e.g. – 915 mV).
4 Record the fixed remote instant off structure-to-soil potential of the "other" protected structure {"B"} in millivolts (e.g. – 908 mV).
5 Record the voltage difference observed between structure "A" and structure "B" when conducting point-to-point testing (e.g. 1 mV).
6 Document whether the test (fixed cell and/or point-to-point) indicated the protected structure was isolated, continuous, or inconclusive.

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AGENCY INTEREST NUMBER:

XV. IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM SURVEY

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

LOCATION CODE[1]	STRUCTURE [2]	CONTACT POINT [3]	LOCAL REFERENCE CELL PLACEMENT [4]	ON[5] VOLTAGE	INSTANT OFF VOLTAGE[6]	100 mV POLARIZATION		PASS/ FAIL[9]
						ENDING VOLTAGE[7]	VOLTAGE CHANGE[8]	
(EXAMPLE) 1	(EXAMPLE) PLUS TANK	(EXAMPLE) TANK BOTTOM	(EXAMPLE) SOIL @ REG TANK STP MANWAY	(EXAMPLE) - 1070 mV	(EXAMPLE) - 875 mV			(EXAMPLE) PASS
(EXAMPLE) 2	(EXAMPLE) DIESEL PIPING	(EXAMPLE) DISPENSER 7/8	(EXAMPLE) SOIL @ DSL TANK MANWAY	(EXAMPLE) - 810 mV	(EXAMPLE) - 680 mV	(EXAMPLE) - 575 mV	(EXAMPLE) 105 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, diesel piping, flex connector, etc.).
3 Describe where the structure being tested is contacted by the test lead (e.g. plus tank bottom; diesel piping @ dispenser 7/8, etc.).
4 Describe the exact location where the reference electrode is placed for each measurement (e.g. soil @ regular tank STP manway; soil @ dispenser 2, etc.).
5 {Applies to all tests} Record the structure-to-soil potential (voltage) observed with the current applied (e.g. – 1070 mV).
6 {Applies to all tests} Record the structure-to-soil potential (voltage) observed with the current is interrupted (e.g. 680 mV).
7 {Applies to 100 mV polarization test only} Record the voltage observed at the end of the test period (e.g. 575 mV).
8 {Applies to 100 mV polarization test only} Subtract the final voltage from the instant off voltage (e.g. 680 mV – 575 mV = 105 mV).
9 Indicate if the tested structure passed or failed one of the two acceptable criteria (850 instant off or 100 mV polarization) based on interpretation of the 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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